EFFECTS OF INTER ROW SPACING AND VARIETIES ON GROWTH YIELD COMPONENTS AND YIELD OF COMMON BEAN (*Phaseolus vulgaris* L.) IN NEDJO DISTRICT, WESTERN ETHIOPIA

MSc. THESIS

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Effects of Inter Row Spacing and Varieties on Growth Yield Components and Yield of Common Bean (Phaseolus vulgaris L.) in Nedjo District, Western Ethiopia

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Final approval and acceptance of the Thesis is contingent upon the submission of its final copy to the Council of Graduate Studies (CGS) through the candidate’s School Graduate Committee (SGC).
DEDICATION

I dedicate this thesis to my mother Beletu Mokonon, and my father Abebe Alemayehu, who have educated me while they themselves remaining illiterate and to my lovely son Hundaf Teshome.
STATEMENT OF THE AUTHOR

First, I declare that this thesis is a result of my genuine work and that I have duly acknowledged all sources of materials used for writing it. I submit this thesis to Haramaya University in partial fulfilment for the Degree of Master of Science. The thesis is deposited at the library of the University to be made available to borrowers for reference. I solemnly declare that the thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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### LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
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<tr>
<td>ATVET</td>
<td>Agricultural Technical Vocational and Educational Training</td>
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<td>ATTSVE</td>
<td>Agricultural transformation through strong vocational education</td>
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<tr>
<td>CEC</td>
<td>Cation Exchange Capacity</td>
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<td>CIAT</td>
<td>Centre of International Agricultural Tropical</td>
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<tr>
<td>CSA</td>
<td>Central Statistical Agency</td>
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<tr>
<td>FAO</td>
<td>Food Agricultural Organization</td>
</tr>
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<td>FAOSTAT</td>
<td>Food and Agriculture Organization Statistics</td>
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<tr>
<td>LSD</td>
<td>Least Significance Differences</td>
</tr>
<tr>
<td>Masl</td>
<td>Meter above sea level</td>
</tr>
<tr>
<td>MoARD</td>
<td>Ministry of Agriculture and Rural Development</td>
</tr>
<tr>
<td>SAS</td>
<td>Statistical Analysis Software</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

**DEDICATION**

**STATEMENT OF THE AUTHOR**

**BIOGRAPHICAL SKETCH**

**ACKNOWLEDGMENTS**

**LIST OF ABBREVIATIONS**

**LIST OF TABLES**

**LIST OF TABLE IN THE APPENDIX**

**LIST OF FIGURE**

**ABSTRACT**

**1. INTRODUCTION**

**2. LITERATURE REVIEW**

2.1. Origin and Production of Common Bean in World

2.2. Adaptation and Agro Ecological Requirements of Common Bean

2.3. Economic Importance of Common Bean

2.4. Importance of Spacing and Optimum Plant Population

2.5. Effects of Plant Spacing on Phenology and Growth Parameter of Legumes

2.6. Effect of Plant Spacing on Yield and Yield Components of Common bean

2.7. Growth Habit and Plant Spacing Interaction on Common Bean Verities

**3. MATERIALS AND METHODS**

3.1. Description of the Study Site

3.2. Soil Sampling and Analysis

3.3. Experimental Material

3.4. Treatments and Experimental Designs

1

4

4

5

5

6

8

9

9

12

12

13

13

14
3.5. Land Preparation and Field Management

3.6. Data Collection and Measurement
   3.6.1. Phenology data
   3.6.2 Growth parameters
   3.6.3. Yield Components and Yield

3.7. Data Analysis

4. RESULTS AND DISCUSSION
   4.1. Physico-Chemical Properties of Soils of the Experimental Sites
   4.2. Phenological and Growth Parameters
      4.2.1. Days to 50% flowering
      4.2.2. Physiological maturity
      4.2.3. Leaf area and Leaf area index
      4.2.4. Plant height
      4.2.6. Number of branches per plant
   4.3. Yield and Yield Components
      4.3.1. Stand count reduction
      4.3.2. Number of pods per plant
      4.3.3. Number of seeds per pod
      4.3.4. Hundred Seed weight
      4.3.5. Above ground dry biomass
      4.3.7. Grain yield

5. SUMMER AND CONCLUSION

6. REFERENCES

7. APPENDIX
LIST OF TABLES

Table                                                                 page
1. Description of the Variety used for the study area .................................13
2. Soil physico-chemical properties of the experimental site.................................18
3. The main effect of variety and inter row spacing on physiological maturity,
   days to 50% flowering, leaf area and leaf area index.............................................21
4. The interaction effect of variety and inter row spacing on plant height..................22
5. The interaction effect of variety and inter row spacing on number of branch
   per plant on common bean variety........................................................................23
6. The main effect of inter row spacing and variety on number of pod per plant,
   number of seed per plant and Stand count reduction..............................................25
7. The mean effect of variety and inter row space on above ground dry biomass
   , hundred seeds weight and harvesting index ..........................................................27
8. The interaction effect of variety and inter row space on grains.
   yield on common bean .........................................................................................30
LIST OF TABLE IN THE APPENDIX

Appendix Table  

1. Appendix Table 1. Means squares for growth and yield component of common bean… 44  
2. Appendix Table 2. Mean squares for yield and yield components of common bean … 45
LIST OF FIGURE

Figure 1. Study map in the area
Effects of Inter Row Spacing and Varieties on Growth Yield Components and Yield of Common Bean (Phaseolus vulgaris L.) in Nedjo district, Western Ethiopia

ABSTRACT

Common bean is becoming an important pulse crop in Ethiopia due to its use as sources of food security and generated income. However, crop management practice that combine high yielding varieties with inter row spacing are lacking at Nejo. Thus, a field experiment was conducted to assess effect of inter row spacing and varieties on yield components and yield of common bean. It was conducted during 2018 cropping season at Nejo, western Ethiopia. Treatments consisted of factorial combinations of three common bean varieties (Awash-2, Nasir and Seri-125) and four inter row spacing (30cm, 35cm, 40cm and 45cm) laid out in randomized complete block design (RCBD) with three replications. The main effects of varieties was highly significant (P<0.01) on day to 50% flowering, physiological maturity, leaf area, leaf area index, number of seed per plant, 100 seed weight and above ground dry biomass. Variety Seri-125 gave the highest day to 50% flowering (42.33), physiological maturity (92.18 day), leaf area (964.5m²), leaf area index (2.52), number of seed per plant (4.72), 100 seed weight (28.94g) and above ground dry biomass (7315kg/ha). Varieties had significantly (P<0.05) affected stand count, number of pod per plant and harvest index. The highest stand counts (92.01), number of pod per plant (17.44) were recorded from Awash-2 and Seri-125 respectively, while the highest harvest index (58.11%) was recorded from variety Awash-2. Inter row had highly significant (P<0.01) effect on leaf area, leaf area index, stand count, number of seed per pod, 100 seed weight, harvest index and above ground dry biomass. The 45 cm inter row spacing resulted to the highest leaf area (1251.5 m²), leaf area index (2.78), stand count (96.62), number of seed per pod (5.35), 100 seed weight (30.79g),) and harvest index (71.34), while the 30 cm spacing produced the highest above ground dry biomass (8423kg/ha). Inter row had significant (P<0.05) effect on physiological maturity and number of pod per plant. The 45 cm inter row spacing indicates late physiological maturity (91.07), while the highest number of pod per plant (17.87) at inter row space (45cm). Interactions of varieties with inter row spacing showed highly significant (P<0.01) effect on number of branch per plant and significant (P<0.05) effect on plant height and seed yield. The highest number of branch per plant (2.65), tallest plant (56.60cm) and highest seed yield (3202kg/ha) were recorded from variety Seri-125 at 45 cm, at 30 cm and 40 cm, respectively. From the results of this study it can preliminary concluded that there was no significant yield difference of Seri-125 at all spacing; of Nasir at 30, 35 and 40cm and of Awash-2 at 30 and 35 cm. Therefore, all spacing can be used for variety Seri-125. However, as this result is for one season and location; the study has to be repeated over locations and seasons to reach at a more reliable conclusion and recommendation for Nejo.

Key words: Number of pod per plant, Number of seed per plant
1. INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is an annual crop, which belongs to the family of Fabaceae. It is one of the most important food legumes in Latin America and Africa (Francis, 2006). It is in protein, phosphorus, iron, vitamin B₁, fiber, and is free of cholesterol. It is an attractive crop for farmers because of its adaptability to different cropping systems and short growing cycle. In some parts of the Ethiopia it is used as a cash crop for farm families to buy farm inputs, household necessities, and pay school expenses for children. It is among the main food legumes grown in the tropics and subtropics (Dursum, 2007). The area covered with the crop in production has been increasing due to its role in low input agricultural systems and it contains a high percentage of protein as compared to maize, rice and cassava (Mwale, 2008) thus it a nutritious food crop for the poor and an important export commodity crop.

