# Effect of Green Bean-Sugarcane Intercropping on Growth and Yield Performance of Companion Crops at Omo Kuraz Sugar Project, South Omo Ethiopia

**MSc Thesis**

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**College of Agriculture**

**HAWASSA UNIVERSITY**

**Hawassa, Ethiopia**
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# Effect of Green Bean-Sugarcane Intercropping on Growth and Yield Performance of Companion Crops at Omo Kuraz Sugar Project, South Omo Ethiopia

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## Department of Graduate Committee

## HAWASSA UNIVERSITY

As members of the Examining Board of the Final MSc Open Defense, we certify that we have read and evaluated the thesis prepared by Abiy Negesse**,** entitled Effect of Green Bean-Sugarcane Inter-cropping on Growth and Yield Performance of Companion Crops at Omo Kuraz Sugar Project, South Omo Ethiopia and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science in agriculture (specialization, Horticulture).

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# DEDICATION

I dedicate this thesis manuscript to my lovely elder brother, Ayeneye Negesse and my Lovely mother, Ehite Tesgaye for nursing me with affection and love and for their dedicated partnership in the success of my life. My lovely sisters, Emebet Negesse, Mister Negesse and Tersit Negesse, their constant encouragement and confidence imbibing attitude has been a morals support for me. The memory of my lovely little brother, Tarike Negesse, always stays in my heart.

## STATEMENT OF THE AUTHOR

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| CV | Coefficient of Variation |
| Ec | Electrical Conductivity |
| ESC | Ethiopian Sugar Corporation |
| ESP | Exchangeable Sodium Percentage |
| FAO | Food and Agricultural Organization |
| G LM | General Linear Models Procedure |
| OKSDP | Omo Kuraz Sugar Development Project |
| LSD | Least Significant Difference |
| Masl | Meters above sea level |
| SAR | Sodium Absorption Ratio |
| SAS | Statistical Analysis System |

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# Effect of Green Bean-Sugarcane Intercropping on Growth and Yield Performance of Companion Crops at Omo Kuraz Sugar Project, South Omo Ethiopia

**By: Abiy Negesse**

**Advisor: Dereje Haile (PhD)**

## *ABSTRACT*

*Sugarcane is a relatively long-duration crop planted on wider spaced rows with slow initial growth, during this period, much of the solar radiant energy and land is wasted and up to 70% of the land between cane rows is left unutilized. Effects of green bean-sugarcane intercropping trials were conducted to ascertain practicability of intercropping green bean and sugarcane under irrigated farming at Omo Kuraz Sugar Development Project. The study was initiated to evaluate the effect of intercropping of two green bean varieties with sugarcane and that are planted at two row planting space, on growth performance and yield of the two crops. Factorial experiment was laid out in randomized complete block design with three replications. Data on yield and yield contributing traits were collected and subjected to analysis of variance. The analysis of variance for marketable pod yield and phenological parameters showed a significant difference ($p<0.01$) among varieties and interactions of the factors. Amongst the two green bean varieties, variety plati gave the highest (7.6 t $ha^{-1}$) pod yield as compared to that of variety B.C 4.4 which gave the lowest yield (1.75 t $ha^{-1}$). Whereas the highest pod yield (8t $ha^{-1}$) was recorded on the interaction of (variety plati, with 10cm planting space and sole cropped). On contrary the lowest pod yield (0.8 t $ha^{-1}$) was recorded on the interaction of (variety B.C 4.4, with 15cm planting spacing and intercropped with sugarcane). The highest pod yield was recorded (5.108 t $ha^{-1}$) on 10cm planting spacing, while (4.242 t $ha^{-1}$) was recorded on 15cm planting spacing. However, the two planting spacing's and cropping system showed no significant difference ($p<0.05$) on pod yield. Similarly the lowest pod yield (i.e., 4.858 t $ha^{-1}$) and (4.492 t $ha^{-1}$) was recorded on sole cropped green bean and intercropped with sugarcane respectively. Moreover, there was also significant difference ($p<0.05$) among cropping systems and varieties, in number of pod per plant. The highest number of pod per plant (32.33) was recorded on variety plati, followed by sole cropping system (29.25). Variety plati also scored the largest pod diameter (6.7mm) and pod length (11.45cm). Likewise, sugarcane tiller number found to be significantly ($p<0.05$) affected by intercropped planting spacing's of green bean and cropping system. Accordingly, the highest (231,034 tiller number $ha^{-1}$) and the lowest (143,214) tiller number $ha^{-1}$ was recorded in sole sugarcane crop and intercropped crop respectively. Green bean planting space also showed a significant effect on sugarcane tiller number per plot (i.e., 103,189.7 in 10 cm and 183,237.6 in 15 cm spacing's). However no significant difference was observed on mill able cane stalk number per hectare, single cane stalk weight, cane yield and sugar yield among varieties, spacing's, cropping systems and there interaction. The result clearly highlighted that intercropping of sugarcane with green bean has no significant impact on crop yields of both crops and efficient land utilization advantage. Which subsequently confirms the technical viability/practicability of sugarcane-green bean intercrop under irrigated farming system Therefore, under irrigated farming system condition, variety plati with 15 cm spacing and 10cm can be recommended for green bean-sugarcane intercropping, and sole cropping system respectively at Omo Kura at Omo Kuraz Sugar Development Project.*

Keywords: Green Pod Yield, Green Bean Varieties, Inter Crop, Sole Crop, planting spacing's, Sugarcane.

# 1. INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a crop of tropical and subtropical areas that provides around 80% sugar and 35% ethanol of world production (FAO, 2016). In Ethiopia, sugar industry plays a significant role in the socio economy of the country. At present sugarcane is cultivated on 110, 210 ha and factories on operation, like Wonji, Metehara, Fincha, Kessem, Arjodedesa and other seven sugar development projects on different level of construction together produces 350,000 to 400,000 tons of sugar per annum. The current production of sugar only covers about 60% of the annual demand for domestic consumption in Ethiopia (ESC, 2019).

Ethiopia has more than five hundred thousand hectares of land suitable for irrigable agriculture (ESC, 2017). Ethiopian Sugar Corporation (ESC) announced its intention to expand sugarcane cultivation to 320,000 hectares across the country. From this total, the Omo-Kuraz Sugar Development Project (OKSDP) would make up more than half, 175,000 hectares (KSDP, 2016). Moreover a detailed field survey and investigations at feasibility level are being on the progress in Omo sub-basin project area identifies a net irrigable area of additional 150, 000 ha of land for the contemplated sugar cane development (KSDPFS, 2013).

Sugarcane is a relatively long-duration crop planted on wider spaced rows with slow initial growth, and it takes about 90 to 120 days for complete canopy closure in subtropical belt. During this initial 3 to 4 months period, much of the solar radiant energy and land is wasted and during the formative phase of sugarcane, the mean light interception is less than 30% (Ramanujan and Venkataramana, 1999) and up to 70% of the land between cane rows is left unutilized. The sugarcane rhizosphere occupies less than one-third of the soil during this period. In the interspaces, weeds grow and affect the sugarcane tillering and growth (Sundara, 1987, 1998). During this period we can profitably exploit the three valuable natural resources (radiant energy, soil and space) by growing short duration inter crops.

Intercropping is amongst key agronomic strategy to feed the exponentially growing world population (Katyayan, 2005). Almost all the concerns for agriculture (agricultural technologies, government farm policies, modern crop varieties and research efforts) are focused on the production of sole cropping, while some drawbacks in modern agriculture system force the farmers to take interest in intercropping (Iqubal *et al*., 2019). Intercropping systems provide 15–20% of food supply to the world (Lithourgidis *et al*., 2011). Besides, intercropping has ecological, biological and socioeconomic advantages over sole cropping (Waktola *et al*., 2014). In Ethiopian farming system, there are many ways to assure near future food safety.

It is believed that some of the short-duration crop, especially legume crops, can successfully and profitably be intercropped with sugarcane (Kailasam 2008; Geetha *et al*., 2015), maize (Solomon *et al*., 2014; Alemayehu *et al*., 2016), and Sorghum (Gebremichael *et al*., 2019) without seriously affecting their yield. In order to drive benefits from its slow growth and make better use of resources, intercropping of some short duration crop (leguminous crop) can be explored and practiced in many sugar cane plantation in Ethiopia.

Hence, about 110,210 ha of irrigated cane plantation (ESC, 2019) having favorable agro-climatic condition to grow legume crops as intercrop is an added advantage for Ethiopia to ensure its movement towards food self-sufficiency. It is also important to note that with once the on-going sugar projects being completed, Ethiopia would have about 360,000 ha of land under sugarcane production (ESC, 2019). Hence, successful intercropping of legume, vegetables and other crops with sugarcane mean, an increase in legume crop production with additional 360,000 ha. Moreover, Sugarcane out growers need not wait until the harvest of the sole crop to obtain financial returns.

It fixes atmospheric nitrogen via symbiotic rhizobia in root nodules, and consequently, has in rotation, the potential for maintaining soil fertility, and helps in controlling weeds. Previously, in Ethiopia, sugarcane-haricot bean intercropping has been practiced on irrigated sugarcane plantation as a means to support government agenda of ensuring food self-sufficiency. However, as dry bean, its economic viability has been doubted (Feyesa *et al.*, 2014) compared to the revenue generated out of sugar (i.e., a high value product).

Green bean (*Phaseolus vulgaris* L.) is grown for its unripe freshly eaten fibreless succulent pods (Abate, 2006; CIAT, 2006). It is one of fresh legume vegetables grown for export market (Alemu *et al*., 2017). It is widely cultivated in the world due to its contribution to soil fertility through nitrogen fixation (Demelash, 2018) and having high market value and protein (Damián *et al*., 2013; Celmeli *et al*., 2018).

Green bean is one potentially viable option because it is a short-duration crop (60-70 days). Green beans seed germinates within 5 days and can be harvested at 60 days after planting (CIAT, 2015).

Sugarcane and green beans can be best partners under intercropping conditions because both crops have complementary characteristics (Alam *et al*., 2015).

So far there was no attempt to evaluate synergistic effect of sugarcane-green bean or sugarcane-vegetable intercropping in the sugar industry of Ethiopia. At this point, it is important to note that compared to dry beans, green bean would take a shorter period. This ultimately narrows the window of completion between the two crops. Thus, it is hypothesized that it is possible to grow green bean without necessarily affecting cane and sugar yield.

Study in South Africa indicated that, for successful intercropping of sugarcane use a minimum row width of 1.2 m to allow space for the food crops (Parsons and Khubone, 2010). In Ethiopia, conventionally, sugarcane planting is planted at 1.45 meter row spacing (Firehun *et al*., 2004) these spaces shall be used to intercrop green bean to ensure better intercrop yield without affecting the main crop. This confirms the existing potential of sugarcane-green bean intercropping in Ethiopia. In this context, it is hypothesized that growth of green bean between sugarcane rows is feasible. However, it is necessary to evaluate the efficiency of this intercropping system with no significant effect on the main crop to recommend the practice in the area.

