EFFECT OF PLANT DENSITY OF HYBRID MAIZE AND COMMON BEAN VARIETIES ON THEIR PRODUCTIVITY AND ECONOMIC BENEFIT UNDER INTERCROPPING SYSTEM AT JIMMA, SOUTH WEST ETHIOPIA

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JIBRIL TEMESGEN

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

Jibril Temesgen Merga

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I have incorporated the suggestions and modifications given by during the internal defense and got the approval of my advisors. Hence, I hereby kindly request the Department to allow me to submit my thesis for external thesis defense.

Jibril Temesgen ___________________________

Name signature of student

We the thesis advisors have verified that the student has incorporated the suggestions and modifications given during the internal thesis defense and the thesis is ready to be submitted hence, we recommended the thesis to be submitted for external defense.

Major Advisor: Taye Kufa (PhD) Signature ______________ Date ______________

Co-advisor: Zeleke Wondimu (M.Sc.) Signature _____________ Date _______________

Decision/Suggestion of Department Graduate Council (DGC)

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Chair Person, DGC Signature Date

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DEDICATION

I dedicated this thesis to my beloved father Temesgen Merga whose encouragement and enduring love was the bridge to the success of my life. May Allah give him long life.

STATEMENT OF THE AUTHOR

By signing below, I declare that this thesis is a result of my own genuine work. I have followed all ethical principles of scholarship in data collection, data analysis, and write-up of the thesis. All scholarly matter that is included in the thesis has been given recognition through citation. I affirm that I have cited and referenced all sources used in this document. Effort has been made to avoid any plagiarism in the preparation of the thesis.

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Signature: ------------------

Place: Jimma University,

Date of Submission: _______________

BIOGRAPHICAL SKETCH

The author Jibril Temesgen was born in Ethiopia, Oromia region in west wollega zone on April 10/1990 to his father Temesgen Merga and mother Dunge Umer. He attended his elementary education at Haro Gecho elementary school from September 1995 to June 2003. He attended his Senior Secondary School at Bieftu Gimbi high school from September 2003 to June 2005. From September 2005 to June 2007, he attended preparatory education at Gimbi comprehensive high school. Then he joined Wollega University College of Agriculture and Rural development in 2007 and graduated with a Bachelor of Science Degree in plant sciences and crop protection in June 2010. Then, in September 2010 he was employed by the Oromia office of Agriculture and stationed in west Wollega zone, Genji district where he served as an expert/agronomist until he joined the Jimma University College of Agriculture and Veterinary Medicine School of Graduate Studies in 2013 to pursue his Masters of Science (MSc) Degree in Agriculture, Agronomy.

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LIST OF ABBREVIATIONS

CA	Conventional Agriculture
CB	Common bean
ETB	Ethiopian birr
GDP	Gross Domestic Plan
GLM	General linear model
GMV	Gross Monitory Value
JARC	Jimma Agricultural Research Center
LA	Leaf Area
LAI	Leaf Area Index
LER	Land Equivalent Ratio
MLAB	Maize and Local Asendabo
MNB	Maize and Nasir
MV	Monitory Value
MY	Maize Yield
P_2O_5	Phosphorus Oxide
pH	Hydrogen Power
RCBD	Randomized complete Block Design
SLAB	Sole Local Asendabo
SM	Sole Maize
T/ha	Tone per hectare