In Ethiopia, common bean is economically one of the most important sources of protein and cash for both export and local markets. It is mostly grown in the Rift Valley, especially for export. In 2012, Ethiopia exported an estimated production quantity of about 6200 t of common bean mainly to Europe and Middle East, bringing a considerable amount of revenue to the country more than 20 million USD per annum foreign exchange earnings (Beebe *et al.*, 2010 and FAOSTAT, 2017). Farmers grow a wide range of bean types, in terms of color and size, but the most common types are the pure red and pure white beans. Most of the beans produced, traded and consumed in the domestic Ethiopian bean markets are the medium and small red beans whereas white beans are virtually all exported (Ferris *et al.*, 2008).

Low yield of common bean in Ethiopia is attributed to several production constraints which include lack of seeds of improved varieties for the agro-ecological zones, poor cultural practices such as untimely field operations, inappropriate plant spacing, weed infestation, low soil fertility, water stress, diseases and insect pests (Alemitu, 2011). Increase in yield can be ensured, by maintaining appropriate planting spacing through different planting patterns. Planting pattern influences radiation interception and utilization of moisture from soil, Ihsanullah (2002). Main role of planting pattern on plant growth is due to differences in distributing and dispersion of light energy quality and quantity.
among plants which induced improving grain yield and biological yield with increasing ratio uptake, Orcutt (2000).

Plant spacing affects early ground cover, competitive ability of crops with weed, soil surface evaporation, light interception, lodging and development of an optimum number of fruiting sites in a crop canopy. It also affects canopy development, plant architecture and distribution of pods (Matthews et al., 2008). However, optimum spacing varies depending on crop species or varietal differences in vigor, height and branching, time of sowing, and the nature of the season, Anderson (2004). Selecting optimal row spacing is important to improve crop productivity as plants growing in too wide of a row may not efficiently utilize light, water, and nutrient resources. However, crops grown in too narrow rows may result in severe inter row competition. Row spacing also modifies plant architecture, photosynthetic competence of leaves, and dry matter partitioning in several field crops, Hussain et al. (2012)

The spatial distribution of plants in a crop community is an important determinant of yield (Egli, 1988). Many experiments have been conducted to determine the spacing between rows and between plants within the row that maximizes yield. The full yield potential of an individual plant is fully exploited when sown at recommend spacing (Singh et al., 1997). Appropriate spacing brings out certain modification in the growth of the plant i.e. increase plant height, reduction of the leaf thickness, alteration in leaf orientation and leave becomes erect, narrow and arranged at longer vertical interval to intercept more sun light.

Among agronomic practices, spacing deserves special attention. Optimum inter spacing varies with soil fertility status, soil moisture, the nature of the crop varieties and degree of weed infestation (Singh et al., 1997). Moreover, the optimum inter row differs with the availability of soil moisture, relative humidity and nutrients. Spatial arrangement of the plant directly or indirectly affects the production potential of common bean varieties. Most of farmers in Nedjo Woreda use their own spacing and agronomic practices rather than the recommended spacing (personal observation).

About 50 common bean varieties are released nationally from different institutes (Universities and Research Centers), for those all varieties inter and intra row spacing recommended nationally for
different locations is the same (40 cm×10 cm) while the varieties have phenotypic and genotypic characters variations that might respond differently for crop geometry (MoA, 2014). Hence, realizing the importance of developing appropriate cultural practices such use of improved varieties with inter row spacing for optimum production of common bean in Nedjo Woreda, this study is envisaged. In view of the above facts the present study investigation was undertaken with the objective:

- To assess the effects of inter row spacing and varieties on growth yield components and yield of common bean
2. LITERATURE REVIEW

2.1. Origin and Production of Common Bean in World

The common bean was originated in Tropical America (Mexico, Guatemala, and Peru), but there are also evidences for its multiple domestication within Central America (Kay, 1979). The crop is now widely distributed throughout the world and consequently, it is grown in all continents except Antarctica (Singh, 1999). In Ethiopia, it is most likely introduced by the Portuguese in the 16th century (Wortman, 1997).

The world common bean production is estimated to be about 23.6 million tons with an average of 53.7 million hectares (FAOSTAT, 2017) which makes the crop the most widely utilized of legumes. The top five leading common bean producer countries are Myanmar, India, Brazil, China and Mexico taking up more than 50% of the total common bean production of the world (FAOSTAT, 2017). Common bean is produced in a range of crop systems and environments in regions as diverse as Latin America, Africa, the Middle East, China, Europe, the United States, and Canada. Apart from subsistence cultivation, beans have become increasingly commercial produced. With the onset of globalization, the past decade has seen a growing international market that is now reported to reach 2.4 million tons (CIAT, 2008).

In Ethiopia common bean is grown as intercrop with cereals. It covered 10.38% (about 2,671,843.040 tons) of the grain production. Out of this, common beans (red), and common beans (white) were planted to, 1.95% (about 244,049.94 ha) and 0.91% (about 113, 249.95 ha) of the grain crop area respectively. The production obtained from common bean (red) and common bean (white) were 1.43% (380,499.453 tons) and 0.60% (159,739.484 tons) of the grain production respectively. Therefore, the total area devoted for common bean crop production and the yield obtained in Ethiopia are 357,299.89 ha and 540,238.94 tons respectively (CSA, 2016), the produced in almost all the regional states with varying intensity. However, the production is concentrated in two regions: Oromia and the Southern Nations Nationality and Peoples Region (SNNPR), which account for about 85 percent of the total national production. The remaining 15 percent comes from Afar, Amhara, Tigray, Somali, Gambella and Benishangul-Gumuz regions (Alemu, 2002). Among pulses
common bean take the largest share of all pulses in terms of area coverage, with an increasing trend for the last ten years (CSA, 2017). It is solely an important legume in the Ethiopian lowlands as a rotation crop, particularly in the Rift valley where farmers grow white bean for export (EARO, 2001). Beans also yielded fairly well in areas where other pulses performed poorly due to incidence of diseases and unprepared agronomic practiced (CIAT, 1989). However, the current average yield of common bean at the study area (13.10 ku ha⁻¹) is far less than the attainable yield (2500-3000 kg ha⁻¹) under good management conditions for most improved common beans red varieties (CSA, 2017).

2.2. Adaptation and Agro Ecological Requirements of Common Bean

Common bean is adapted to a wide range of climatic conditions ranging from sea level to nearly 3000 meters above sea level (m.a.s.l.) depending on variety Fageria et al., (2011). In tropical Africa, common bean is well adapted to elevations of 1200–2200 m, with mean temperatures during the growing season of 15–23°C. However, it does not grow well below 600 meters due to poor pod set caused by high temperature. It grows best in warm climate at temperature range of 18°C to 24°C Abebe (2005). Mekonnen (2007) suggested that common bean grows well between 1400 and 2000 meters above sea level (m.a.s.l). In addition, Kay. (1979) reported that the crop is well adapted to areas that receive an annual average rainfall ranging from 500-1500mm with optimum temperature range of 16°C-24°C, and a frost-free period of 105 to 120 days for maturity. Moreover, common bean performs best on deep, friable and well aerated soil types with optimum pH range of 6.0 to 6.8.

2.3. Economic Importance of Common Bean

Common bean is an important source of protein and energy in human diets in the tropical and subtropical developing countries, particularly in the Americas, Eastern and Southern Africa (Walelign, 2002) while, in Latin America, beans are a traditional, significant food, especially in Brazil, Mexico, the Andean Zone, Central America, and the Caribbean (Graham and Ranalli, 1997). In Africa, beans are grown mainly for subsistence, where the Great Lakes region has the highest per capita consumption in the world. Beans are a major source of dietary protein in Kenya, Tanzania, Malawi,
Uganda, and Zambia. While, in Asia, dry beans are generally less important than other legumes, but exports are increasing from China (Wortmann and Allen, 1994).