Therefore, this paper was initiated to meet the following objectives

- To ascertain practicability of sugarcane-green bean intercropping
- To evaluate the effect of sugarcane-green bean intercropping on growth, yield and yield components of companion crops
- To evaluate green bean varieties and planting spacing for successful sugarcane-green bean intercropping system

# 2. LITERATURE REVIEW

## 2.1. Concept of intercropping

Though of intercropping were defined by different authors in different ways, the basic idea is more or less alike. It is defined as the growing of two or more crops simultaneously on the same field with crop intensification in both time and space dimensions and crops interact during all or part of crop growth and farmers manage more than one crop at a time in the same field (Francis, 1986; Willey, 1979). Comparably, intercropping has been defined as the growing of two or more crops in different but proximate rows (Ruthenberg, 1980). Common characteristics of different forms of intercropping have the effect on intensifying crop production and exploiting more efficiently environments with limiting or potentially limiting resources (Papendick *et al.*, 1976; Trenbath, 1982).

Andrews and Kassam, (1976), further divide intercropping in four mixed intercropping (growing crops simultaneously with no distinct row arrangement), row intercropping (growing crops simultaneously in different rows), strip intercropping (growing crops simultaneously in different strips to permit the independent cultivation of each crop) and relay intercropping (growing crops in relay, so that growth cycles overlap).

Crop combinations in intercropping differ with geographical Experiment, crop morphology and growth durations. Based on geographical Experiment crop combination for intercropping would be intercropping of tree crops, intercropping of tree and field crops, or intercropping of field crops (Trenbath, 1982). On the basis of morphology and growth duration, Herrera and Harwood (1973), distinguished the following crop combinations: crops of similar heights and growth durations such as barley and oats; crops of similar morphology but different growth durations such as 6 month sorghum and 3 month millet; annual or biennial crops with those of longer growth durations such as millet and cassava or soy bean and sugarcane; and annual crops of cereals and legumes such as sorghum and pigeon pea, maize and cowpea. Thus, combination of crops for intercropping should be primarily determined by the length of the growing season and the adaptation of crops to particular environment (Ofori and Stern, 1987).

### 2.2. Socio-economic advantage of intercropping

The main advantage of intercropping systems is efficient and complete use of growth resources such as solar energy, soil nutrients and water (Francis, 1986; Sivakumar, 1993). Some of the suggested reasons for the popularity of intercropping in the tropics and subtropics are efficient use of growth resources like water, nutrients and light (Willey, 1979; Natarajan and Willey, 1980), balanced nutritional supply of energy and protein (Jodha, 1981), highest yield and greater land use efficiency (Ofori and Stern, 1987), expensive weed control (Enyi, 1973); minimization of agricultural risks (Jodha, 1981; Rao and Willey, 1980), improvements of soil fertility (Bandy-opadhyay and De, 1986), minimization of peak of labor and demand (Okigbo and Greenland, 1976). And risk avoidance is one of the prominent advantages that intercropping offers (Willem, 1990).

Agronomists and social scientists have come to understand biological, social and economic advantages of multiple cropping for minimizing risks (ICRISAT, 1977) due to a realization that research should aimed at improving the existing cropping system of the traditional system. In most multiple cropping systems developed by smallholders, productivity in terms of harvestable products per unit area is highest than under sole cropping with the same level of management. Yield advantages can range from 20% to 60% (Steiner, 1984, Francis, 1986). Lamberts (1980), reported that farmers practice intercropping due to its importance in yield increment or increase productivity, better use of available resources (land, labor, time, water and nutrient); reduction in damage caused by pest (diseases, insects, and weeds); and its socio economic and other advantages (greater stability, economics, human nutrition, and biological aspect).

Intercropping of cereals and pulses is widely practiced in Africa. About 83 to 98 percent of the production of the two primary components of African diets namely, cowpea and beans are estimated to come from intercropping land use system (CIAT, 1986; Davis and Smithson, 1986). Common bean is the usual popular legume component grown in association with sorghum in highest and medium altitude areas. In sorghum-bean combination, beans have short maturing duration, which ensures its harvest with minimum availability moisture, makes bean a dependable catch crop when sorghum fails due to the absence of late rain or other factors (Dagnew, 1981).

### 2.3. Crop ecology and intercropped competition

In the relationship between competition and ecological niches, if the niches of two species are too similar, they probably compete sufficiently intensely to exclude one another (Colwell and

Fuentes, 1975; Pianaka, 1976). Simply, two species cannot occupy the same niche. If their niche requirements are sufficiently similar they compete with one another intensely, as a result one or the other were come extinct. This is referred as competitive exclusion principle. On the other hand, if the two species have similar but distinct requirements, they compete with one another weakly and hence they will persist indefinitely in the environment and this referred as 'competitive togetherness' principle (Vandermeer, 1989).

Mixtures of plants on the farm are not just a random collection of genetic resources. Indeed, the success of an intercropping system depends upon the selection of crop types and Varieties that have were intercropped (Francis, 1986; Willem, 1990). Each species must fit in to the biophysical and socioeconomic environment of the farm and must perform productive, reproductive, protective and social functions or a combination of these (Francis, 1986; Willem, 1990). The species and Varieties selected depend greatly on what the combination of these and what the household needs to produce and what can be obtained from the local market (Francis, 1986; Willem, 1990).

In terms of land use, growing crops in mixed stands is regarded as more productive than growing them in separately (Andrews and Kassam, 1976; Willey, 1979). Like a beneficial effect of shade in a certain cropping system, there are also situations in which a given crop will actually grow better in the presence of another crop than as a sole crop (Willey, 1985). Usually a yield advantage occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to complement each other and make better overall use of resources than grown separately.

In terms of competition, the component crops not competing for exactly the same resource and thus inter crop competition is less than intra-competition. Competition between crops for growth limiting factors is regulated by basic morpho-physiological differences and agronomic factors such as the proportion of crops in the mixture, fertilizer applications, and relative time of planting (Trenbath, 1976). Where crops are arranged in defined rows, the degree of competition is determined by the relative growth rates, growth durations, and proximity of roots of the different crops. Most likely, cereal has relatively higher growth rate, height advantage, and a more extensive rooting system. Hence they favored in the competition than the associated legume. In this case, the cereal is described as the dominant and the legume as the dominated component (Huxley and Maingu, 1978).

### 2.4. Green bean and intercropping history from other crops

Khan *et al.,* (2012) stated that the sole cultivation of green bean was the most effective cropping system in terms of yield and yield components of green bean crop. However, according to Prasad and Brook, (2005) maize-bean intercropping is common where the risk of total crop failure due to environmental constraints is high. It helps to improve income and food production per unit area (Woomer *et al*,. 1997; Mukhala *et al*., 1999), and to improve family nutrition (Mukhala *et al*., 1999). Maize-bean intercropping reduced the risk of crop failure that resulted from terminal moisture deficit, as bean matures early relative to maize (Mukhala *et al*., 1999).

The influence of different intercropping treatments on yield and yield components of green bean were investigated in different researches. However, variation in maturity of the component crop species is a major consideration with intercropping (Seran and Brintha 2010). Bhatnagar and Chaplot (1991), Reported 55% increase in productivity for maize-legumes intercrop compared with the sole crops. Tana and Mulatu (2000); Workayehu and Wortmann (2011) also reported the agronomic importance and economic feasibility of maize–bean intercropping in Ethiopia.

### 2.5. Sugarcane based intercropping system and its effect on cane yield

The influence of different intercropping treatments on yield and yield components of sugarcane were investigated by different researches (Prakash and Yadav, 2017). Though these there are overall biological advantages in intercropping system, most of the studies have indicated depressing effect of intercrops on the base crop of sugarcane. Although intercropping has been practiced traditionally for thousands of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective and research in this area is far less advanced than comparable work in monoculture.

According to Geetha *et al.,* (2015), in their review clearly brings out the positive, neutral and negative effects of combining crops in sugarcane based cropping systems. The widespread adoption of no-tillage soybean on sugarcane straw has achieved tremendous success in enhancing soil quality, preventing soil erosion, and weed control (Christoffoleti *et al.* 2007, Bolonhezi 2008). Intercropping of sugarcane with grain crops is one possibility to associate energy and food production and has been used in commercial fields since the late 1960's, especially with common bean (Tokeshi 1980; Govinden 1991).

### 2.5.1. Sugarcane intercropped with vegetables

Intercropping of cereals, legumes, oilseeds, vegetables and spices in autumn sugarcane have been found to enhance natural resources use efficiency, productivity and profit margins (Singh, K., 2007; Singh, A.K 2008). Singh *et al.,* (*20*18), stated that Sugarcane intercropped with radish recorded the highest number of shoots and it was at par with sugarcane intercropped with garlic, turnip, and onion. The intercropping of sugar beet as vegetable and linseed suppressed tillering and significantly reduced the shoot production of autumn sugarcane. The vertical planted sugarcane intercropped with garlic as vegetable followed by onion as vegetable produced similar cane yield and were significantly better than rest of the intercropping systems (Singh *et al., 20*18).

Vegetables like radish, potato, turnip, cow pea, carrot, amaranths, cauliflower, and cabbage have been found to be compatible with sugarcane in tropical and subtropical region (Jayabal, chokalingam and Nankar, 1990). Among vegetables potato with one row were recorded better profit and proved an ideal intercrop for subtropical region. Waddington *et al*., (1989), reported that Potato was most successful intercrop on sugarcane and it considered as the main intercropping research achievements and they stated that fairly complete package of technology has been developed and it has been widely adopted by all farmer groups; small growers and large estates each account for about half of the total production. And the success was attributable in large measure to the fact that potato does not reduce the yield of intercropped sugarcane conversely, sugarcane does not affect potato yields. It has been established that all commercial potato varieties can be intercropped with sugarcane, In relation to sugarcane harvest and planting dates. (Waddington *et al*., 1989)

### 2.5.2. Sugarcane intercropped with green manures and Spices

Several investigations have been carried out on intercropping with green manure crops and in situ incorporation (Nasir Ahmed, 1999). There results indicated positive influence on the cane crop. However, a recent study by Guru *et al.*, (2000) on sun hemp intercrop showed increased shoots, stalk population and cane yield. But there was residual effect on the ratoon crop with higher cane yield in the plots where intercrop was incorporated in the plant. Prakash and Yadav, (2017), reported that like garlic, coriander, black pepper, onion and chilies have been gave better net return compared to cane alone. Among spices garlic increased the cane yield (100.16 t/ha) about 8.25% and gave maximum net return of sugar recovery. However, little works has been done so far to grow spices as inter crops with autumn planted sugarcane. As spices are highly remunerative and labor intensive, their intercropping in autumn cane may increase the income level as well as employment potential for small farmers. (Prakash and Yadav, 2017)

#### 2.5.3. Sugarcane intercropped with haricot Bean

In Ethiopia, sugarcane-haricot bean intercropping has been practiced as a means to support government agenda of ensuring food self-sufficiency. However, as dry bean, its economic viability has been doubted (Feyesa et al, 2014), compared to the revenue generated out of sugar (i.e., a high value product). Moreover, studies conducted in South Africa indicated that intercropping of beans and sugar-cane has no impact on final yield of cane and sucrose (Leclezi, 1985).