TGMV	Total Gross Monitory Value
TLER	Total Land Equivalent Ratio

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ABSTRACT

*Limited farmland size owned by smallholding farmer is one of the challenges to increase crop production and productivity at Jimma area in particular and in the country at large. Accordingly, famers have a long standing traditional knowledge of growing multiple crops in different cropping patterns. Intercropping is one of the crop combination systems practiced by resource poor farmers to increase crop production per unit area of land per year and reduce the risks to food and cash sources. However, research information is scanty on optimum intercropping technology options for irrigated agriculture. Hence, this study was conducted at the Jimma Agricultural Research Center in 2014 with the objectives to determine the effects of component density of maize and common bean varieties on growth, yield and yield components of the associated crops and on their productivity, To identify the best performed common bean variety with component population density that maximizes productivity of maize and common bean under Jimma conditions; and To identify economically suitable maize-bean intercropping system under Jimma conditions, southwest Ethiopia. The experiment was conducted in factorial experiment arranged in a Randomized Complete Block Design of three replications. The treatment combinations included six component densities (100% * 17.7%, 100% * 26.7%, 100% * 53.3%, 75% * 17.7%, 75% * 26.7%, 75% * 53.3%) of hybrid maize and common bean respectively, and two common bean varieties (Nasir and Local Asendabo) along with sole maize and common bean varieties. Data on some soil chemical properties, phenology, growth, yield and yield components of the two crops as well as system productivity and economic benefits were recorded and analyzed. The analysis of variance showed that the interaction effects of bean varieties and component population densities as well as the main effects were comparable on the phenology of maize and common beans, except the main effects of varieties indicated significant variation on days to 50% emergency of common bean. All yield and yield components showed significant effect due to the main effect of common bean variety, component density and interaction effects of the main effects on maize and common bean. Conversely, harvest index of maize showed significant effect only due to component density. In general, the yield obtained from the mean intercropped maize 4990 kg/ha was greater than the mean yield obtained from sole cropped maize 4790 kg/ha. However, the yield obtained from the mean intercrop common bean 697 kg/ha was less than the yield obtained from sole crop 2,177kgt/ha. Moreover, Land Equivalent Ratio (LER), Gross Monetary Value (GMV) and Monetary Advantage (MV) showed significant variation due to the main effects of common bean varieties, component density and the interaction of them. The highest LER (1.90) and Monetary Advantage (MV) (3710.73 Birr) were obtained when 100% maize population density intercropped with 26.7% Nasir common bean population density. The results showed that intercropping maize with common beans was advantageous than sole cropping of either of each crop; particularly during the summer season when production during main season is running out and shortage of food supply occurred. Generally, the findings clearly depicted that intercropping of hybrid maize and common beans had more yield and monetary benefits. In general maize 100% population density intercropped with 26.7% population density of Nasir common bean variety; and as an alternative: - Maize with 75% population density intercropped with 53.3% population density of both varieties of common beans make farmers benefited from the system. Nonetheless, further investigations are required to generate reliable technologies and draw recommendations on irrigated maize-beans production systems.*

Key words: Irrigation, Density, Monetary value, Land equivalent ratio

1. INTRODUCTION

Suitable land area for food production through most parts of the world remains fixed and may even be decreasing, and it is becoming more important to raise crop productivity in order to meet the increasing food requirements of an increasing population all over the world (Midmore, 1993). Most of the developing nations lie in the tropical region and the population pressure is felt more acutely by these developing countries since the rate of population growth is higher and economic development is unable to keep pace with it (Palaniappan, 1985). Thus, the only way to increase agricultural production is to increase yield per unit area (Tamiru, 2013).

Maize (*Zea mays L.; Poacceae*) is the most important cereal after wheat and rice with regards to cultivation area in the world (Osagie, 1998). In Ethiopia, it is one of the major staple crops ranking first in yield potential per hectare and fourth in total area after teff (*Eragrostis tef*), barley and sorghum. Maize is the staple crop with the greatest production at 4.2 million tons in 2007/08, compared to teff at 3.0 million tons and sorghum at 2.7 million tons (IFPRI, 2010). The production obtained from maize in Ethiopia in 2012/13 is 2,013,044.93ha with the total production of 6,158,317,595kg and productivity of 3059 kg/ha (CSA, 2013). This was why Benti *et al*. (1997) explained that the annual production and productivity of maize exceeded all other crops grown in Ethiopia with the exception of teff in terms of area coverage.

Common bean (*Phaseolus vulgaris L.*) is a major food legumes and ranks third most important worldwide food crop next to soybean and peanut (Singh, 1989). It is an important pulse crop distributed and grown in different parts of Ethiopia depending on climatic and socio-economic factors (Tenaw, 1990). In terms of area, Kenya is the leading producer of common bean in Africa followed by Uganda and then Tanzania, Malawi and Ethiopia rank eighth and ninth, respectively (FAO, 2008). Common bean (*Phaseolus vulgaris L.*) plays an important role in human nutrition and market economies of some rural and urban areas of the Ethiopia (CSA, 2009). It is mainly used as sources of food and cash. It is exported to earn foreign exchange and is also one of the cash crops locally used by farmers (Mitiku, 1990). It is considered as the main cash crop and protein source of farmers in many low lands and mid altitude zones of Ethiopia. Between 2004 and 2010, the exported navy bean alone almost tripled from USD 18 million to 50 million while other food bean types are also consumed or traded in local and regional markets. Since 2004, the areas under bean have been expanding very drastically. The production obtained from common beans in Ethiopia in 2012/13 is 366,876.94ha with the respective production and productivity of 463,008,490kg and 1262 kg/ha (CSA, 2013).