In Ethiopian common bean is highly preferred by farmers because of its quick maturing characteristic that enables households to get cash income required purchasing food and other household needs when other crops have not yet matured (Legesse et al., 2006). It has been known as an export crop for long period contributing to the foreign exchange earnings, the country’s export income was estimated to be over 85% of export earnings from pulses, exceeding that of other pulses such as lentils, faba bean and chickpea (Rahmeto, 2007). It had produced highly for consumptions than export, also grown as a food crop consumed in traditional dishes. Dry beans are mostly prepared as nifro (boiled grain), mixed with sorghum or maize, wet (local soup) and with kocho. Fresh beans (mature whole non dried grain) are popular for their taste and crack ability. The protein content is 22% and its amino acid composition is high lysine (Adamu, et.al. 2005).

It compliments cereals and other stable foods in the diet and bean plays an important role in the economy of small farmers. Its grain used for food and making money, whereas it’s by product including its stalk and leaves is used for fire wood and feed. Moreover, since it is short maturing and has moderate drought tolerance trait. It is used as the main the only food in short growing seasons and poor annual harvest areas. Thus it plays a vital role in farmers risk aversion strategies (Adamu, et.al., 2005)

2.4. Importance of Spacing and Optimum Plant Population

Individual plant productivity is typically limited by competition for light, water, soil nutrients or competition of each. To avoid nutrient competition, sufficient spacing between plants is vital to get maximum yield in a given plot of land. Appropriate spacing enables the farmers to keep appropriate plant population in their field. Hence, a farmer can avoid over and less population in a given plot of land which has negative effect on yield (Alemitu, 2011). Spacing is an important factor governing the plant population per unit area, the development of individual plants and ultimately crop yield. Thus, the effect of plant population on yield is needed to design proper management practices.
Spacing trials in many countries, worldwide, have generally shown varying differences in yield within different plant species.

According to Singh and Singh (2002), establishment of optimum population per unit area of a field is essential to get maximum yield plant population completely depends on inter and intra row spacing. Among agronomic practices, which affect the yield, inter row spacing has a special significance since it is ultimately related with plant population, root development, plant growth and pod formation (Davi, 1995).

Generally, the most appropriate spacing is one, which enables the plants to make the best use of the conditions at their disposal (Malik, 1993). Too close spacing interferes with normal plants development and increase competition resulting in yield reduction, while too wide spacing may result in excessive vegetative growth of plant and abundant weed population due to more feeding area available. Therefore, use of optimum plant population per unit area without exceeding the economic threshold can increase the competitive ability of the crop plants in weed-infested field (Murphy, 1996). However, growing crops in narrower row spacing can reduce weed growth although the degree of reduction will depend on the crop (Alford, 2004).

According to Donald (1963), as the number of plants per unit area increased, competition for growth resources such as nutrients, water and light also increased. Willey (1982) stated that an essential component of plant density is spatial arrangement, which is the pattern of distribution of plants on the ground, which determines the shape of the area available to the individual plant (Reddy, 2000).

Under conditions of sufficient soil moisture and nutrients, higher plant population is necessary to utilize all the growth factors efficiently. The level of plant population should be such that maximum solar radiation is utilized. The full yield potential of an individual plant is fully exploited when sown at wider spacing. Yield per plant decreases gradually as plant population per unit area increases. However, the yield per unit area is increased due to efficient utilization of growth factors (Singh and Singh, 2002).
2.5. Effects of Plant Spacing on Phenology and Growth Parameter of Legumes

The optimum plant spacing varies with the growth habit of the variety, soil fertility, moisture and etc. decreased inter row spacing increased the number of leaves per unit area but inversed to LA and LAI Gebremedhin (2015) obtained more branch number when spacing became less and less. The highest number of branches per plant 5.10 was recorded at spacing while the lowest number of branches per plant (4.81) was recorded at the narrowest spacing due to narrowest spacing decreased the available growth resources per plant, Bennet et al. (1977). However, decrease space leading to a significant curvilinear reduction in branches per plant was observed,

At narrowest spacing plant stands leads to reduction in leaf area and alters leaf orientation. Dry matter production per unit area increased with increases in spacing up to a limit as in biological yield of common bean (Esubalew, 2014). When plants are widely spaced, vegetative dry matter yields will at first tend to increase with inversed plant density. This indicates that no appreciable competition is occurring between neighboring plants. Shortest plant height at narrowest spacing can also be due to excessive branching. This tends to encourage lateral growth while suppress apical growth (Mtaita and Mutetwa, 2014). Row spacing also modifies plant architecture, photosynthetic competence of leaves, and dry matter partitioning in several field crops (Hussain et al., 2012)

Plant spacing had highly significant effect on physiological maturity in which plants at narrowest spacing mature earlier 74.44 days while, widest spacing mature late 80.22 days (Mulatu et al. 2017). Esubalew (2014) who worked on green bean reported that longest number of days to 50% flowering (39.67) was recorded at wider plant spacing (40 cm x 10 cm) and the least number of days to 50% flowering was recorded at narrow plant spacing (35.23). Full maturity for dry bean seed type was attained from 45 to 150 days after emergence, depending on growth habit type and location (Singh, 1982). The late maturing beans were more often indeterminate while those of the early ones were determinate (Kelly, et al., 1987).
2.6. Effect of Plant Spacing on Yield and Yield Components of Common Bean

The seed yield of bean is the result of many plant growth processes which ultimately influenced the yield components via number of branch per plant, number pods per plant, number seeds per pod and weight of seed. The highest seed yields were obtained when all the above got maximized. Adams (1967) observed that compensation for yield components might prevent large changes in seed yields because of negative correlation between yield components from inter plant competition for nutrients and metabolites.

Spatial arrangement of the plant spacing or indirectly affects the production potential of common bean (Mehmet, 2008). Plant stand count at harvest was significantly affected by plant spacing where plant mortality rate increased as inter row spacing of plant decreased in common bean. Schatz et al. (2000) reported plant stand count increased from 84.79% to 90.54% with increased inter row spacing on dry bean plants. The highest number of pods per plant (13.1) and number of seeds per pod (4.3) were recorded at widest inter row spacing while, the lowest number pods per plant (9.5) and number of seeds per pod (3.2) were recorded at narrowest spacing common bean.

The decrease in number of pods per plant with increase in plant spacing could be due to increased competition which eventually caused reduction in number of pods per plant (Mulatu et al., 2017). Spacing is important to determinant of yield of common bean, Mulatu et al., (2017) reported that highest yield (3685 kg ha\(^{-1}\)) at moderate narrow space and the lowest yield 1487 kg ha\(^{-1}\) from lowest widest row spacing on common bean. Similarly, Maguje (2017) reported that highest yield (2125kg ha\(^{-1}\)) was obtained from (30cm) inter-row spacing and lowest yield (1807kg ha\(^{-1}\)) with inter-row spacing (50cm). However, crops grown in too narrow rows may result in severe inter row competition.

2.7. Growth Habit and Plant Spacing Interaction on Common Bean Verities

The spatial distribution of plants in a crop community is an important determinant of yield (Egli, 1988) and many experiments have been conducted to determine the spacing between rows and between plants that maximizes yield. Two general concepts are frequently used to explain the
relationship between row spacing, plant density and yield. First, maximum yield could be obtained only if the plant community produced enough leaf area to provide maximum light interception during reproductive growth (Johnson et al., 1982). Secondly, equidistant spacing between plants affected interplant competition (Pendleton and Hartwing, 1973).

Mutual shading of leaves is considered undesirable. It reduced yield directly by reducing light available for photosynthesis and indirectly by allowing light energy to pass directly to the soil, where it may be dissipated as latent heat removing water from the root zone (Wilson and Teare, 1972). They also indicated that small plants closed their canopies as readily as the larger plants and absorbed about 90 per cent of the incident light energy. Decreasing spacing brings out certain modifications in the growth of plants example, increase in plant height, reduction in leaf thickness, alteration in leaf orientation, and leaves become erect, narrow and are arranged at longer vertical intervals to intercept more sun light. Singh and Singh, (2002) indicated that the crop plants should cover the soil as early as possible to intercept maximum sunlight to produce higher dry matter as the intercepted solar radiation and dry matter production are directly related. Closely spaced and quick growing crops like common bean which can intercept more light within a short period gives higher yield as compared to wider spaced crops. As such for the proper light interception at various growth stages, optimum plant spacing is necessary (Singh and Singh, 2002).

In developmental terms, there are two types of common bean: determinate, in which the main axis terminated in an inflorescence and produced no vegetative nodes after flowering, the determinate type is short, self-supporting or bushy and of short growth duration and the other one is in determinate genotypes showed a wide range of node number on the main stem, climbing tendency and growth duration. Most beans cultivated in East Africa are determinate, with bushy growth habit but indeterminate non-climbing, semi-bush types, and indeterminate climbing types also are adopted (Acland, 1971).