### 2.6. Nutritional compositions and uses of green bean

Green bean comprises a group of common bean that has been selected for succulent pods with reduced fiber primarily grown for its young edible and fleshly pods (Myer and Baggett, 1999; Getachew, 2006). It is the most important vegetable crop which is rich in protein, carbohydrates, calcium, vitamins and amino acids. It is also the most important vegetables crop it have been exported from developing countries and several African countries have focused on exporting green beans to high value European markets (Ghonimy *et al*., 2009). Green bean is the second most important source of human dietary protein and the third most important source of calories (Pachico, 1993) for over 100 million people in rural and poor Urban Communities in Africa. Its protein is cheaper than animal protein, making it highly competitive and important to people dietary regimes in Africa (CIAT, 2006).

In most countries, green bean is considered as an elite vegetable. They are rich in protein as well as iron and contain essential nutrients such as ascorbic acid, Vitamin A, Vitamin B and calcium (Kelly and Scott, 1992; Ndegwa *et al*., 2006). It is also an important staple foods and sources of dietary minerals that potentially provide all of the 15 essential minerals required by humans (Kelly and Scott, 1992; Ndegwa *et al*., 2006). Ethiopia has a geographic comparative advantage over other competitive countries. It takes nine weeks for sea shipments of beans from China to reach EU markets, whereas it only takes three weeks from Ethiopia (Ferris and Kaganzi, 2008).

# 3. MATERIAL AND METHODS

## 3.1. Description of the study area

The study was conducted at Omo Kuraz Sugar Development Project (OKSDP), which is found in the plain areas of the lower Omo basin of the Southern Nations Nationalities and People's Region. It situated at 5° 8'18"–6° 16' 59" latitude N and 35° 43' 37"–36° 13' 54" longitude E and its elevation ranges from 370–500 meters above sea level (NMA, 2007). The area has a mean maximum and minimum monthly temperature of 37.29 and 29.29°C, respectively with mean annual rain fall of 1133.3 mm but the rain fall distribution of study area is erratic (Kuraz Metrological Station, 2020). According to World Reference Base for Soil Resource FAO, (2006), the soils in the study area has been classified in to four major Reference Soil Groups namely, Vertisols, Camisole, Fluvisols and Solonetz which covers 64.2 %, 21.6 %, 3.3 % and 2.6 % of the total command area of Omo Kuraz sugar development project respectively (WWDSE, 2011). The experiment was implemented on Vertisol that cover the largest area of the plantation.

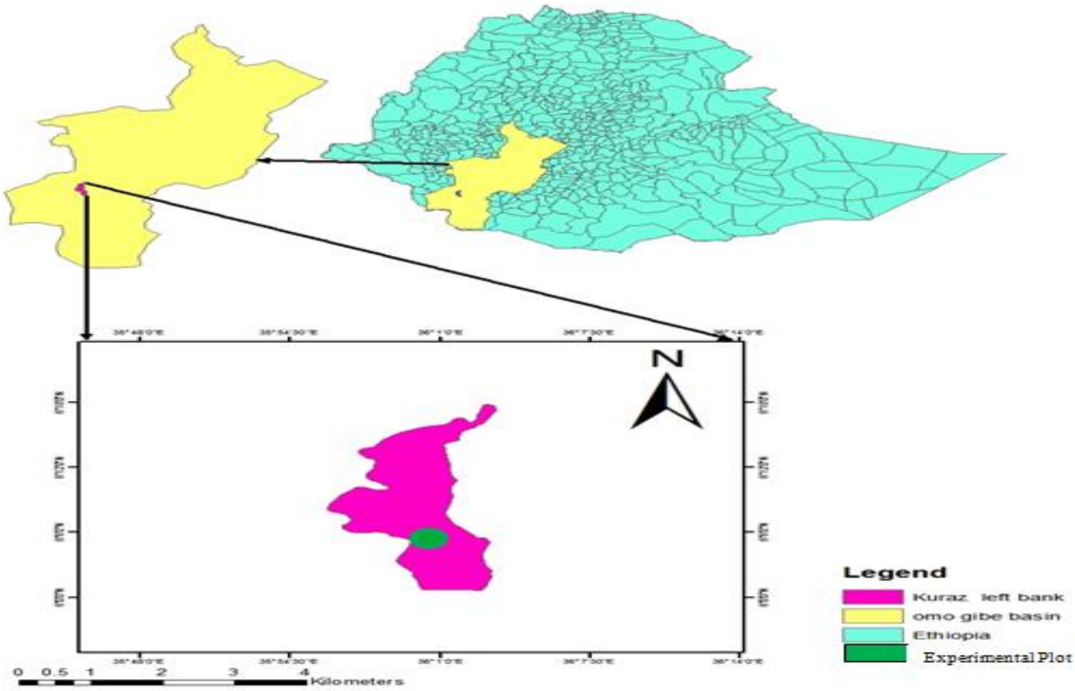


**Figure 1.** Map of the study area

## 3.2. Planting material

Two green bean and one sugarcane varieties were used as experimental planting materials. The two green bean varieties were generously provided by Melkasa Agricultural Research Center and the sugarcane variety was obtained from OKSDP. The key characteristics of the varieties were indicated in Table (1).

**Table 1.** Planting materials used for the experiment conducted at OKSDP

| S.N | Variety Name | Seed Source | Adaptability | Released year/commercia ized year | Productivity (t ha$^{-1}$) |
|---|---|---|---|---|---|
| 1 | Plati(Green bean) | Melkasa Agricultur Research Centre | Central rift valley and simila agro ecologies of Ethiopia | 2016 | 11.7-Research Field<br>9.6- Farm Fielc |
| 2 | B.C 4.4(Greer bean) | Melkasa Agricultur Research Centre | | 2012 | 7-8 |
| 3 | NCO-334(suga cane) | Omo OKSDP | High area coverage variety o OKSDP | 1954 | 150-200 |

Source: (MOANR 2012; 2017)

### 3.1. Experimental design and treatments

The experiment was laid out as Randomized Complete Block Design (RCBD) in factorial arrangement with three replication. The first factor included two green bean varieties; the second factor was two green bean intra row planting space (10 and 15 cm). Therefore, the experiment contained in total nine treatments including sole sugarcane and sole green bean with two intra row spacing. The experimental treatment combinations are indicated in Table 2. The experimental plot consisted of 6 furrows with 8.7 meter length making an area of 52.2 m$^2$. The four central rows constituted the net plot area 4 furrows with 5.8 meter length making an area of 34.8 m$^2$, from which data was collected. The other two furrows on each side of the plot serve as border rows.

**Table 2.** Treatment combinations.

| S.N | Treatments | Green bean Varieties | Spacing(cm) | Cropping type |
|---|---|---|---|---|
| **1** | A | Plati | 10 | Inter cropped |
| **2** | B | Plati | 15 | Inter cropped |
| **3** | C | B.C 4.4 | 10 | Inter cropped |
| **4** | D | B.C 4.4 | 15 | Inter cropped |
| **5** | E | Plati | 10 | Sole cropped |
| **6** | F | Plati | 15 | Sole cropped |
| **7** | G | B.C 4.4 | 10 | Sole cropped |
| **8** | H | B.C 4.4 | 15 | Sole cropped |
| **9** | I | Sugarcane Sole | Conventional spacin | Sole cropped |

### 3.2. Experimental procedures and crop management

The experimental site was properly ploughed, leveled and furrow making was done by tractor in month of May, 2021. Sugarcane was planted primary, and green bean crops were planted immediately after the first irrigation on July 21 and 22, 2021. Green beans seeds were planted at spacing of 10 and 15 cm between plant and 20 cm between rows in double rows within sugarcane rows planted at spacing of 1.45 m and as sole crops. Sugarcane sets having 3 bud of seed cane cuts were planted 120 on each plots of intercropped and sole sugarcane plots was. Based on the sugarcane plantation sugarcane crop management practice a calculated amount (135 kg/ha $^{-1}$.rate) of NPS fertilizer for each experimental unit was applied in band method of application at the time of planting. The first manual weeding was done at 15 days after planting, while the second weeding was done 30 days after planting and the last weeding was done 45 days after planting. We used similar chemical the plantation were user for sugarcane crop black betel management and The first insecticide was applied at planting and the second insecticide application was done twenty days after planting for beetle when the crops have emerged and leave scorching symptom showed. In general uniform field management practices were carried out as conventionally used for the area. Finally both crops were harvested from net plot area (34.8 $m^{2)}$

## 3.3. Data collection

### 3.3.1. Soil sample collection and laboratory analysis

Prior to planting, a composite soil sample was made from five random representative samples drawn from the experimental field with auger from 0-30 cm depth of soil. The soil sample was mixed and formed one representative composite sample. The composite sample was then air dried at room temperature under shade by spreading on plastic sheet. Soil test of the composite sample was done at Ethiopian Sugar Corporation Research Main Center Soil Laboratory at Wonji. Total N was determined by the modified Micro Kjeldahl method (Ethio SIS, 2014) and available P by Olsen method (Olson *et al*., 1954). Exchangeable bases (Na, K, Mg, and Ca), organic carbon and effective CEC were determined according to the procedure given by Landon, (1991) and Barber, (1984), respectively. Soil texture and EC, were determined by standard procedure. Soil pH was determined by the pH meter.

### 3.3.2. Green bean data

#### 3.3.2.1. Phenological Data

**Days to 50%; emergence, flowering** and **marketable pod formation** were recorded on each plot while the green bean crops were emerged, flower formed and when days to first picking were started, respectively.

#### 3.3.2.2. Growth parameters

**Number of leaves per plant:** was determined by randomly selecting five plants from net area plot and their leaves counted at flowering and average leaves per plant was calculated.

**Leaf area (LA) ($cm^2$):** was measured from leaves that are collected from five randomly selected plants at time of flowering using leaf area mater (LI-3100, lincolin, Nebraska USA) and it was converted average per plant.

**Number of primary branch per plant:** was counted from the five plant randomly selected from central plot at harvesting stage.

#### 3.3.2.3. Yield and yield components

**Total marketable pod yield (kg):** was determined by harvesting pod from net plot area 34.8 $m^2$) from the middle row and finally the marketable yield per plot were converted to tone per hectare.

Pods with uniform in color, slightly curved and straight shape were considered as marketable yield.

**Dry matter content of green bean:** was measured from five plants randomly sampled from the four middle rows of each plot at harvest, after taking the fresh weight sample were dried in an oven at $70^0C^0$ for 24.

**Number of pod per plant:** was determined by counting the pod numbers from the five randomly selected plants from four middle rows, at harvest and later on converted in to an average per plant.

#### 3.3.2.4. Quality parameters

**Pod length (cm):** primarily pods were harvested from the five plants randomly selected from four middle rows of each plots at harvesting time, twenty pods was randomly selected, the length of the pods was measured from the node where the pod emerged to the tip of the pod, using ruler.