The common bean crop is grown by subsistence farmers either as a sole crop and/or intercropped with either cereal or tree crops. Shade tolerance and early maturity contributes to common beans. Therefore, these characteristics make it an ideal crop for intensification of existing farming system (Shimelis *et al.,* 1990). Morpho-physiological differences and agronomic factors such as the proportion of crops in the mixture and fertilizer application regulate competition between component crops for growth-limiting factors (Trenbath, 1974). Selection of appropriate cultivars, planting dates and plant densities are cultural practices that have been shown to affect common bean yield potential and stability (Norwood, 2001).

Intercropping is an old and commonly used agricultural cropping practice, of cultivating two or more crops in the same space at the same time (Carlson, 2008). Maize/legume intercropping has become one of the solutions for food security among small scale maize producers (Thobatsi, 2009). It is being advocated as a new and improved approach to farming. However, it has been avoided because of the complications of planting and harvesting (Avcioglu *et al*., 2003). Being the under story crop in most intercropping systems, growth and yield of legumes are usually suppressed by the dominant crop. Complementarities in an intercropping situation can occur when the growth patterns of the component crops differ in time or when they make better use of resources in space (Tamiru, 2013).

Decline in soil fertility due to mono cropping is becoming a limiting factor for crop production in Ethiopia (Abeya *et al*., 2012). Intercropping improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation with greater ground cover as compared to sole cropping, and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture (Abraha, 2013). Maize-legume rotation and intercropping systems in the context of conservation agriculture are believed to break or mitigate the continuous mono-cropping effect of maize in Western Ethiopia (Abeya *et al*., 2012).

In Ethiopia, as it is also true in most tropical countries, traditional cropping systems are based on resource poor farmers' subsistence requirements, and are not necessarily the most efficient ones (Sanchez, 1989). Because of this, crop production per unit land area is usually below world average. Therefore, in diversified crop production systems having production constraints, diversified options need to be assessed (Fininsa, 2001).

The overall mixture densities and the relative proportion of component crops are important in determining yields and production efficiencies of cereal-legume intercrop systems (Zardari *et al.*, 2013; Willey and Osiru, 1972). Seeding ratios and competition capability within mixtures may affect the growth of the species used in intercropping systems in rain-fed areas (Dhima *et al*., 2007; Agegnehu *et al*., 2006; Banik *et al*., 2006; Carr *et al*., 2004).

The production obtained from maize in Jimma 2012/13 was 144,362.82ha with the total production of 454,755,428kg and productivity of 3,150kg/ha and the production obtained from common bean in 2012/13 was 4906.32ha with the total production of 4,428,590kg and productivity of 903 kg/ha (CSA, 2013). In this area, farmers land holding are very small. The average farmers land holding of maize and common bean is 0.33ha and 0.03ha, respectively (CSA, 2013). This acute land scarcity necessitates farmers to use other alternatives to improve their productivity.

Different bean cultivars were tested under intercropping system with maize in Jimma condition; Nasir and Dimtu variety were confirmed to be the best compatible released varieties during rainy season (Tesfa *et al*., 2011). Even though intercropping systems plays an important role in subsistence and food production in Jimma area; to solve the problem related with land shortage, for the number of released bean cultivars in the area their performance under intercropping system and component densities have not been tested at off-season. This is also true for maize where the more robust hybrids are gaining acceptance by farmers and are increasingly replacing open pollinated varieties (personal communication).