At any given plant spacing, determinate bean type tended to have more branches/plant and fewer nodes/branch than indeterminate types. Plant characteristics, such as growth habit and canopy structure (modulated by sowing date, plant density, etc.), were not only affected directly but also indirectly through their influence on disease incidence. For the common bean, indeterminate types
recorded relatively high yield potential, though seed yield per day or per unit leaf area duration were similar to or lower than that of determinate bush types (Norman, *et al.*, 1984; Kelly *et al.*, 1987).

A major factor influencing optimum seed rate for any particular crop is the genotype (Mekonnen, 1999). Genotype by plant spacing interaction was found to be evident in faba bean (Amare *et al.*, 1993), field pea (Rezene, 1994), chickpea and lentil (Million, 1994). The population and growth habit interaction affected seed yield in soybean and the interaction was also large for plant height. However, growth habit differences were consistent across populations for days to maturity and number of main stem nodes (Ouattara and Weaver, 1994).
3. MATERIALS AND METHODS

3.1. Description of the Study Site

Field experiment was carried out at Nedjo ATVET College, West Wollega Zone of the Oromia National Regional State and western Ethiopia (Figure 1) from June to September 2018. Nedjo town is located at a distance of 515 km West of Addis Ababa on the main road to Assosa. The site is located at 1735 metres above sea level (m.a.s.l) in a sub-humid agro ecological zone. It is a mid altitude area with an annual rainfall of 1200-1600 mm having a unimodal pattern and increasing from April to October with the peak rainy season in July and August. The average minimum, mean and maximum temperatures of the area are $12^0\text{C}$, $19^0\text{C}$, and $26^0\text{C}$, respectively. The soil of the area is reddish brown dominated by oxisols, which is acidic (Gauchan et al., 1998). Oxisols are the most highly weathered soils with high clay content, but the clays are of low-activity, non-sticky type since they are dominated by kaolinite clay. The high concentration of oxides and hydroxides of iron and aluminium also gives these soils a capacity to bind too tightly with the little available phosphorous present (Gauchan et al., 1998).

Figure 1. Map of study area
3.2. Soil Sampling and Analysis

To describe the soils of the study area, surface soil samples at 0-30cm depth were collected from 5 random spots in zigzag form field before sowing, composited and used to analyze soil texture, pH, available P, total N, organic carbon (OC) and CEC. Soil texture determination was done by Bouyoucos hydrometric method. Organic matter determined based on the oxidation of organic carbon with acid dichromate medium following the Walkley and Black method as described by Dewis and Freitas (1970). Kjeldahl method (Dewis and Freitas, 1970) used to determine total N. Soil Cation Exchange Capacity determined by NH₄ - AOC method. The available soil P will be determined according to the methods of Olsen and Dean (1965). Soil pH determined in 1:2.5 soils: water ratio using a glass electrode attached to a digital pH meter.

3.3. Experimental Material

Three improved common bean varieties, Nasir, Awash-2 and Seri-125 were used. The varieties were released by Melkassa Agricultural Research Centre in 2003, 2013 and 2014 respectively. They are adapted to altitudes ranging between 1200 - 2000 metres above sea level. They can grow well under rainfall ranging between 350-1000mm. (Table 1)

Table 1. Description of the Variety used for the study area

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Awasha-2</th>
<th>Nasir</th>
<th>Seri-125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed colour</td>
<td>White</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Day to maturity</td>
<td>85-90 Day</td>
<td>86-88 Day</td>
<td>85-100 Day</td>
</tr>
<tr>
<td>Year of Release</td>
<td>2013</td>
<td>2003</td>
<td>2014</td>
</tr>
<tr>
<td>Rainfall adaptation(mm)</td>
<td>400-750 mm</td>
<td>350-1000 mm</td>
<td>450-700 mm</td>
</tr>
<tr>
<td>Altitude adaptation(msal)</td>
<td>1300-1700 m.s.a.l</td>
<td>1200-1800 m.s.a.l</td>
<td>1450-2000 m.s.a.l</td>
</tr>
<tr>
<td>Yield(kg/ha) on Research</td>
<td>28-31</td>
<td>20-30</td>
<td>32-35</td>
</tr>
<tr>
<td>Yield(kg/ha) on Farmer</td>
<td>18-22</td>
<td>23-27</td>
<td>22-25</td>
</tr>
<tr>
<td>Flower colour</td>
<td>White</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td>Centres of Released</td>
<td>Melkassa Research</td>
<td>Melkassa Research</td>
<td>Melkassa Research</td>
</tr>
</tbody>
</table>

Research attempts and some of the achievements in common bean improvement. (Adapted from variety register booklet MoA of (1997-2014).
3.4. Treatments and Experimental Designs

The treatments consisting of four inter-rows spacing (45, 40, 35 and 30 cm) and three varieties (Nasir, Awash-2 and Seri-125). The experiment was laid out in randomized complete block design (RCBD) in factorial with three replications.

3.5. Land Preparation and Field Management

Prior to sowing, the land was prepared by repeated ploughing using oxen plough. Common bean seeds were planted as per proposed inter row spacing. Initially two seeds per hill were planted and latter thinned to one plant at 5 to 6 leaf stage. At time of planting, all plots receive a basal application of (NPS) fertilizer at the recommended rate of 100kg/ha. All cultural practice for common bean production was used.

The gross plot had 4, 5, 5 and 6 rows for 45cm, 40 cm, 35 cm, and 30cm inter row spacing respectively. The length of each row is 4m. One row from each side of the plot served as border row, thus the 2, 3, 3, and 4 central rows for 45 cm, 40 cm, 35 cm, and 30cm inter row spacing respectively were used as net plot. The row length of the net plot was 3m. The net plot area were 3mx0.9m=2.7m², 3mx1.2m=3.6m², 3mx1.05m=3.15m² and 3mx1.2m=3.6m² for 45cm, 40cm, 35cm, and 30cm inter row spacing, respectively. The blocks were separated by 1 m.

3.6. Data Collection and Measurement

3.6.1. Phenology data

**Days to 50% flowering:** This was determined based on the number of days from sowing to the time 50% of the plants start flowering through visual observation.

**Physiological maturity:** This was recorded as the number of days from planting to when 90% of the plants per net plot show yellowing of pods and leaves.
3.6.2 Growth parameters

**Leaf area (LA):** This was recorded by taking a destructive sample of five plants from each plot. Leaf area was measured just before flowering using pictorial method.

**Leaf area index (LAI):** leaf area index was calculated as the ratio of total leaf area per five plants (cm²) per area of land occupied by the plants (Diwaker And Oswalt, 1992).

**Plant height:** This refers to as distance from ground level to the apex of each plant at the time of physiological maturity from each plot based on 5 random plants

**Number of branch:** This was determined by counting the number of primary branches on the main stem from five randomly taken plants from the net plot at physiological maturity.

3.6.3. Yield Components and Yield

**Stand count:** stand count per plot was recorded from the net plot was area after thinning and at harvest. The final plant stand percentage (final plant stand was counted at maturity/population established after thinning x 100) of the respective treatments were used to determine the stand loss due to competition.

**Number of pods per plant:** It was based on five randomly sampled plants per net plot at harvest and the average were taken as number of pods per plant

**Number of seed per pods:** It was recorded from average of 5 randomly taken pods from the net plot counted and divided by total number of pods to find the number of seed per pod.

**Above ground dry biomass:** At physiological maturity five plants were randomly taken close to the ground surface. The sample after sun drying to constant weight. Then average dry biomass per plant was multiplied by the number of total plants in net plot area at harvest and it was expressed as dry biomass in kg ha⁻¹. This biomass yield was also used for the calculation of harvest index.
**Hundred grain weight (g):** was measured weight of 100 seed will be determined by counting 100 seed from each plot and weighted using sensitive balance.

**Grain yield (kg/ha):** It was determined after sun drying from the net plot area and adjusted to 10% moisture level. The seed was cleaned and converted in to kg ha\(^{-1}\)

**Harvest index (%):** To determine calculated as the ratio of grain yield to above ground dry biomass per net plot and multiplied by 100.