**Pod diameter (mm):** was measured on the central part of the pod by using caliper, from twenty randomly selected pods which were selected for pod length measurement and later on converted in to an average per pod.

**Pod texture:** was scored using visual rating scale method, used by (Beshir *et al.*, 2015), which modified from (Martinez *et al* 1995) and (Proulx *et al.*, 2010). Five data collectors visually rated the pod texture, by looking the pod total harvest for each plot using the rates shown on the (Table 3) below and took the average.

**Table 3.** Pod texture visual rating scale

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very fine | Fine | Reasonable fine | Coarse | Very Coarse surface |

**Pod appearance:** were expressed as the overall look of the pod, which is combination of different expression (fineness of texture, absence of defect, straightness of pod, small and immature seed) on the pod from each plots total harvest by using visual rating scale method, used by (Beshir *et al.*, 2015), which modified from (Martinez *et al* 1995) and (Proulx *et al.*, 2010), as shown on the (Table 4)

**Table 4.** Pod appearance visual rating scale

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Excellent | Good | Acceptable | Poor | Rejected |

**Straightness of the pod:** were rated for each plot at harvest by visual rating using test panel of 5 people on the basis of 1-3 scale (Table 5), which was used by (Getachew *et al*., 2014).

**Table 5.** Pod straightness visual rating scale

| 1 | 2 | 3 |
|---|---|---|
| Curved | Moderately straight | Straight |

### 3.3.3. Sugarcane data

#### 3.3.3.1. Agronomic data

**Number of sprout count (%)**: Data on sprouting was recorded at 30 days after planting from each four middle rows in a plot, which was intercropped and solo cropped sugarcane and it was converted to sprout percent.

**Number of tiller counts ($ha^{-1}$)**: number of tiller per setts were counted at 90 days after planting from the four middle rows of each plot of the treatments. The result was converted to tiller number per hectare.

**Number of millable canes ($ha^{-1}$)**: number of stalk population was counted at 10 months from each plots and it was calculated per hectare on the basis of collected data.

**Stalk weight (kg)**: It was taken from pre marked twenty stalks per plot at 10 months after planting from each four middle rows in a plot, which was intercropped and solo cropped sugar-cane and converted to average single cane weight.

**Cane yield (t $ha^{-1}$)**: It was recorded at 10 months after planting, It was calculated using number of millable canes/ha * single stalk weight (kg) then converted to (t $ha^{-1}$).

#### 3.5.3.2. Sugar quality parameters and estimated sugar yield

10 stalk samples were taken from each experimental plot at harvest and were crushed using Jef-cco grinder. The extracted juices of samples were taken to laboratory for determination of Juice

quality parameters, which are, brix (%), Pol (%), Purity (%) and estimated recoverable sugar (ESR).

**Brix (%):** was measured using bench refractometer to determine the value percentage by mass of soluble solid matter (sucrose and soluble non-sucrose) in solution.

**Pol (%):** juice was determined from 100 mg cane filtering juice sample the, after adding lead acetate for facilitation of precipitation and flocculation and filtering through what man paper 19, the clear juice was filled in to 20cm pol tube for recording polarized reading in polarimeter. The polarized reading was corrected for a particular brix (%) at $20^0$C and Pol % juice was recorded.

**Purity:** The percentage ratio of sucrose (or pol) to the total soluble solids (or brix) in a sugar product or percentage of sugar in brix (Chen and Chou, 1993). It was determined by dividing pol (%) with its Brix (%) and multiplying by 100.

**Estimated recoverable sugar (ers) (%):** The estimated recoverable sucrose refers to the recoverable sugar percent cane. It was calculated as described by Berg (1972): Sucrose (%) = [pol %-( Brix - pol %) 0.61] 0.75), where 0.61 = non-sugar factor, representing the amount of sucrose lost in final molasses and 0.75 = cane factor, representing the correlation factor between theoretical yields of molasses mixed juice and primary juice for the same genotype

**Sugar yield:** was determined by the weight of cane/cane field yield/ multiplied by the estimated recoverable sugar %cane (sugar field yield).

### 3.5.4. Land equivalent ratio (LER)

This parameter was derived by calculating the absolute yield of each inter cropped yield to its yield on sole cropped yield. Therefore, the productivity of sugarcane-green bean intercropping was assessed using land equivalent ratio (LER).

$$LER = \frac{Yij}{Yii} + \frac{Yji}{Yjj}$$ Where;

Yij= Yield of sugarcane under intercropping conditions

Yii= Yield of sugarcane under sole crop conditions

Yji= Yield of green bean under intercropping conditions

Yjj= Yield of green bean under sole crop conditions

#### 3.5.5. Data analysis

The collected data was subjected to analysis of variance (ANOVA) using SAS version 9.3 (2014) GLM procedures and Least Significant Difference (LSD) were used to separate means at $p<0.05$ probability levels of significance.

# 4. RESAULT AND DISCUSION

## 4.1. Physical and chemical properties of the soils at experimental site

The laboratory analysis of the soil of the experimental site before planting presented Table 6. The proportions of sand, silt and clay particles in the soil of the experimental field were found to be 8.3, 9.9, and 81.9 percent, respectively (Table 6). The available phosphorus content values in the soil at the start of experiment 12.388 ppm. The experiment site also indicated pH of 7.35 and (0.1) percent total nitrogen (N). In addition to this effective cation exchange capacity (CEC) of the soil was 54.75 which was very high as Hazelton and Murphy (2007). Generally, the soil was clay textured, calcium had dominated the soil exchange complex, and the low EC value (0.31dsm$^{-1}$) indicates the absence of salinity (Hazelton and Murlphy, 2007).

**Table 6.** Physical and chemical properties of the soils study conduct at OKSDP

| Soil properties | Mean Value |
|---|---|
| Sand (%) | 8.3 |
| Silt (%) | 9.9 |
| Clay (%) | 81.9 |
| Textural Class | Clay |
| pH (1:5) | 7.35 |
| Ec ds/m (1:5) | 0.31 |
| OC (%) | 1.40 |
| TN (%) | 0.10 |
| Avail.P (ppm) | 12.38 |
| Avail.K (ppm) | 269.0 |
| Na (mg/100g) | 1.31 |
| K (mg/100g) | 2.21 |
| Mg (mg/100g) | 18.02 |
| Ca (mg/100g) | 33.21 |
| CEC (mg/100g) | 54.75 |

*EC = Electrical conductivity; OC = Organic carbon; CEC = Cation exchange capacity

## 4.2. Effect of varieties, cropping system and intra-row spacing on growth and yield parameters of green bean

### 4.1.1. Phenological parameters

**Days to emergences**

Days to emergence was significantly ($P<0.05$) affected by the main effect of green bean varieties (Table 7). Green bean variety plati took an average of seven days to emerge after planting while variety B.C 4.4 emerged within ten days after planting. This variation might be due genetic variation among the varieties. However, there was no significant ($P<0.05$) difference among the spacing, cropping system and the interactions on days to emergency (Table 7 and Table 9). This result in agreement with the finding of Amato *et al.,* (1992), who reported that seed germination and establishment rate of soybean was not affected by sugarcane soybean intercropping.

**Days to flowering**

The analysis of variance showed that days to flowering was significantly (P<0.01) affected by main effect of green bean varieties. Variety Plati took 40 days on average after planting to attain flowering. Whereas, it took 45 days for variety B.C 4.4 for the 50% flowering (Table 7). However, there was no significant difference (P<0.05) among the main effects of two planting spacing, cropping system and the interaction (Table 7 and Table 9). This result is in agreement with Njuguna *et al*. (2008), who reported differences in days to flowering among green bean varieties. The authors suggested such difference was because of the innate genetic variability of the varieties. The result of variety Plati was almost similar to the result obtained by Yosef *et al.,* (2018) (i.e., 43 days after planting).

**Days to maturity**

The analysis of variance indicated that days to maturity was significantly (P<0.01) affected by main effect of green bean varieties. As compared to variety B.C 4.4, variety Plati achieved its maturity ten days earlier (55 days after planting) (Table 9 ). However, planting spacing's, cropping systems and the interaction had no significant effect on days to maturity (P<0.05) (Table 7 and Table 9). Similarly, the variation might be due to considerable variation among the varieties. Moreover, the current result in days to maturity after planting recorded for of variety Plati was almost similar with what reported at time of variety release by the authority (MoANR, 2016).

### 4.2.2. Growth parameters

**Numbers of leaf per plant**

The analysis of variance showed leaves numbers per plant was not significantly *(P*<0.05) affected by main effects of green bean variety, planting spacing, cropping system and their interaction (Table 7).The highest leaf number (68) per plant was recorded on interactions of variety Plati with 15cm planting spacing and in sole cropped. The lowest leaf number (60.33) per plant was recorded on the interaction of variety B.C 4.4 planted at 10 cm spacing and intercropped (Table 7). This variation might be due to considerable variation from competition with sugarcane crop.

The result was in argument with the finding of Adugna *et al.*, (2019) who was reported the highest (83.92) and lowest (71.24) number of leaves per plant was statistically similar.

**Table 7**. Main effects of varieties and planting spacing of the intercropping green bean with sugarcane on Phenological and growth Parameters.

| TREATMENTS | DEM | DFLOW | DMATU | NLPP | NBPP | LA |
|---|---|---|---|---|---|---|
| **VARIETY** | | | | | | |
| Plati | 7a | 40a | 55a | 65.5 | 5.47 | 1250.5b |
| B.C 4.4 | 10b | 45b | 65b | 61.75 | 4.83 | 1837.6a |
| LSD | ** | ** | ** | NS | NS | ** |
| CV | 2.1 | 6.24 | 9.48 | 17.7 | 21 | 33.9 |
| **SPACING** | **DEM** | **DFLOW** | **DMATU** | **NLPP** | **NBPP** | **LA** |
| 10CM | 8.5 | 42.5 | 60 | 65.17 | 5.67 | 1458.6 |
| 15CM | 8.5 | 42.5 | 60 | 62.08 | 4.58 | 1629.5 |
| LSD | NS | NS | NS | NS | NS | NS |
| CV | 2.1 | 6.24 | 9.48 | 17.7 | 21 | 33.9 |
| **CROPPING SYSTEM** | **DEM** | **DFLOW** | **DMATU** | **NLPP** | **NBPP** | **LA** |
| Sole | 8.5 | 42.5 | 60 | 63.33 | 5.2 | 1816.5a |
| Inter | 8.5 | 42.5 | 60 | 63.92 | 5.1 | 1271.6b |
| LSD | NS | NS | NS | NS | NS | ** |
| CV | 2.1 | 6.24 | 9.48 | 17.7 | 21 | 33.8837 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference (P<0.05), NS= Not significant. DEM= days of emergency, DFLOW= days of flowering, DMATU= days to maturity, NLPP= number of leaf per pod, NBPP=number of branch per plant and LE=leaf area.