The importance of wetland and irrigation production for farmers lies in the fact that they can be harvested from mid-June when other food supplies are becoming exhausted. In this regard, the harvest from wetlands comes at the time of critical food shortage when the supply from upland fields is running out for many families and the “hungry season” is starting (EWNRA, 2002). Intercropping had been practiced in the studied area with common bean varieties by farmers during the main season; however, there is no intercropping practice by farmers in Jimma zone during off-season. Evaluation of released crop varieties for plant density and irrigated agriculture remains as critical research issues for increased productivity and secure family food and cash security. Thus, it is essential to determine the effects of component density of maize and common bean varieties on yield and yield components of the whole associated crops and the productivity of the system.

The present study was therefore, initiated with the following specific objectives:

1. To determine the effects of component density of maize and common bean varieties on growth, yield and yield components of the associated crops.

2. To identify the best performed common bean variety with optimum component population density that maximizes productivity of both crops.

3. To identify economically suitable maize-bean intercropping component density under Jimma conditions, southwest Ethiopia

2. LITRATURE REVIEW

2.1. Maize Production and its Importance in Ethiopia

Ethiopia is among the major maize producers in Africa and ranked fourth next to South Africa, Nigeria and Egypt. The crop is widely cultivated at altitudes ranging from 1500–2200 meters above sea level of Western, Southwestern, and Southern parts of the country. Maize production takes significant share of cereals and grain in any production year. Regional states including Oromia, Amhara and SNNP contribute to 94% of the total annual production. Oromia region alone contributes to 60% of the country's maize production. West Gojam, East Showa, Jimma, East welega and West welega zones are major producing areas and together contribute to 60% of total production (Ethiopia Commodity Exchange Authority, 2009). This region is considered to be the major maize growing zone in the country. The region lies at an altitudes between 1000 to 1800 m above sea level and receives a fairly reliable average annual rainfall (1000 to 1500 mm/year), rendering it a region of high potential for maize production (CSA, 2010). The mid altitude, sub-humid agro-ecology is the most important maize producing environment in Ethiopia (Birhane and Bantayehu, 1989; Kebede *et al*., 1993). Agriculture continues to be the dominant sector in Ethiopia's economy, with cereals playing a central role. Grain production and marketing are particularly important: studies show that cereals account for 65 percent of the agricultural value added, equivalent to about 30 percent of the national GDP (IFPRI, 2010). Out of the total grain crop area, 78.17% (9,601,035.26 hectares) was under cereals. Teff, maize, sorghum and wheat took up 22.23% (about 2,730,272.95 hectares), 16.39% (about 2,013, 044.93 hectares), 13.93 % (1,711,485.04 hectares) and 13.25% (1,627,647.16 hectares) of the grain crop area, respectively. Out of total grain production Cereals contributed 84.96% (about 19,651,151,546kg) of the grain production. Maize, teff, wheat and sorghum made up 26.63% (6,158,317,595kg), 16.28% (37,652,41166kg), 14.85% (34,347,06122kg) and 15.58% (3,604,261,965kg) of the grain production, in the same order. Maize is Ethiopia's largest cereal commodity in terms of total production, acreage, and the number of farm holdings (CSA, 2013).

Maize production has remained low, with the estimated national average yield of 2.5 t/ha due to several constraints: biotic (inadequate improved varieties, pests and diseases), abiotic (low soil fertility, land and water degradation, and drought) and socio-economic (input unavailability, lack of storage facility, poor access to markets) (CSA, 2010). Therefore, maize production components such as farmer-preferred, improved varieties, farming technologies, farm inputs, and access to markets should be developed and made available to enhance maize production, in order to achieve food security (Abera *et al*., 2013)

Maize continues to be a significant contributor to the economic and social development of Ethiopia. As the crop with the largest smallholder coverage at 8 million holders (compared to 5.8 million for teff and 4.2 million for wheat), maize is critical to smallholder livelihoods in Ethiopia. In addition, maize is the staple crop with the greatest production (IFPRI, 2010). Maize is increasingly used for human consumption and accounts for 70% of the food consumed in sub-Saharan Africa (FAO, 2007). The recent volatile food market and rising prices for most food crops may increase the importance of maize production. In addition, because of its productivity and wide adaptation, maize remains an important source of food with great potential to improve the livelihoods of most poor famers in developing countries (FAO, 2011).