**3.7. Data Analysis**

The measured variables were analyzed using the SAS computer software program. Effects were considered significant if P values are < 0.05. Significant differences among treatment means was tested using LSD at 5% level of significance.
4. RESULTS AND DISCUSSION

4.1. Physico-Chemical Properties of Soils of the Experimental Sites

The pre planting soil analysis showed that the experimental soil has a pH (H₂O) of 4.6 (acidic). FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil is within the range for productive soils. Textural class of the soil is clay loam with composition of 30% clay, 31% silt and 39% sand. The experimental soil was found to have a CEC of 27.3 cmole kg⁻¹ soil. Tekalign (1991) has classified soil total N content of <0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and >0.25% as high. According to this classification, the soil samples were found to have moderate level of total N (0.18%), indicating that the nutrient is a limiting factor for optimum crop growth. The available P of the soil was 3.2 ppm (Table 1) which is very low according to the rating by Landon (1991).

The organic carbon content of the soil was 2.20% which was medium according to the rating of Tekalign (1991) indicating moderate potential of the soil to supply nitrogen to plants through mineralization of organic carbon. Cation exchange capacity (CEC) is an important parameter of soil because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Hazelton and Murphy (2007), top soils having CEC greater than 40 cmol (+) kg⁻¹ are rated as very high and 25-40 cmol (+) kg⁻¹ as high. Thus, according to this classification, the soil of the experimental site had high CEC (27.3 cmol (+) kg⁻¹ soil) indicating its better capacity to retain the cations. The exchangeable K in in the soil was rated as high. Critical values for K that begin to limit plant growth are around 0.2-0.5 cmol (+)/kg (Gourley, 1999).
Table 2. Soil physico-chemical properties of the experimental site

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Values</th>
<th>Rating</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical Property</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td>39</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>31</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td>30</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Textural class</td>
<td>Clay loam</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Chemical Property</strong></td>
<td>Value</td>
<td>Rating</td>
<td>References</td>
</tr>
<tr>
<td>pH(H₂O) (%)</td>
<td>4.6</td>
<td>Acidic</td>
<td>FAO (2000)</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>2.2</td>
<td>Medium</td>
<td>Tekalign Tadesse (1991)</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.18</td>
<td>moderate</td>
<td>Tekalign Tadesse (1991)</td>
</tr>
<tr>
<td>CEC [cmol(+)/kg soil]</td>
<td>27.3</td>
<td>high</td>
<td>Hazelton and Murphy (2007)</td>
</tr>
<tr>
<td>Exchangeable K [cmol(+)/kg soil]</td>
<td>0.66</td>
<td>Low</td>
<td>Metson (1961)</td>
</tr>
</tbody>
</table>

4.2. Phenological and Growth Parameters

4.2.1. Days to 50% flowering

The main effect of variety highly significant (P<0.01) on days to 50% flowering while effect of inter and interaction were non significant on days to 50% flowering (Appendix Table 1)

Variety Seri-125 significantly was delayed in flowering than variety Awash-2 and Nasir (Table 3). This difference in day to 50% flowering among the varieties might be due to genetic variation. In conformity to this result, Wogayehu (2005) and (Tripathi et al., 2012) reported the same result significant differences among the varieties of common bean on days to 50% flowering, Similar CIAT (1975) reported that day to 50% flowering of (Phaseolus vulgaris) is usually initiated 28-42 days after planting, but varieties growing at high elevation flowering later.
4.2.2. Physiological maturity

Variety had highly significant (P<0.01) effect on physiological maturity while, the inter row spacing showed significant (P<0.05) effect and the interactions were not significant (Appendix Table 1). Amongst inter row spacing, the 45 cm delayed days to physiological maturity than the narrow spacing of 30 cm. As the inter row spacing increased from 30 cm to 45 cm the days to maturity increased from 86.64 days to 91.07 days (Table 3). This might be due to high amount of radiation energy at wider row spacing destroys growth regulating hormones at the cell differentiating parts of the plant that resulted in stopping further growth increments also high availability of growth resources that promote luxurious growth enhanced the lateral growth and prolonged maturity.

The hastened days to maturity due to narrow inter row spacing might be due to less competition of light interception. In agreement with this result, Mulatu (2017) obtained significantly early days to maturity of haricot bean increasing due to increasing row spacing. Similarly, Mebrat et al., (2013) also reported increasing days to maturity as inter-row spacing increased from 20cm to 30cm and 40 cm of check pea likewise; Beruktawit (2012) reported that days to maturity increased from 79.89 days to 82.33 days as increasing inter row spacing from (30 cm) to (50 cm) on common bean.

Variety Nasir and Awash-2 matured earlier than variety Seri-125 (Table 3). The possible reason for this difference is genetic since variety Seri-125 is late maturing with more vegetative growth whereas other variety were early maturing with less vegetative growth. In agreement with this result, Woku (2005) and Wogayehu (2005) reported similar significant difference among varieties on days to physiological maturity on common bean. Full maturity for dry bean seed type was attained from 45 to 150 days after emergence, depending on growth habit type and location (Singh, 1982)

4.2.3. Leaf area and Leaf area index

Analysis of variance showed that both main effects of varieties and inter row spacing had highly significantly (p<0.01) effect on leaf area and leaf area index while, the interaction had not significantly (Appendix Table 1). The highest leaf area (1251.5 cm²) and leaf area index (2.78) were
observed due to widest inter row spacing (45cm) while, the lowest leaf area (632.6 cm$^2$) and leaf area index (2.11) were obtained due to narrowest inter row spacing (30cm) (Table 3).

The widest inter row space tended to enhance vegetative growth of the plant resulting in the development of large leaf area. This could be most likely to be due to more availability of growth factors and better penetration of light, consequently increased number of leaves produced and the size of individual leaves in plants and increased leaf area index. In agreement with this result Beruktawit (2012), reported the highest leaf area (3678 m$^2$) and leaf area index (4.82) while, the lowest leaf area (1350 m$^2$) and leaf area index (4.45) were due to the widest and narrowest spacing respectively on common bean. Similary, Hodgson (2005) and Abdel (2008) reported that the development of more and vigorous leaves under wide inter row space in spatial arrangement helped to improve the photosynthetic efficiency of the crop and supported large number of pods, Mekonnen (2012) also reported that as inter row spacing decreased the leaf area and leaf area index become decreased in common bean.

With respect to the variety Seri -125 at inter row spacing had the highest leaf are (964.5 cm$^2$) and leaf area index 2.52 and the values were statistically at par with variety Nasir leaf area 954.9 cm$^2$ and leaf area index (2.51). On the other hand, variety Awash-2 gave the lowest leaf area (857.2 cm$^2$) and leaf area index 2.19 (Table 3). The variation in leaf area and leaf area index within common bean varieties might be attributed to their inherent genetic characters. In agreement with this result, Wogayehu (2005) found that the leaf area and leaf index of Common bean was significantly affected by the main effect of varieties.
Table 3: The main effect of variety and inter row spacing on physiological maturity, days to 50% flowering, leaf area and leaf area index at Nejo in 2018

<table>
<thead>
<tr>
<th>Inter- Row (cm)</th>
<th>Days to 50% flowering</th>
<th>Physiological Maturity</th>
<th>Leaf area(cm²)</th>
<th>Leaf area index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>41.00</td>
<td>86.64&lt;sup&gt;c&lt;/sup&gt;</td>
<td>632.6&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.11&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>35</td>
<td>39.89</td>
<td>87.78&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>796.6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.28&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>40s</td>
<td>38.56</td>
<td>89.54&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>995.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.49&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>45</td>
<td>39.78</td>
<td>91.07&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1251.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.78&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Awash-2</td>
<td>37.08&lt;sup&gt;c&lt;/sup&gt;</td>
<td>86.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>837.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.19&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nasir</td>
<td>40.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>87.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>954.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.51&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Seri-125</td>
<td>42.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>92.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>964.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.52&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (%)</td>
<td>2.24</td>
<td>1.83</td>
<td>65.0</td>
<td>0.17</td>
</tr>
<tr>
<td>CV(%)</td>
<td>6.6</td>
<td>2.4</td>
<td>8.4</td>
<td>8.5</td>
</tr>
</tbody>
</table>

LSD= Least Significant Difference; CV= Coefficient of Variation. NS= Non-significant Means in columns followed by the same letter(s) are not significantly different at 5% level of significance

4.2.4. Plant height

The analysis of variance showed that the main effect of inter row and variety were highly significant (P<0.01), while, the interaction was significant (P<0.05) effects on plant height (Appendix Table 1). The narrowest (30 cm) and widest (45cm) inter row spacing resulted in tallest (56.60cm) and shortest (43.90cm) plant for variety Seri-125 (Table 5).

In general, as inter row spacing increased, the plant height decreased showing that inter row spacing to be inversely related to plant height among varieties. This increase in plant height could be justified on the bases of increase in the number of plants per unit area coupled with high plant to plant competition.