### Number of primary branch per plant

The analysis of variance showed that number of primary branch per plant was not significantly (*P*<0.05) affected by main effects of green bean variety, planting spacing and cropping system (Appendix I).The highest primary branch (6) per plant was recorded on interactions of Variety B.C 4.4 with 15cm planting spacing and Sole cropped. While the lowest (3.33) primary branch was recorded on the interaction of Variety B.C 4.4 with 15 cm planting spacing and intercropped (Table 7). Similarly, Adugna *et al.*, (2019) reported the highest number of branch per plant (9.64) were statistically similar with the lowest number of branch per plant (5.73).

### Leaf area (LA) per plant

The analysis of variance showed that leaf area was significantly (P<0.05) affected by main effects of varieties and Planting spacing (Table 7). Amongst the varieties, variety B.C 4.4 showed the highest value of LA (1,837.6 $cm^2$), while variety Plati showed the lowest (1,250.5 $cm^2$). Similarly, sole cropped green bean scored the highest value of LA (1,816.5$cm^2$) compared to intercropped system (1,271.6 $cm^2$ Table 7). However, interaction of the treatments did not showed significance (P<0.05). The highest value (2,092.7 $cm^2$) of leaf area was scored on from Variety B.C 4.4 planted at spacing of 10 cm insole cropping system whereas the lowest value (1,030.3$cm^2$) of leaf area was scored on combination variety Plati planted at spacing of 15cm, in intercropping system (Table 7). From the physical observation, green bean variety B.C 4.4 showed good vegetative growth but did not set flower and pod properly (Figure 2 A and B).

**Table 8.** Interaction effects of varieties and planting spacing of the intercropping green bean with sugarcane on Phenological and growth parameters.

| TERETMENT | DEM | DFLW | DMATU | NLPP | NBPP | LA($cm^2$) |
|---|---|---|---|---|---|---|
| B.C 4.4 10 cm Sole crop | $10^b$ | $45^b$ | $65^b$ | 64.7 | 5.7 | 2092.7 |
| B.C 4.4 10 cm intercrop | $10^b$ | $45^b$ | $65^b$ | 60.3 | 4.3 | 2287.3 |
| B.C 4.4 15 cm Sole crop | $10^b$ | $45^b$ | $65^b$ | 61.0 | 6.0 | 1408.7 |
| B.C 4.4 15 cm intercrop | $10^b$ | $45^b$ | $65^b$ | 61.0 | 3.3 | 1561.7 |
| Plati 10 cm Sole crop | $7^a$ | $40^a$ | $55^a$ | 67.0 | 5.3 | 1247.3 |
| Plati 10 cm intercrop | $7^a$ | $40^a$ | $55^a$ | 61.3 | 5.3 | 1638.7 |
| Plati 15 cm Sole crop | $7^a$ | $40^a$ | $55^a$ | 68.0 | 5.7 | 1085.7 |
| Plati 15 cm intercrop | $7^a$ | $40^a$ | $55^a$ | 65.7 | 5.3 | 1030.3 |
| **Mean** | 8 | 42 | 60 | 63 | 5 | 1544 |
| LSD 5% | ** | ** | ** | NS | NS | NS |
| CV (%) | 2.1 | 6.24 | 9.48 | 17.7 | 21.1 | 33.9 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference (P<0.05), NS= Not significant DEM= days of emergency DFLW= days of flowering DMATU= days to maturity NLPP= number of leaf per pod NBPP=number of branch per plant and LA=leaf area.


Figure 2. Variation in the Flowering stage of green bean varieties. A: variety Plati and B: variety B.C 4.4

### 4.2.3. Yield and yield component parameters

**Number of pod per plant**

The number of pod per plant was highly significantly ($P<0.05$) affected by main effect of green bean varieties and their interaction with cropping system as well as overall interaction of the three main factors. The highest number of pods per plant (32.33) was obtained from variety plati, while lowest (21.75) from variety B.C 4.4 (Appendix II). The highest number of pod per plant (35.33) was recorded from variety plati planted at 10cm planting spacing intercropped system, the lowest number of pods per plant (15.67) was obtained from variety B.C 4.4 planted at 15cm spacing intercropping system (Table 8). However the analysis of variance did not showed significant effect on main effect planting spacing and cropping systems (Table 9). Similar result was reported by Meaza *et al*., 2019, from their work improvement on yield and pod quality of green bean in fertilizer trial.

**Aboveground dry matter content of green bean**

Aboveground dry biomass was not significantly (P<0.05) affected by main effects of green bean varieties, spacing and cropping system interaction. The highest dry matter weight (55.1g) was recorded on variety plati and the lowest value of (51.6g) was recorded on variety B.C 4.4 (Table 9).

**Table 9.** Main effects of varieties and planting spacing of the intercropped green bean with sugarcane and cropping system on yield and yield component of green bean

| TREATMENTS | NPPP | PL(mm) | PD(cm) | DMC (g) | YIELD$_{(t\ ha^{-1})}$ |
|---|---|---|---|---|---|
| **VARIETY** | | | | | |
| Plati | 32.33a | 11.45a | 0.67a | 55.1 | 7.6a |
| BC44 | 21.75b | 10.78b | 0.5b | 51.36 | 1.75b |
| LSD | ** | ** | ** | NS | ** |
| CV | 20.45 | 4.72 | 17.42 | 19.76 | 25.4 |
| **SPACING** | **NPPP** | **PL(mm)** | **PD(cm)** | **DMC (%)** | **YIELD** |
| 10CM | 29.25 | 11.12 | 0.63 | 52.9 | 5.108 |
| 15CM | 24.83 | 11.12 | 0.58 | 53.5 | 4.242 |
| LSD | NS | NS | NS | NS | NS |
| CV | 20.45 | 4.72 | 17.42 | 19.76 | 25.4 |
| **CROPPING SYSTEM** | **NPPP** | **PL(mm)** | **PD(cm)** | **DMC (%)** | **YIELD** |
| Sole | 27.83 | 11.21 | 0.59 | 53.47 | 4.858 |
| Inter | 26.25 | 11.03 | 0.62 | 52.92 | 4.492 |
| LSD | NS | NS | NS | NS | NS |
| CV | 20.4507 | 4.75 | 17.42 | 19.76 | 25.44 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference (P<0.05), NS= Not significant NPPP= number of pod per plant PL=pod length PD=pod diameter, DBM=dry matter content (g).

## Marketable pod yield

The analyses of variance showed that marketable pod yield is significantly (*P*<0.01) affected by main effects of varieties. The highest marketable green pod yield (7.6 t $^{ha-1}$) was recorded from variety Plati, while the lowest marketable green bean pod yield (1.75 t $^{ha-1}$) was recorded on variety B.C 4.4 (Table 9). This results is in agreement with the finding of Yosef *et al* 2018, who reported marketable green pod yield of green bean variety vary within variety and locations where it was grown. The variation in marketable green pod yield in the two bean varieties could be due to inherent factors of the varieties. However, marketable pod yield did not affected by the main effects of planting spacing and cropping system.

The highest marketable green pod yield (8.0 t ha$^{-1}$) was recorded from combinations of (variety Plati planted at 10 cm planting spacing sole planted), the second highest pod yield weight (7.933 t ha$^{-1}$) was obtained from combinations of (Plati variety, sole cropping and 15 cm planting spacing), the third pod yield weight (7.533qt ha$^{-1}$) was obtained from combinations of (Plati variety, intercropped at 10 cm planting spacing). While the lowest marketable green bean (0.8 t ha$^{-1}$) pod yield was recorded for variety B.C 4.4, 15 cm planting spacing intercropped (Table 10). Planting green bean at 10 cm plant spacing gave more yields than planting at 15 cm spacing between plants. The highest marketable green pod yield weight (5.108 qt ha $^{1}$) was obtained from10 cm planting space, while the lowest marketable green pod yield weight (4.242 qt ha $^{-1}$) was recorded on 15 cm planting space. The highest marketable green pod yield weight (4.858qt ha $^{-1}$) was obtained from sole cropped green bean, while the lowest marketable green pod yield weight (4.492 qt ha $^{-1}$) was recorded on intercropped green bean (Table 9). The result was similar with Birhanu *et al*., (2021), who reported variety plati produced higher mean marketable green pod yield, pod length, pod width, pod weight and less percentage of non-marketable green pod yields across locations.

However, Yosef *et al*., 2018, stated that, the combined total green pod yield over the three locations under solo cropping showed lower yield under sole planted (i.e., 9.14 t ha $^{-1}$ for variety plati & 7 t ha $^{-1}$ for variety B.C 4.4 ). Feyesa *et al.*, (2014), reported on non-feasibility of intercropping (sugarcane-haricot bean) due to shattering and loss of seed quality. In the current study, green bean was harvested at vegetable and without loss of quality. Thus, we believe, it is possible to grow green bean without losing this quality as a green pod yield. This indicates, it is important to note that the intercropping would be possible and advantageous.

**Table 10.** Interaction effects of varieties and planting spacing of the intercropping green bean with sugarcane on growth and yield and Yield component parameters.

| TERETMENT | NPPP | PL(cm) | PD(mm) | DMC (g) | YIELD$_{(t\ ha-1)}$ |
|---|---|---|---|---|---|
| B.C 4.4 10 cm Sole crc | 28.3$^{abc}$ | 11.23 | 0.59 | 51.46 | 2.2$^{b}$ |
| B.C 4.4 10 cm intercro | 17.0$^{bc}$ | 10.06 | 0.54 | 45.53 | 1.7$^{b}$ |
| B.C 4.4 15 cm Sole crc | 26.0$^{abc}$ | 10.83 | 0.58 | 53.03 | 2.3$^{b}$ |
| B.C 4.4 15 cm intercro | 15.7$^{c}$ | 10.47 | 0.48 | 52.20 | 0.8$^{b}$ |
| Plati 10 cm Sole crop | 30.7$^{ab}$ | 11.27 | 0.61 | 54.80 | 8.0$^{a}$ |
| Plati 10 cm intercrop | 35.3$^{a}$ | 11.73 | 0.64 | 60.03 | 7.533$^{a}$ |
| Plati 15 cm Sole crop | 32.0$^{ab}$ | 11.13 | 0.74 | 54.80 | 7.933$^{a}$ |
| Plati 15 cm intercrop | 31.3$^{ab}$ | 11.67 | 0.67 | 54.10 | 6.933$^{a}$ |
| **Mean** | 27.05 | 11.12 | 0.61 | 53.229 | 46.8 |
| LSD 5% | ** | NS | NS | NS | ** |
| CV (%) | 20.45 | 4.72 | 17.4 | 19.76 | 25.44 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference (P<0.05), NS= Not significant NPPP= number of pod per plant PL=pod length PD=pod diameter, DMC = dry matter content (g)

### 4.2.4. Green bean quality parameters as affected by main and interaction effect

**Pod length**

The analysis of variance showed that pod length was significantly (P<0.05) affected by main effect of varieties (Table 9). Variety Plati scored higher mean value of (11.45 cm) pod length and (10.78 cm) was scored from variety B.C 4.4. However the main effects of planting spacing's, cropping systems and their interactions had no significant effects on pod length (Table 9 and Table 10). Pod length results obtained from variety Plati in this study was in agreement with the finding of MOANR, 2016, who reported Pod length of 11.93cm.