Maize is instrumental for the food security of Ethiopian households, and is the lowest cost caloric source among all major cereals, which is significant given that cereals dominate household diets in Ethiopia. The unit cost of calories per US dollar for maize is one-and-a-half and two times lower than wheat and teff respectively. Maize is also a low-cost source of protein in comparison to other cereals: maize provides 0.2 kg of protein per USD, compared to 0.1 kg of protein per USD from teff and 0.2 kg of protein from wheat and sorghum. An average Ethiopian consumes a total of 1,858 kilocalories daily of which four major cereals (maize, teff, wheat, and sorghum) account for more than 60 percent, with maize and wheat representing 20 percent each (IFPRI, 2010).

2.2. Common Bean Production and its Importance in Ethiopia

In Ethiopia, common bean is one of the most important cash crops and source of protein for farmers in many lowlands and mid-altitude zones. The country's export earnings is estimated to be over 85 % of export earnings from pulses, exceeding that of other pulses such as lentils, horse (faba bean and chickpea) (Rameto, 2007). Overall, common bean ranks third as an export commodity in Ethiopia, contributing about 9.5 % of total export value from agriculture (FAOSTAT, 2010). In Ethiopia, Pulses grown in 2012/13 (2005 E.C.) covered 15.17 % (1,863,445.42 hectares) of the grain crop area and 11.89% (about 27,510,31188kg) of the grain production was drawn from the same crops. Faba beans, common beans, and chick peas were planted to 4.67 % (about 574,060.45 hectares), 2.99% (about 366,876.94 hectares) and 1.95% (about 239,512.43 hectares) of the grain crop area. The production obtained from faba beans, common beans and chick peas was 4.08% (about 943,964,170kg), 2.00**%** (about 463,008,490kg) and 1.77**%** (409,733,163kg) of the grain production, respectively (CSA, 2013).Common bean is also highly preferred by Ethiopian farmers because of its fast maturing characteristics that enables households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse *et al*., 2006).

2.3. Maize Plant Origin and Morphological Requirements

There is some controversy on the origin of maize, though it is generally accepted that its Centre of origin is located in Mesoamerica, primarily Mexico and the Caribbean. Maize as we know it today has never been found growing in a wild state. Its domestication, probably from a wild teosinte form (*Euchlaena Mexicana*), is believed to have started some 6,000 to 7,500 years ago in the Mexican highlands (McCann, 2001)

Maize is a member of the grass family *Poaceae (Gramineae)*, a classification it shares with many other important agricultural crops, including wheat, rice, oats, sorghum, barley, and sugarcane. Based on fossil evidence, it is estimated that these major grass lineages arose from a common ancestor within the last 55–70 million years, near the end of the reign of dinosaurs. Maize is further organized in the genus *Zea*, a group of annual and perennial grasses native to

Mexico and Central America. The genus *Zea* includes the wild taxa, known collectively as *teosinte (Zea ssp.*), and domesticated corn, or maize (*Zea mays L. ssp. Mays*) (Edward *et al*., 2005).

Maize arrived in Africa after 1500 as part of the massive global ecological and demographic transformation that historian Alfred Crosby called the "Columbian Exchange." The importation of the maize seeds to various parts of Africa generally went unremarked, though it certainly was not unremarkable. The first reference to maize's introduction to Africa may be that of an anonymous Portuguese pilot in 1540, who described its already well-established cultivation on the Cape Verde Islands (McCann, 2001). Maize is first introduced in Ethiopia in 16th century (Yoseph *et al*., 2006).

Maize is a 2-3 m high grass with a solid single stem (stalk), 3-4 cm in diameter, with clearly defined nodes and internodes. The number of internodes ranges from 15 to 20. These are short and fairly thick at the base, but become longer and thinner near the terminal male inflorescence. The leaves arise from the nodes, alternately on opposite sides on the stalk. It is a monoecious grass with male and female flowers borne in separate inflorescences on the same plant. Although it is self-fertile, the plant's monoecious character and protandry ensure a cross-pollination of 90-95%. The tassel male inflorescence is a terminal panicle, up to 40 cm long, which stretches out from the enclosing leaves at the top of the stalk. The male or staminate flowers are present within spikelet on the branches. The stamens elongate at anthesis and the pollen is released by the anthers. The maize kernel consists of the embryo (10-13% of the grain), endosperm and pericarp and may differ in color, structure and chemical composition (McCann, 2001).