Due to this lower amount of light intercepted by a single plant resulting into increased inter node length and under narrowest space there might be comparatively low solar interception through crop canopy and under increased inter spacing probably the reduced interplant competition for light might have resulted in such variation in plant height. In agreement this result, Maguje (2017) found on
determinate common bean varieties where inter row spacing increasing from 30cm to 50cm the plant height decreasing from 47.20cm to 42.93cm respectively. Caliskan et al. (2007) also reported that tallest plants were obtained in a 30 cm row width, while the shortest was obtained in 70 cm row width of soybean. Likewise, Chabot et al. (1996) reported that, plant height difference within common bean varieties could be due to differences among the genotype.

Table 4. interaction effect of variety and inter row spacing on plant height (cm) at Nejo, in 2018

<table>
<thead>
<tr>
<th>Inter -Row(cm) Varieties</th>
<th>Aawash-2</th>
<th>Nasir</th>
<th>Seri-125</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>46.63&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>54.90&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>56.60&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>35</td>
<td>46.30&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>53.80&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>53.40&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>40</td>
<td>44.47&lt;sup&gt;de&lt;/sup&gt;</td>
<td>45.63&lt;sup&gt;de&lt;/sup&gt;</td>
<td>49.27&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>45</td>
<td>43.52&lt;sup&gt;de&lt;/sup&gt;</td>
<td>44.40&lt;sup&gt;de&lt;/sup&gt;</td>
<td>43.39&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD</td>
<td>3.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>3.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD= Least Significant Difference; CV= Coefficient of Variation. Means in columns Followed by the same letter(s) are not significantly different at 5% level of significance

4.2.6. Number of branches per plant

The result of analysis showed that, the main effect of variety, inter row spacing and interaction were highly significant (P<0.01) on number of branches per plant. (Appendix Table 1). Variety Seri-125 had highest number of branches with mean value of 2.65 at widest inter row space (45cm) and lowest (1.2) was at 30cm spacing. The number of branches increasing as inter-rows spacing increasing (Table 6).

The increased numbers of branches at the wider inter row space also attributed to more interception of sunlight and nutrients available that might have resulted in higher axillary buds formation and differentiation leading to higher number of branches per plant. In agreement to the result of this study, Maguje (2017) reported the highest number of branches per plant (4.5) obtained at widest inter row spacing (50 cm), while the lowest number of branches (1.5) was recorded at narrow inter row spacing (30 cm) on common bean varieties. Likewise, Mehmet (2008) who stated that as spacing gets wider more interception of sunlight for photosynthesis,
which results in the production of more nutrients for partitioning toward the development of more branches. Beruktwit (2012) also reported the highest number of branch per plant (3.08) was obtained with inter row spacing of (50cm), while the lowest branch per plant (2.63) was scored at lowest inter row spacing of (30cm) on common bean.

Table 5. The interaction effect of variety and inter row spacing on number of branch per plant on common bean variety at Nejo in 2018

<table>
<thead>
<tr>
<th>Inter Row(cm)</th>
<th>Varieties</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Awash-2</td>
<td>Nasir</td>
<td>Seri-125</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>1.39&lt;sup&gt;de&lt;/sup&gt;</td>
<td>1.41&lt;sup&gt;de&lt;/sup&gt;</td>
<td>1.20&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>1.50&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>1.41&lt;sup&gt;de&lt;/sup&gt;</td>
<td>1.50&lt;sup&gt;cd&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>1.63&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>1.53&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>2.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>1.74&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.10&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

LSD= Least Significant Difference; CV= Coefficient of Variation. Means in columns Followed by the same letter(s) are not significantly different at 5% level of significance

4.3. Yield and Yield Components

4.3.1. Stand count

Variety showed significant effects (P<0.05), while the inter row spacing was highly significant (P<0.01) on stand count. However, the interaction was not significant effect (Appendix Table 1). The highest stand count (96.62%) was recorded at wider inter row spacing (45cm), whereas the lowest stand (85.87%) was observed from narrowest inter row spacing (30 cm) (Table 6).

In general, closer inter row spacing resulted in higher stand reduction than wider spacing. The lowest reduction in narrowest inter row spacing might be due to canopy effect, there is a possibility that at narrower inter row spacing (with higher population density) plants crowded out and die due to intense competition for growth resources and growth vegetative. In line with the study Maguje (2017) who worked on common bean as increasing inter row space from 30cm to 50cm reduced
stand count from (13.1%) to (12.3%) respectively. Similarly, Njoka et al., (2005) reported that increased plant mortality with decreasing inter row spacing in common bean.

Variety Awash-2 was highest stand count (92.01) and the lowest stand count (89.52) from variety Seri-125 (Table 6). It was observed that Awash-2 has low canopy as compared to other. The possible reason for variety Awash-2 due to low canopy growth this enhances to increase sufficient resource and sunlight due to this low mortality. In conformity with this result, Mekonnen (2010) reported that a major factor influencing plant arrangement for any particular crop is the genotype.

4.3.2. Number of pods per plant

The variety and inter row spacing showed significant (P<0.05) effect on the number of pods per plant. However, the interaction effect was not significant. (Appendix Table 2). Variety Seri-125 had higher number of pods per plant (17.44) and the lowest was from variety Awash-2 (15.45) (Table 6). The possible reason behind is the deference within variety having the potential to produce number of pod per plant and other sink that determines the growth component and yield of common bean. In line with result study, Gebre-Egziabiabher et al., (2014) reported significant difference among haricot bean varieties for number of pod per plant.

Widest inter row spacing (45 cm) resulted in highest pods per plant (17.87) and narrowest inter row spacing of (30 cm) scored the lowers pods per plant (14.42) (Table 6). In wider inter row spacing, the growth factors (nutrient, moisture and light) for individual plants might be easily accessible hence retaining more flowers for pod formation and support the development of lateral branches for more pod development. In agreement to the result of this study, Hodgson and Blackman (2005) and Abdel (2008), reported that the development of more and vigorous leaves under wide inter row space spatial arrangement helped to improve the photosynthetic efficiency of the crop and supported large number of pods.

With similar study Abubaker (2008) reported that wider row spacing of 60 cm gave significantly higher number of pods compared to (30cm) narrow spacing in common bean. Chandhla (200) also reported that the highest number of pods per plant (7.2) at (40cm) inter row spacing and the lowest
Likewise, Azarakhash (2007) found that the highest number of pods per plant (26.73) was obtained from 50 cm inter-row spacing, while the lowest number of pods per plant (7.53) was found at 20 cm inter row on haricot bean.

Table 6. The main effect of inter row spacing and variety on number of pod per plant, number of seed per pod and Stand count at Nejo in 2018

<table>
<thead>
<tr>
<th>Inter Row(cm)</th>
<th>Number of pod per Plant(NPPP)</th>
<th>Number of seed per pod(NSPP)</th>
<th>Stand count reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>14.42&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.36&lt;sup&gt;d&lt;/sup&gt;</td>
<td>85.87&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>35</td>
<td>15.69&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.88&lt;sup&gt;c&lt;/sup&gt;</td>
<td>87.12&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>40</td>
<td>16.75&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>4.94&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>45</td>
<td>17.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>96.62&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.88</td>
<td>0.37</td>
<td>1.983</td>
</tr>
<tr>
<td>Awash-2</td>
<td>15.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.98&lt;sup&gt;b&lt;/sup&gt;</td>
<td>92.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nasir</td>
<td>15.65&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.69&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Seri-125</td>
<td>17.44&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.72&lt;sup&gt;a&lt;/sup&gt;</td>
<td>89.52&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LSD (%)</td>
<td>1.63</td>
<td>0.32</td>
<td>1.71</td>
</tr>
<tr>
<td>CV(%)</td>
<td>11.9</td>
<td>8.7</td>
<td>2.2</td>
</tr>
</tbody>
</table>

LSD = Least Significant Difference; CV = Coefficient of Variation; NS = Non-significant Means in columns followed by the same letter(s) are not significantly different at 5% level of significance.

4.3.3. Number of seeds per pod

Effect of inter row spacing and variety on number of seed per pod was highly significant (P<0.01) and their interaction effect was non significant (Appendix Table 2). The highest number of seed per pod was (5.35) recorded at widest inter row spacing (45 cm) whereas, the narrowest inter row spacing (30cm) produced the lowest number of seed per pod (3.367) (Table 6).