**Pod diameter**

Pod diameter was significantly (P<0.05) affected by main effects varieties (Table 9). The highest (6.7 mm) pod diameter was scored from variety Plati whereas the least (5 mm) was recorded from the variety B.C 4.4. However, pod diameter was not significantly (P<0.05) affected by planting spacing's, cropping systems and their interactions (Table 9 and Table 10). The highest pod diameter (7 mm) was recorded on the combination of (Plati variety planted at 15 cm in Sole crop**),** and the lowest pod diameter (4.8mm) was recorded on the variety B.C 4.4 planted at 15cm intercrop) (Table 10). Pod diameter results obtained from variety Plati in this study was in agreement with the characteristics on variety released time MOANR, 2016, they reported pod diameter of 6-8 mm. and Yosef *et al.*, 2018 who reported diameter of 7.02 mm.

**Pod appearance and texture**

Based on combination of different expressions (fineness of texture, absence of defect, and straightness of pods, small and immature seeds) on the pod, pod appearance and texture were rated visually using scale method. Results of the rating panels showed 50% of the total marketable pod was scored excellent pod appearance, and the rest was scored good appearance (Figure 3). Pod texture was rated as the 75% of the marketable pod were scored fine texture appearance and the rest 25% was recorded reasonably fine pod texture appearance (Figure 3) for both green bean varieties.

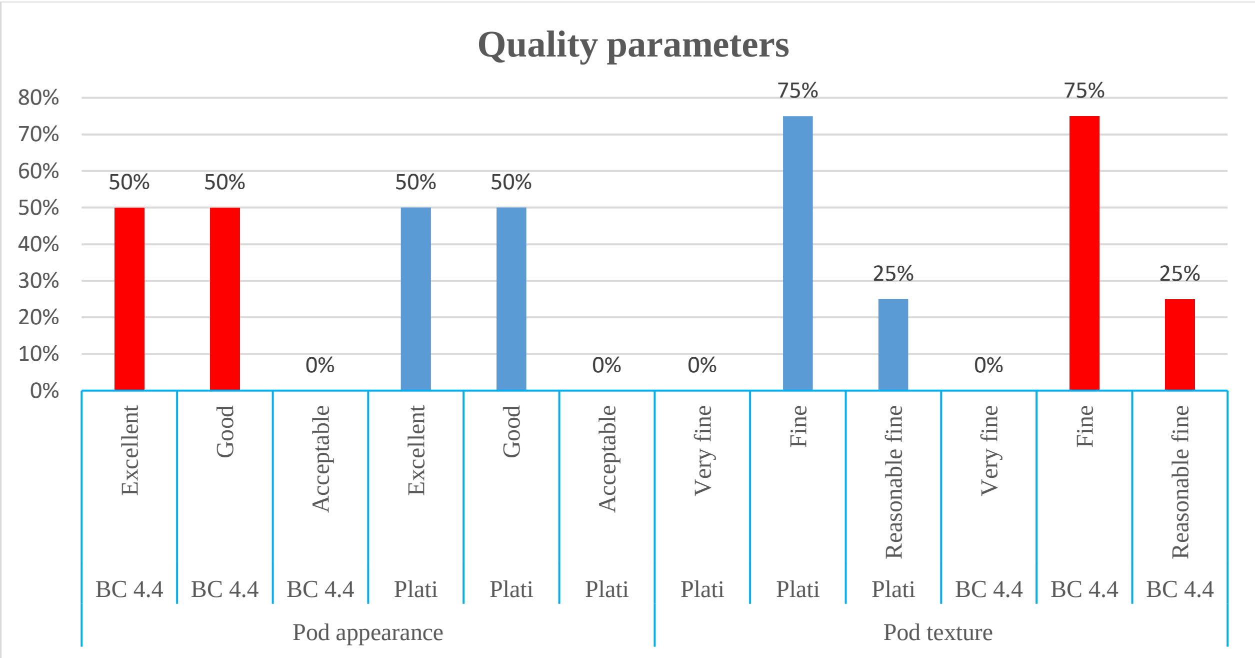


**Figure 3.** Mean Values of Pod Appearance and Pod Texture in percent

**Straightness of the pod**

Pod straightness was rated by using visual rating test panel of 5 people on the basis of 1-3 scale. The result indicates that 100% of the marketable pod of the two green bean varieties was scored moderately straight pod appearance (Figure 4 and 5).

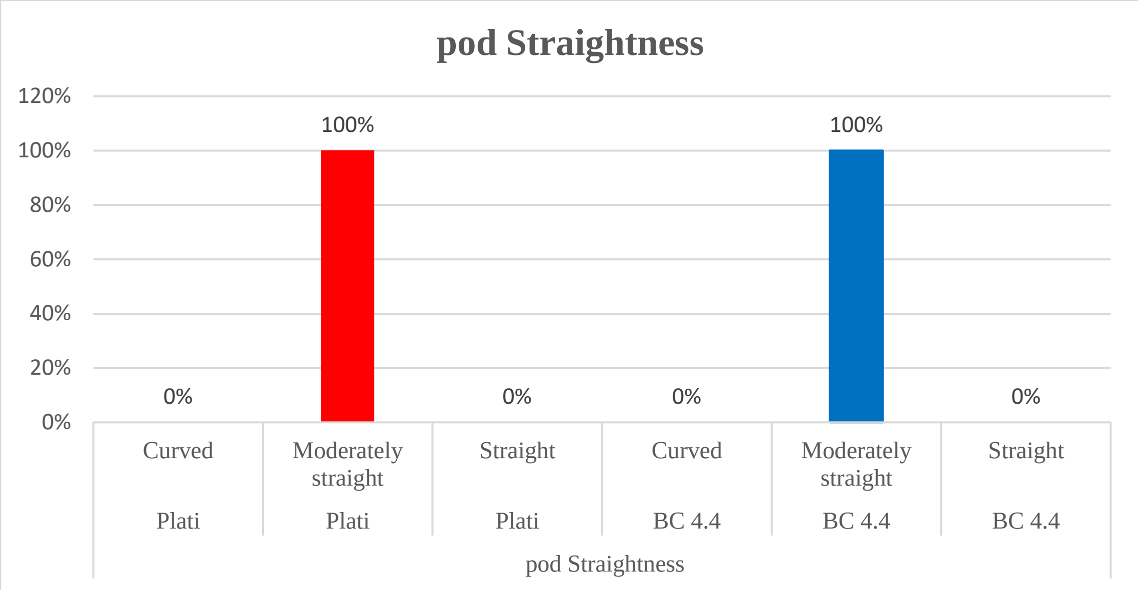


**Figure 4**. Visual Rating scale mean value of pod Straightness of the varieties

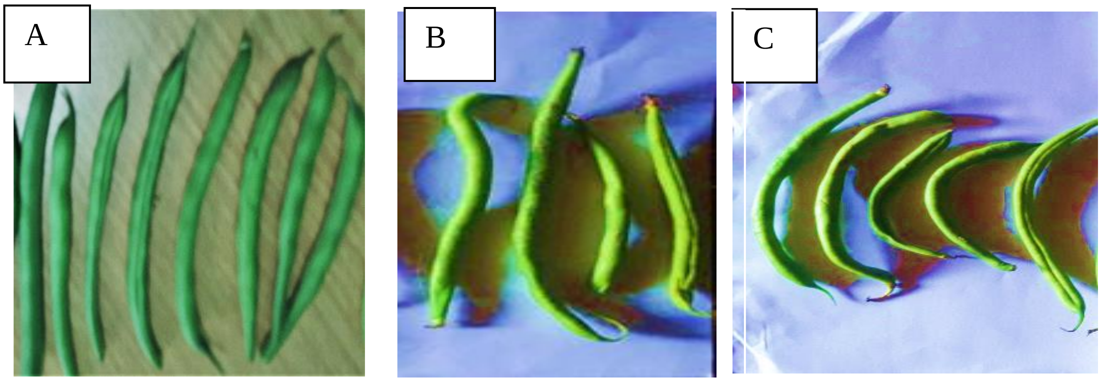


Figure 5**.** Green bean Pod Straightness. A., straight pod B, moderately curved and C, curved

### 4.3. Effects of intercropping on sugarcane yield and yield components

Main effects varieties, planting spacing, cropping system and their interaction had no significant effects of on sugarcane stalk population count, single cane weight, and cane yield at harvest (Table 12). However, the higher tiller number count (231, 034.48 ha$^{-1}$) was obtained from solo cropping than intercropped (143, 213 ha$^{-1}$). And higher Stalk population count (120,671 ha$^{-1}$) was obtained from solo cropping than intercropped (109,918 ha$^{-1}$). The decrease in the number of sugarcane stalk population under intercropping might be due to self-thinning as a result of competition between the two crops for growth resources. The main effect of variety and planting spacing of the intercropped green bean and their interaction showed no significant effect on sugarcane yield at harvest. However, the highest sugarcane yield of 107.77 t ha-1 was obtained from plots intercropped with green bean variety B.C 4.4, with planting spacing of 15cm (Table 11).

The highest sugarcane yield recorded for sugarcane intercropped with green bean at 15 cm planting spacing might be due to less planting density or variety genetic potential that might have resulted in less competition with sugarcane. Likewise, the highest sugarcane yield recorded for sugarcane intercropped with variety B.C 4.4 might be due to the late germination, late flowering and late maturity of the variety that provided temporal or not competitive of the green bean as compared to the variety plati. Which were having good potential for intercrop in sugarcane.

#### 4.3.1. Sugarcane setts sprout count

Sugarcane sprout count was significant ($P<0.05$) influenced by the main effect of planting spacing at which green bean on intercropped (Table 12). In this study, the highest germination percentage (62.5%) was observed on sugarcane intercropped with green bean planted at 15 c m planting spacing, while (55%) was observed from sugarcane intercropped with 10 cm planting spacing of green bean. However varieties and cropping systems did not significantly affected cane germination (Table 12). Analysis of variance also showed a significant ($P<0.05$) difference among the interactions of the treatments. In our observation the highest germination percentage (66.67%) was observed on sugarcane sole planted, and the lowest result was obtained from the combination of sugarcane intercropped with green bean variety palate at 10 cm planting spacing (Table 11). Therefore, main effect of green bean variety planting spacing 10cm had significant influence on sprouting percentage of sugarcane on.

#### 4.3.2. Number of tiller

Cropping system and green bean planting spacing has significant ($P<0.05$) influence on sugarcane tiller number. The analysis shown the highest average mean value of (231,034.48 $ha^{-1}$) tiller number per hectare was recorded on sole cropped sugarcane, while (143,213.60 $ha^{-1}$) tiller number was obtained from the intercropped system. The highest tiller number (183,237.55 $ha^{-1}$) was recorded on green bean, planted at 15 cm plant spacing while the lowest tiller number (103,189.66 $ha^{-1}$) was recorded on plant spacing 10 cm (Table 12). Sugarcane tiller number was significantly affected by the interaction of the treatments. The highest tiller number (214,817 $ha^{-1}$) was obtained from the intercropping variety B.C 4.4, plant spacing 15 cm, while the least tiller number (91, 916 $ha^{-1}$) was observed from variety Plati, planted at 10cm, in intercropping system (Table 11). Moreover, the result was shows some tiller number redaction effects on intercropping of green bean with sugarcane on the cropping system and planting spacing of green bean on tiller number of sugarcane crop. Similar type of results was reported by Jayabal (1992) and Zarekar (2017).

### 4.3.3. Number of millable canes

The results of analysis of variance revealed that the main effect of sugarcane intercropping has not significant (P<0.05) effect on number of millable canes ($ha^{-1}$). The highest number (122, 433 $ha^{-1}$) was obtained from variety B.C 4.4, planting spacing 15 cm intercropped, whereas, the lowest cane stalk (104,061 $ha^{-1}$) was observed from green bean variety Plati, planting spacing 10 cm in intercropped (Table 11). Similarly Khandgave, 2010, reported intercropping soybean between rows of sugarcane gave higher number of cane (87,830$ha^{-1}$) than sugarcane alone (85,910$ha^{-1}$). On the other hand the analysis of variance did not showed statically difference on main-main effects of variety, planting spacing and cropping systems (Table 12). Therefore, the difference observed on the tiller number did not affected the millable cane. This could be due to reduced competition once after harvest of the intercropped green bean crop. The results are in conformity with the findings of Islam *et al*., (2007) where sugarcane intercropping with potato mung bean combination and Zarekar *et al*., (2017) who intercropped different crops with different planting methods with groundnut, sweet corn, green gram, cabbage and amaranths.

**Table 11.** Interaction effect of treatments on Yield and yield components of sugarcane

| TERETMENT | SCGER | SCTILLER | SCMSTALI | SCWEIGH | SCYIELD($_{t\ ha\text{-}1)}$ | ESY (%) |
|---|---|---|---|---|---|---|
| NCO334 Sole crop | 66.67[a] | 231034[a] | 120670 | 0.9 | 106.5 | 12.06 |
| B.C 4.4 15cm intercrop | 63.33[ab] | 214847[a] | 122433 | 0.9 | 107.77 | 12.93 |
| Plati 15cm intercrop | 61.67[ab] | 151628[ab] | 105337 | 1.0 | 103.5 | 11.56 |
| B.C 4.4 10cm intercrop | 60.33[ab] | 114464[ab] | 107839 | 0.97 | 103.73 | 11.07 |
| Plati 10cm intercrop | 49.67[b] | 91916[b] | 104061 | 0.97 | 100.63 | 11.24 |
| Mean | 60.33 | 163065.13 | 113750.96 | 0.94 | 104.66 | 11.77 |
| LSD 5% | ** | ** | NS | NS | NS | NS |
| CV (%) | 9.37 | 29.26 | 10.29 | 10.49 | 3.03 | 5.97 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference (P<0.05), NS= Not significant SCGER= sugarcane germination SCTILLER= sugarcane tiller SCMSTALK=sugarcane Millable stalk SCWEIGHT= sugarcane weight SCYIELD= sugarcane yield, ESY= estimated sugar yield.

### 4.3.4. Millable canes weight per plant

The results of analysis of variance revealed that the main effect of sugarcane intercropping has no significant (P<0.05) influence on sugarcane millable single stalk weight (kg) measurement. The highest weight (1kg) was obtained from the interaction of (Plati 15cm intercrop), while the lowest (0.9kg) was obtained from (sugarcane sole crop) (Table 11). However, the analysis of variance did not showed statically difference on main effects of variety, planting spacing and cropping systems (Table 12).

### 4.3.5. Millable cane yield

The results of analysis of variance revealed that the main effect of sugarcane intercropping has no significant (P<0.05) influence on sugarcane millable cane yield (t $ha^{-1}$). The highest yield (107, 77 t $ha^{-1}$) was obtained from the interaction of green bean (variety B.C 4.4, planting spacing 15 cm spacing intercropped), while the lowest (100, 63 t $ha^{-1}$) was obtained from green bean (variety Plati, planting spacing10cm intercropped) (Table 11). Similarly, Zarekar *et al.*, 2017, reported the highest cane yield obtained from sugarcane intercropped with green gram (265, 00 t $ha^{-1}$), was statistically similar with groundnut (225, 33 t $ha^{-1}$), cabbage (194, 00 t $ha^{-1}$) and amaranths (191, 67 t $ha^{-1}$).

**Table 12.** Main effects of Varieties and planting spacing of the intercropped green bean with sugarcane and cropping system on yield and yield component of sugarcane

| TEREATMENTS | SC Ger | SC Till | SCM Stalk | SC Weight | SC Yield(t ha-1) |
|---|---|---|---|---|---|
| **Variety** | | | | | |
| Plati | 55.67 | 133045.98 | 104699.23 | 0.98 | 102.07 |
| Bc44 | 61.83 | 153381.23 | 115136.02 | 0.95 | 105.75 |
| LSD (0.05) | NS | NS | NS | NS | NS |
| CV (%) | 9.36 | 29.3 | 10.29 | 10.49 | 3.03 |
| **Spacing** | **SC Ger** | **SC Till** | **SC Stalk** | **SC Weight** | **SC Yield(t ha-1)** |
| **10CM** | 55b | 103189.66b | 105950.19 | 0.97 | 102.18 |
| **15CM** | 62.5a | 183237.55a | 113885.06 | 0.97 | 105.63 |
| LSD (0.05) | ** | ** | NS | NS | NS |
| CV (%) | 9.36 | 29.3 | 10.29 | 10.49 | 3.03 |
| **Cropping system** | **SC Ger** | **SC Till** | **SC Stalk** | **SC Weight** | **SC Yield(t ha-1)** |
| **Sole cropped** | 66.67 | 231034.48a | 120670.50 | 0.9 | 106.5 |
| **Inter cropped** | 58.75 | 143213.60b | 109917.62 | 0.97 | 103.91 |
| LSD (0.05) | NS | ** | NS | NS | NS |
| CV (%) | 9.36 | 29.3 | 10.29 | 10.49 | 3.03 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference (P<0.05), NS= Not significant SCGER= sugarcane germination SCTILLER= sugarcane tiller, SCM Stalk= sugarcane Millable stalk SCWEIGHT= sugarcane weight SCYIELD= sugarcane yield.

### 4.3.1. Estimated sugar yield

In the present finding, the analysis of variance did not show significant difference (P<0.05) in the juice quality parameters brix, pol, and purity, indicating their direct correlation to sucrose content of sugarcane which is the determinant parameter for sugar yield (Mendoza, 2007). The maximum sucrose percent cane (12.93 t $ha^{-1}$) was obtained from the interaction of (variety Plati, planting spacing 10 cm intercropped), while the lowest (11.07 t $ha^{-1}$) was obtained from interaction of (variety B.C 4.4, planting spacing 10 cm intercropped) (Table 11). All the treatments responded higher values for pol%, purity% and recoverable sugar percent cane (Appendix I), which is the determinant factor of estimated recoverable percent cane (Mendoza, 2007), at the present finding showed intercrop was not affected the sugar yield. Similarly, Zarekar *et al*., 2017 stated that intercropping did not affect the juice quality of the associated sugarcane.

## 4.4. Land equivalent ratio (LER)

The results of LER indicated that green bean-sugarcane intercropping at different combination were depicted better land productivity than sole planting of sugarcane as well as green bean. The same has been proved via the results in its LER value (i.e., greater LER in intercropping and lower LER in sole plantings; Table13). The value of LER above one indicates that the inter-cropped utilize the available resource efficiently than sole cropped. From the current study out-come indicated in Table (13), a total area of 1.81 ha was be required for sole cropping to produce the equal quantity of yields produced on the 1 ha land where the green bean-sugarcane inter-cropped system. Similarly, a total of 1.91 ha of sole cropping area was being required to produce the same yields as 1 ha of the sugarcane intercropped system. This indicates that intercropping system would be feasible using intercrop than mono crop.

**Table 13.** Land Equivalent Ratio (LER) of sugarcane and green bean intercropping

| Treatment | Intercropped Y$_{(t\ ha^{-1})}$ | Sole Y $_{(t\ ha^{-1})}$ | LER |
|---|---|---|---|
| Plati + 10cm | 7.533 | 8.0 | 0.94 |
| Plati + 15cm | 6.933 | 7.933 | 0.87 |
| **LER for green bean** | | | **1.81** |
| Plati + 10cm | 100.63 | | 0.94 |
| Plati + 15cm | 103.5 | | 0.97 |
| Sugarcane Sole | | 106.5 | |
| **LER for Sugarcane** | | | **1.91** |
| **Total LER** | | | **3.72** |

Therefore, the calculated total LER enlightened that intercropping of sugarcane and green bean was productive and had yield advantage over solo cropping of sugarcane or green bean. Such advantage is resulted from the efficient utilization of growth resource by the intercropped or could be due to the intercropping advantages of weed reduction, nitrogen fixation and the like. Accordingly, Chemeda (2003) found up to 28% higher total productivity increase of maize-bean intercropping compared with pure stand. Osiru and Willey (1972) also reported that 55% yield advantage when 85 day beans intercropped with 120 day sorghum and 38 % yield advantage when 85 day beans intercropped with 120 day maize. Baker (1979) also pointed out that, both early and slow maturing crops are combined to ensure efficient utilization of the whole growing resource.

# 5. CONCLUSION AND RECOMMENDATION

## 5.1. Conclusion

In this study, the effect of green bean varieties-sugarcane intercropping and different plant spacing has been studied and their effects on the growth and yield parameters of both companion crops were recorded.

Days to 50% emergences, days 50% flowering and days 50% maturity were significantly affected by main effect of green bean variety. Green bean variety Plati took less number of days to emergence, day to flower forming and day to maturation compared to variety B.C 4.4. Leaf area and biomass among treatments was significantly affected by main effect of green bean variety. Green bean variety B.C 4.4 recorded the highest percentage of biomass and leaf area.

Number of pod per plant was significantly affected by main effect of variety B.C 4.4 and combinations of the two spacing's as well as cropping systems. The highest number of pod per plant (35.3) was recorded from the interaction of (Plati 10cm intercropped) while the lowest number of pods per plant (15.67) was obtained from (B.C 4.4 15cm intercropped). With regards to variety, the highest number of pods per plant was obtained from variety Plati while variety B.C 4.4 had the lowest. Significantly higher number of pods per green bean plant was obtained from intercropped than sole cropped green bean. Green pod yield was significantly affected by green bean variety. The highest green pod yield was recorded for variety Plati while the lowest seed weight was recorded for variety B.C 4.4. Green pod yield of green bean was significantly affected by associated varieties, planting spacing and cropping system. The highest green pod yield was obtained from the intercropped variety Plati.