This variation might be due to the fact that at wide inter row spacing plants encountered less competition than closely spaced plants and thus exhibited better growth that contributed to production of more number of seeds per pod than closely spaced plants. This result was in
agreement with, Beruktawit (2012) who obtained the highest number of seeds per pod (5.9) at widest space and the lowest seeds per pod (5.6) at the narrowest spacing on common bean.

Variety Seri-125 had the maximum number of seeds per pod of 4.72 and the values were statistically at par with variety Nasir 4.44 number of seeds per pod while, the lowest were recorded 3.89 from variety Aawash-2 (Table 6). Generally, the number of seeds per pod was significantly affected due to varieties. Thus, variation on the number of seeds per pod was highly affected by genetic factors and environment. In conformity with this result, Fageria and Santos (2008) reported that the number of seeds per pod of different common bean genotypes varies in the range of 3.1 to 6 and attributed the difference mainly due to the genetic variation of cultivars.

4.3.4. Hundred Seed weight

Variety and inter row spacing were highly significant (P<0.01) and the interaction effects did not show were significant effect on hundred seed weight (Appendix Table 2). Widest inter row spacing of 45 cm the resulted is highest hundred seed weight of (30.79 g) and the lowest 100 seed weight (23.71g) measured at 30cm inter row space (Table 7).

The decrease in 100 seed weight could be attributed to decrease assimilate division among seeds as a result of the increased inter plant competition in utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues, hence decrease in weight. However, in wider inter row spaced plants, there could be improved supply of assimilates stored in the seed, hence, increase in a 100 seed weight. In line with result, Solomon (2010) reported that 1000 seed weight of common bean decreased with reduction inter row space. Maguie (2017) also reported that wider spacing (50cm) highest hundred seed weight (36.12 g) and the narrowest spacing (30cm) lowest hundred seed weight (32.79 g) of common bean. Likewise, Melaku 2012 obtained the highest 100 seed weight of 27.47 g at the widest row spacing (50cm) and the lowest (24.99 g) at narrowest row spacing (30cm) on common bean.

Variety Seri-125 gave the highest 100 seed weight (28.94 g) than the other variety and the lowest (24.55 g) from variety Awash-2 (Table 8). The variation in seed weight of common bean could be
due to genetic difference. In agreement with this result, Dechasa (1996) found significant difference on the number of pods per plant, number of seeds per pod and hundred seed weight due to different common bean genotypes. Turk et al. (1980) also reported that individual seed weight was highly affected by genetic factors except in case of severe water stress and hot desiccating winds causing forced maturity on cowpea.

Table 7. The mean effect of variety and inter row space on above ground dry biomass (kg ha\(^{-1}\)), hundred seeds weight (g) and harvesting index (%) at Nejo in 2018

<table>
<thead>
<tr>
<th>Inter- Row(cm)</th>
<th>Above ground dry biomass(kg ha(^{-1}))</th>
<th>Hundred seed weight (g)</th>
<th>Harvesting index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>8423(^{a})</td>
<td>23.71(^{b})</td>
<td>35.78(^{c})</td>
</tr>
<tr>
<td>35</td>
<td>6975(^{b})</td>
<td>24.57(^{c})</td>
<td>40.49(^{bc})</td>
</tr>
<tr>
<td>40</td>
<td>5918(^{c})</td>
<td>27.71(^{b})</td>
<td>49.0(^{b})</td>
</tr>
<tr>
<td>45</td>
<td>4041(^{d})</td>
<td>30.79(^{a})</td>
<td>71.34(^{a})</td>
</tr>
<tr>
<td>LSD (%)</td>
<td>580.8</td>
<td>1.41</td>
<td>10.94</td>
</tr>
<tr>
<td>Awash-2</td>
<td>5527(^{c})</td>
<td>24.55(^{c})</td>
<td>58.11(^{a})</td>
</tr>
<tr>
<td>Nasir</td>
<td>6177(^{b})</td>
<td>26.59(^{b})</td>
<td>47.04(^{b})</td>
</tr>
<tr>
<td>Seri-125</td>
<td>7315(^{a})</td>
<td>28.94(^{a})</td>
<td>42.33(^{b})</td>
</tr>
<tr>
<td>LSD (%)</td>
<td>503.0</td>
<td>1.22</td>
<td>9.47</td>
</tr>
<tr>
<td>CV(%)</td>
<td>9.4</td>
<td>5.4</td>
<td>22.8</td>
</tr>
</tbody>
</table>

LSD= Least Significant Difference; CV= Coefficient of Variation. Means in columns Followed by the same letter(s) are not significantly different at 5% level of significance

4.3.5. Above ground dry biomass

Main effect of inter row spacing and variety were highly significant (P<0.01) whereas interaction effect was not significant effect on above dry biomass (Appendix Table 2). The highest above ground dry biomass (8423 kg ha\(^{-1}\)) was recorded from the narrowest inter row spacing of (30 cm), whereas as the lowest (4041 kg ha\(^{-1}\)) was recorded from the widest inter row spacing of (45 cm). The above ground dry biomasses decreased as inter row spacing increased from 30 cm to 45 cm (Table 7).

The highest above dry biomass at the narrowest space might be due to more number of plants per unit area. In agreement with results Bakry et al., (2011) and Mtaita and Mutetwa (2014) reported
that increase in above dry biomass with decrease in the intra and inter row spacing because of higher populations per unit area. Similarly, Solomon (2010) and Pawar (2007) reported that dry biomass per hectare was significantly increased with decreasing inter row spacing on haricot bean. Ayaz et al. (2001) and Board et al. (1990) also reported an increase in biomass due to decrease in inter row spacing could be attributed to an increase in plants m\(^{-2}\) and consequently an increase in dry matter weight (kg ha\(^{-1}\)).

The heights (7315 kg ha\(^{-1}\)) and lowest (5527 kg ha\(^{-1}\)) above ground dry biomass was recorded from variety Seri-125 and Awash-2 respectively (Table 7). The highest dry biomass produced by the variety Seri-125 might be due to its late maturity as late maturing varieties usually produce large biomass. Similarly, Champion et al. (1998) reported that earlier developing cultivars produced greater biomass through stem extension and increased shading at ground level. The differential response of the varieties was attributed to variation in their genetic makeup. Such variations in dry biomass production in relation to maturity were reported by Mukhtar et al. (2013).

### 4.3.6. Harvest index (HI)

The main inter row spacing was highly significant (P<0.01) effect, while the variety was significant effect (P<0.05), whereas the interaction not significant. (AppendixTable 2). The highest (58.11%) and lowest (42.33%) harvesting index were observed form variety Awash-2 and Seri-125 respectively (Table 7). Variety Awash-2 had higher harvest index than the other varieties indicating the ability of these varieties in translocation dry matter to their seeds. This may be attributed to the genotypic differences with regard to efficiency in dry matter partitioning. In agreement to the result of this study, Fageria and Santos (2008) reported that harvest index of 20 common bean genotypes varied from 21% to 54%. Similarly, Wallace (1978) and Brown et al. (1989) reported significant influenced on harvest index among genotypes of chickpea.

The highest harvesting index (71.34%) was recorded at widest spacing (45 cm), while the lowest (34.41%) was due to the narrowest (30 cm) spacing harvesting index increased as inter row spacing increased (Table 7). In line with this result, Khan (2010) reported highest harvesting index (41.66%) at wider inter row spacing (45 cm) of chickpea than (32.6%) narrowest inter row spacing (15 cm).
Similary, Asaye (2018) reported harvesting index (62%) was obtained at widest inter (50 cm), while the lowest (28% and 33%) were obtained at (20 cm) and (30 cm) respectively. Solomon (2010) also reported that harvesting index was reduced with decreased row spaced on haricot bean.

4.3.7. Grain yield

Variety and inter row spacing highly significant (P<0.01) effect, while the interaction significant (P<0.05) effect on grain yield (AppendixTable 2). The highest yield (3202 kg ha⁻¹) and lowest (1901 kg ha⁻¹) were due to Seri-125 at 40cm spacing and Awash-2 at 45cm respectively. The trend show that yield of Awash-2 decreased as spacing increased from 30cm to 45cm, while Seri-125 and Nasir yield showed a slight increase with increased inter-row spacing up 40cm and 35cm respectively, beyond which it decreased. (Table 8).

This might be different variety common bean response to inter row spacing thus affected the grain yield. The reduced yield was as result of decreased inter row space and leading to intense inter plant competition for resources such as nutrients, water and solar radiation, this is manifested by high plant mortality and low numbers of pods per plant at the narrow inter row space, while increased grain yield might be due to narrowest inter row space seems to be more plants per unit area.

In line agreement with result study, Ozveren (2013) reported that further increases inter row spacing causes reduction in grain yield of field pea cultivars. However, further decreases inter row spacing together for large seeded field pea cultivars (Sefinesh) result in seed yield. Similary, Beruktawit (2012) reported that highest grain yield (3818 kg ha⁻¹) at widest inter row spacing (40cm) and the lowest grain yield (3274 kg ha⁻¹) at widest inter row spacing (50cm) on common bean varieties (Roba-1) within determinate bush growth habit. Maguje (2017) also reported that grain yield decreasing from (2125 kg ha⁻¹) to (1807 kg ha⁻¹) as increased inter row space from (30cm and 50cm) respectively on common bean varieties.

Table 8. The mean interaction effect of variety and inter row space on grains yield (kg ha⁻¹) of common bean at Nejo in 2018.
<table>
<thead>
<tr>
<th>Inter-Row(cm)</th>
<th>Varieties</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aawash-2</td>
<td>Nasir</td>
<td>Seri-125</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>3011&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>2982&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3094&lt;sup&gt;ab&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>2834&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3184&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3152&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>2357&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2935&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3202&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>1901&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2376&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2939&lt;sup&gt;ab&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

LSD: 408.0  
CV%: 8.5

LSD = Least Significant Difference; CV = Coefficient of Variation. Means in columns followed by the same letter(s) are not significantly different at 5% level of significance.
5. SUMMER AND CONCLUSION

Low yield of common bean in Ethiopia is attributed to several production constraints which include lack of improved varieties for the agro-ecological zones for suitable field operations; poor cultural practices such as inappropriate inter row spacing, weed infestation, low soil fertility, moisture stress, diseases and insect pests. Proper inter row spacing levels should be maintained to exploit maximum natural resources, such as nutrients, sunlight and soil moisture, to ensure satisfactory yield.

Increase in yield of common bean can be making certain, by maintaining appropriate inter row through different variety requirement spacing. In view of this, a field experiment was conducted at Nejo, western Ethiopia in 2010, to assess the effects of inter row spacing and varieties on growth yield components and yield of common bean. The factors studied were three common bean varieties (Awsh-2, Nasir and Seri-125) and fours inter row spacing (30, 35, 40 and 45cm) in factorial combination of randomized complete block design with three replications.

The main effects of varieties showed highly significantly (P<0.01) on day to 50% flowering physiological maturity, leaf area, leaf area index, number of seed per pod, 100 seed weight above ground dry biomass and grain yield significant effect (P<0.05) on stand count at harvesting. The highest day to 50% flowering (42.33) and physiological maturity (92.18 day), the highest leaf area (964.5m²), leaf area index (2.52), number of seed per plant (4.72), 100 seed weight (28.94g), and above ground dry biomass (7315kg/ha) were recorded from variety Seri-125, while the lowest leaf area (837.2), leaf area index (2.19), number of seed per pod (3.98), 100 seed weight (24.55g) and above ground dry biomass (5527 kg/ha) were recorded from variety Awash-2. Varieties had also significantly (P<0.05) effect on stand count, number of pod per plant and harvest index. Significantly the highest stand count (92.01) and number of pod per plant (17.44) where recorded from variety Seri-125, while harvesting index (58.11%) from variety Awash-2.

Inter row spacing showed highly significant (P<0.01) effects on plant height, number of branch per plant, leaf area, leaf area index, stand count, number of seed per pod, 100 seed weight and harvest index. Among the inter-row spacing the highest leaf area (1251.5m²), leaf area index (2.78), stand count (96.62), number of seed per pod (5.35), 100 seed weight (30.79g) and harvesting index
(71.34%) were observed at widest inter row spacing (45cm), while the highest above ground dry biomass (8423kg ha\(^{-1}\)) was recorded at narrowest inter row spacing (30cm) and inter-row spacing also significant (P<0.05) effect on physiological maturity and number of pod per plant, the late physiological maturity (91.07), while the early maturity (86.64) was due to the widest (45cm) and narrowest (30cm) inter row spacing respectively and the highest number of pod per plant (17.87) was at widest inter row spacing and the lowest number of pod per plant (14.42) was recorded at (30 cm) inter row spacing.

Interactions of varieties with inter row spacing showed highly significant (P<0.01) effect on number branch per plant, but significant (P<0.05) effect on plant height and seed yield. The tallest plant (56.60cm) was due to Seri-125 at (30cm) inter row spacing, the highest number of branch (2.65) showed from variety Seri-125 at 45cm inter row space and highest seed yield (3202 kg ha\(^{-1}\)) were recorded from variety Seri-125 at (40cm) inter row spacing.

Generating reliable information on agronomic management practices such as appropriate inter row spacing with improved varieties are quite important to sustainable common bean production and productivity. This study provides evidence that varieties and inter-spacing has influence on the phenology, growth, yield and yield components of common bean. It could be concluded that there was no significant yield difference of variety Seri-125 at all spacing, while variety Nasir at 30, 35 and 40cm and variety Awash-2 at 30 and 35 cm. Therefore, all spacing can be used for variety Seri-125. However, as this result is for one season and location; the study has to be repeated over locations and seasons to reach at a more reliable conclusion and recommendation for Nejo.
6. REFERENCES


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7. APPENDIX
Appendix Table 1. Means squares for growth and growth component yield of common bean

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>Day to 50% flower</th>
<th>Day to maturity</th>
<th>Leaf area</th>
<th>Leaf area index</th>
<th>Pant height</th>
<th>Number of branch per plant</th>
<th>Stand count at harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>6.028</td>
<td>15.867</td>
<td>1391.</td>
<td>0.01725</td>
<td>1.622</td>
<td>0.07510</td>
<td>22.1312</td>
</tr>
<tr>
<td>Variety (V)</td>
<td>3</td>
<td>83.028**</td>
<td>105.237**</td>
<td>60273 **</td>
<td>0.41906**</td>
<td>100.682**</td>
<td>0.48910**</td>
<td>23.268*</td>
</tr>
<tr>
<td>Space (S)</td>
<td>2</td>
<td>8.991ns</td>
<td>34.358*</td>
<td>640378 **</td>
<td>0.75840**</td>
<td>154.215**</td>
<td>1.27947**</td>
<td>217.646**</td>
</tr>
<tr>
<td>VxS</td>
<td>6</td>
<td>2.102ns</td>
<td>8.116ns</td>
<td>12079ns</td>
<td>0.06248ns</td>
<td>19.240*</td>
<td>0.28826**</td>
<td>8.531ns</td>
</tr>
<tr>
<td>Error</td>
<td>22</td>
<td>6.997</td>
<td>4.666</td>
<td>5887</td>
<td>0.04234</td>
<td>3.548</td>
<td>0.02716</td>
<td>4.113</td>
</tr>
</tbody>
</table>

CV %  6.6  2.4  8.4  8.5  3.9  9.7  2.2

Ns-non significant (P>0.05); * and ** significant at 5% and 1% probability levels, respectively
Appendix Table 2. Mean squares for yield and yield components of common bean

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>Number of pod per plant</th>
<th>Number of seed per plant</th>
<th>Above ground biomass kg ha(^{-1})</th>
<th>100%seed Weight</th>
<th>Grain yield kg ha(^{-1})</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>2.400</td>
<td>0.4243</td>
<td>93662</td>
<td>2.773</td>
<td>188882</td>
<td>86.2</td>
</tr>
<tr>
<td>Variety(V)</td>
<td>3</td>
<td>25.684*</td>
<td>1.6758**</td>
<td>9826382**</td>
<td>57.908**</td>
<td>991345**</td>
<td>786.5*</td>
</tr>
<tr>
<td>Space (S)</td>
<td>2</td>
<td>15.678*</td>
<td>7.6654**</td>
<td>30615034**</td>
<td>93.618**</td>
<td>813951**</td>
<td>2238.2**</td>
</tr>
<tr>
<td>V x S</td>
<td>6</td>
<td>3.928ns</td>
<td>0.2557ns</td>
<td>288816.ns</td>
<td>2.933ns</td>
<td>166956*</td>
<td>200.8ns</td>
</tr>
<tr>
<td>Error</td>
<td>22</td>
<td>4.469</td>
<td>0.1458</td>
<td>352942</td>
<td>2.080</td>
<td>58046</td>
<td>125.2</td>
</tr>
</tbody>
</table>

CV % 13.4 8.7 9.4 5.4 8.5 22.8

* and ** significant at 5% and 1% probability levels, respectively.

Ns - non significant (P>0.05).