The main effects of green bean variety showed not significant effect on sprout percent, tiller number, stalk number, single cane weight and yield of sugarcane. The main effects of 10 cm planting spacing showed significant effects on germination percent and tiller number of sugarcane.

Generally, maximizing intercropping advantage is a matter of maximizing the degree of complementarities between the component crops and minimizing inter-competition. On this basis, this work met the intercropping requirements stated by Yadav, (2017). The requirements indicates that for successful intercropping with sugarcane, (i) intercrops should be short duration and complement with sugarcane, (ii) shading effect of intercrops on sugarcane should be minimum and (iii) the time of peak nutrient demands of intercrops should not overlap with sugarcane.

So far, there was no attempt no research work had been made in intercropping green bean-sugarcane in Ethiopia sugarcane plantations. However, different vegetables like Swiss chard and lettuce has been intercropping and cultivating in Ethiopian Sugar Estates for their desirable characteristics that includes but not limited to competition with sugarcane is low (minimum competition for light), early maturity (short duration), not hamper of mechanical operations such as molding in sugarcane fields since they can be harvested before the operation.

Therefore, as this study revealed optimum pod yield and quality from green bean-sugarcane intercropping without significantly affecting the yield and quality of sugarcane, green bean-sugar cane intercropping can be incorporated in to the country's food self-sufficiency agenda via enhances land productivity (i.e., producing two crops from a unit of land without affecting the yield for both crops). However, in order to give conclusive recommendation for the study area, similar field and economic feasibility studies need to be carried out at list for one cropping season.

## 5.1. Recommendation

Considering the experimental findings intercropping of sugarcane with green bean proved to be practicable. Accordingly, green bean variety Plati with 15 cm spacing is recommended for the study area for intercropping with sugarcane. However if it is necessary to be plant green bean alone variety Plati with planting spacing 10 cm is recommended for the study area.

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# 7. APPENDIX

## 7.1. List of tables

**APPENDIX I.**

Treatment interaction effect on cane juice quality parameters brix, pol, purity and sugar yield

| Treatment | Bx% juice | Pol% juice | Purity% | ERS % |
|---|---|---|---|---|
| NCO334 Sole crop | 19a | 16.71a | 87.94a | 11.33a |
| Plati 10cm intercrop | 18.1a | 16.85a | 93.09a | 12.00a |
| Plati 15cm intercrop | 17.2a | 15.84a | 92.09a | 11.17a |
| B.C 4.4 10cm intercrop | 17.74a | 15.67a | 88.33a | 10.67a |
| B.C 4.4 15cm intercrop | 17.96a | 16.15a | 89.92a | 11.17a |
| Mean | 18 | 16.244 | 90.27756 | 11.26 |
| LSD 5% | NS | NS | NS | NS |
| CV (%) | 6.64 | 9.24 | 7.9 | 6.38 |

Means followed by the same letter in a column are not significantly different from each other, CV= Coefficient of Variation, LSD= Least significant Difference ($P<0.05$), NS= Not significant Brix %= solid substance for solutions of pure sucrose in water Pol% = apparent sucrose content of the juice Purity% = The percentage ratio of sucrose (or pol) to the total soluble solids (or brix) in a sugar product. ERS= recoverable sugar percent cane

**APPENDIX II.**

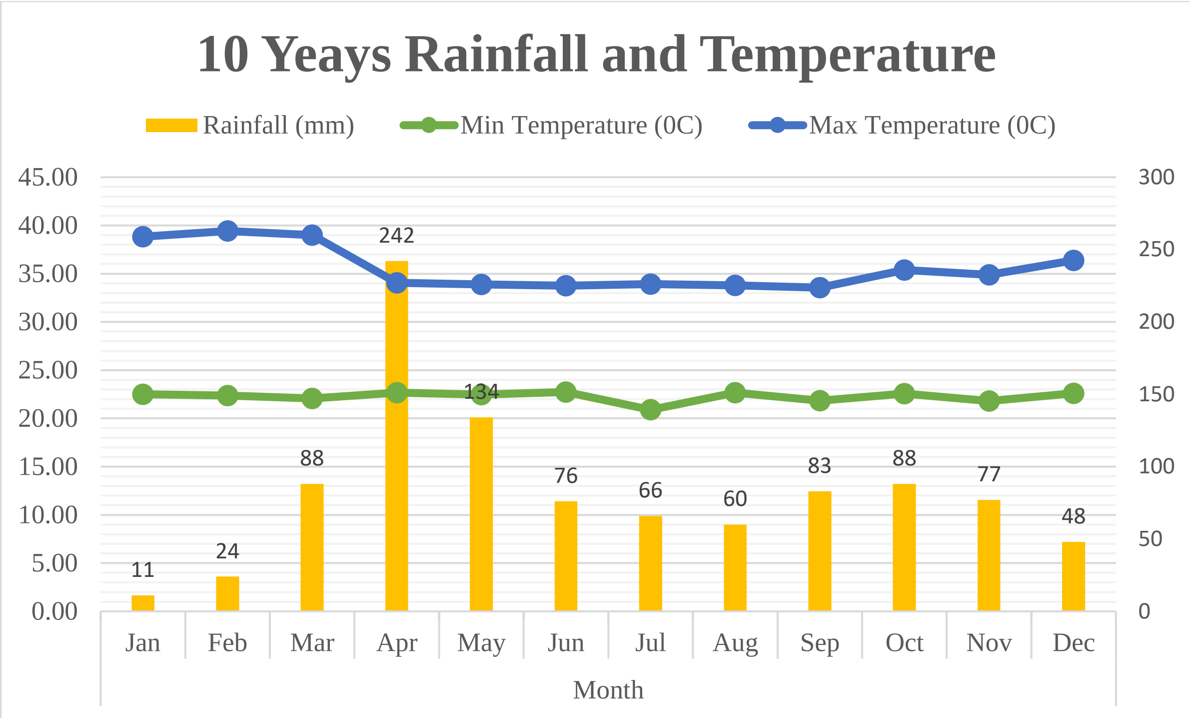
Analysis of variance of fixed effects for the experiments involving two varieties of Green beans and two planting spacing intercropped with sugarcane conducted on plant cane crop at Omo Kuraz during 2021 – 2022.

| Source of Variation | DF | Mean square values | | | | | |
|---|---|---|---|---|---|---|---|
| | | DEM | DFLW | DMATU | NLPP | NBPP | LA |
| Variety(A) | 1 | 40.04 | 150.00 | 693.38 | 84.38 | 2.04 | 2068001.04 |
| Spacing(B) | 1 | 3.38 | 1.50 | 3.38 | 2.04 | 0.04 | 1781605.04 |
| Cropping System(C) | 1 | 1.04 | 6.00 | 0.38 | 57.04 | 7.04 | 175275.04 |
| A*B | 1 | 0.38 | 1.50 | 0.38 | 26.04 | 0.38 | 153440.04 |
| A*C | 1 | 0.04 | 0.00 | 0.38 | 5.04 | 5.04 | 51.04 |
| B*C | 1 | 0.04 | 1.50 | 0.38 | 22.04 | 1.04 | 89426.04 |
| A*B*C | 1 | 0.38 | 1.50 | 18.38 | 0.38 | 0.38 | 61509.38 |
| Error | 16 | 0.46 | 12.38 | 175.00 | 127.29 | 1.17 | 273715.21 |
| CV (%) | | 8.60 | 4.89 | 16.00 | 17.33 | 21.08 | 33.88 |

| Source of Variation | DF | Mean square values | | | | |
|---|---|---|---|---|---|---|
| | | NPPP | PL | PD | DMC | Yield |
| Variety(A) | 1 | 672.04 | 1.98 | 0.08 | 70.04 | 20533.50 |
| Spacing(B) | 1 | 15.04 | 0.12 | 0.00 | 24.40 | 80.67 |
| Cropping System(C) | 1 | 117.04 | 0.07 | 0.01 | 14.73 | 450.67 |
| A*B | 1 | 0.38 | 0.18 | 0.02 | 36.51 | 0.67 |
| A*C | 1 | 247.04 | 1.17 | 0.00 | 10.94 | 10.67 |
| B*C | 1 | 7.04 | 0.09 | 0.01 | 26.04 | 88.17 |
| A*B*C | 1 | 15.04 | 0.05 | 0.00 | 29.04 | 8.17 |
| Error | 16 | 30.58 | 0.36 | 0.01 | 8.32 | 141.50 |
| CV (%) | | 20.45 | 5.35 | 17.42 | 3.36 | 25.44 |

| Source of Variation | DF | Mean square values | | | | | |
|---|---|---|---|---|---|---|---|
| | | SCGER | SCTILLER | SCMSTALK | SCWEIGHT | SCYIELD | ESY |
| Variety(A) | 1 | 98.12 | 156749571 | 76807289 | 0.0003333 | 73.7944 | 1.6875 |
| Spacing(B) | 1 | 114.1 | 119896948 | 58749505 | 0.0033333 | 20.393 | 0.02083333 |
| A*B | 3 | 30.08 | 23148148 | 11342592 | 0.0011111 | 32.4022 | 1.6875 |
| Error | 10 | 23.93 | 174764390 | 85634551 | 0.0053333 | 24.6981 | 0.45 |
| CV (%) | | **8.038** | 8.978 | 8.978351 | 7.7144 | 5.19394 | 5.971695 |

## 7.2. List of figures




APPENDIX FIGURE 1. Ten Years Monthly Minimum and Maximum Temperature ($^{0}$C) and Rainfall (mm) of the study area **Source:** kuraz research sub center meteorological station

**APPENDIX FIGURE 2.** The intercropped experiment plot before harvest

**APPENDIX FIGURE 3.** Pod length and Pod diameter Measurement

**APPENDIX FIGURE 4.** Intercropped and Sole planted green been at early stage

**APPENDIX FIGURE 5.** Data collection and Green Pod harvesting

# BIOGRAPHI

The author, Abiy Negesse, was born on March, 23 1985G.C. in Debre Birhan. He attended his elementary and secondary school in Debre Birhan. After completion of secondary education, he joined Alage ATVT College in 2004, and graduated with diploma in plant science. Then, he was employed by Amhara Regional state, North Shewa Zone, Angolelana Tera Wereda Agriculture and Rural Development office and served as crop development expert from October 30/2007 up to June 19/06/2008. In June 20/2008 he joined Ethiopian Sugar Corporation Research and Development Centre at Wonji and served as field forman and technical assistant till November 24/2016. He joined Haramaya University to pursue his BSc study and graduated in plant sciences in November 2016. After returning to the organization, he served as training and extension senior officer from November 24/2016 up to September 28/2020 at Tendaho Research and Development Centre in Afar Regional State. Later on, he was transferred to Kuraz Research sub Centre (SNN, South OMO) as junior researcher II in soil science. In July 2019, he joined the school of graduate studies of Hawassa University to study his Master of Science degree in horticulture.