Maize is the primary food staple in Ethiopia, averaging slightly more than 20% of daily caloric intake. The Ethiopian Commodity Exchange reports that three-quarters of maize produced is used for household consumption, only about ten percent is marketed and the remainder is used for seed, in-kind payments for labor, and animal feed (Schneider and Anderson, 2010). Currently, it is the second most important crop, exceeded only by teff (*Era-grostisteff* in terms of production area. However, it exceeds all other cereals in terms of annual production and yield per ha. Since its introduction, it has gained importance as a food and feed crop. It is one of the cereals that provide most of the calorie requirements in the traditional Ethiopian diet. It is prepared and used as unleavened bread, roasted and boiled green ears, parched mature grain porridge and in local drinks like '*tella*','*borde*' and '*areke*'(Mulatu *et al*., 1992). Apart from these uses maize leaves are feed to animals, while dry stalks are used as fuel and for the construction of fences and huts.

2.4. Common Bean Plant Origin and Morphological Requirements

Dry beans (*Phaseolus spp.)* originated in Central and South America. It is of new world origin and is cultivated in many parts of the tropics and subtropics, and in temperate regions. It has been cultivated throughout North, Central and South America. Remains of common beans, dated to 4,975 B.C. have been found in the caves of the Tehuacan valley in Mexico. Vessels containing bean have been recovered from the Pre-Inca tombs in Peru. The remnants of common beans and lima beans have been recorded from archaeological deposits in the inter-montane Peruvian valley, and dated to about 6,000 B.C. The common bean was introduced into Europe in the sixteenth century by the Spaniards and Portuguese and was later carried to Africa and other parts of the world (Usha, 2006).

Africa is considered to be a secondary center for bean genetic diversity. Beans are a major staple in Eastern, Southern and Great Lakes of Africa, where they are the second most important source of dietary protein after maize and the third most important source of calories after cassava and maize (Abate, 1996). Haricot bean (*Phaseolus vulgaris L.*) is an annual pulse crop with considerable variation in habit, vegetative characters, flower color and the size, shape and color of the pods and seeds (Onwueme , 1991). It also referred to as dry bean, is an annual leguminous plant that belongs to the genus, *Phaseolus*, with innately compound trifoliate large leaves. Common bean shows variation in growth habits from determinate bush to indeterminate, extreme climbing types. The bushy type bean is the most predominant type grown in Africa (Buruchara, 2007)

It is well adapted to the range of an altitude between 1200 and 2000m above sea level (Wortmann, 1998), and in areas with annual average rainfall 500-1500mm. It is not drought resistant; ideally needs moist soil throughout the growing period. However, rainfall towards the end of growing periods is undesirable. It can be grown successfully on most soil types, from light sands to heavy clays, but friable, deep and well-drained soils are best preferred (Onwueme, 1991).

Common bean (*Phaseolus vulgaris L.*) is a warm-season crop that does not tolerate frost or long periods of exposure to near-freezing temperatures at any stage of growth. Usually high temperatures do not affect it if adequate soil water is present, although high nocturnal temperatures will inhibit pollination (Wortmann *et al*., 1998). It is a very important source of protein and natural fiber in eastern, central and southern Africa and tropical America (Pachico, 1993).The area under common bean production in Ethiopia is estimated, about 200,000 hectare annually (CSA, 2000). The productivity of the crop is low due to lack of high yielding varieties adapted to diverse agro ecological conditions and adaptation of better agronomic practices (Dawit *et al*., 2012).

Generally, common bean is considered a short-season crop with most varieties maturing in a range of 65 to 110 days from emergence to physiological maturing (Buruchara, 2007). Maturity period can continue up to 200 days after planting amongst climbers that are used in cooler upland elevations (Gomez, 2004) the crop is not sensitive to soil type as long as it is reasonably fertile, well-drained and does not have conditions that interfere with germination and emergence (Wortmann *et al.*, 1998).

2.5. Cropping System

Cropping system research has recently assumed, added dimensions and attracted worldwide attentions both in developed and in developing countries. Temporal and spatial intensification of crops constitutes the basic ingredients of national food production strategy. It helps to create varied income source and labor use distribution. Cropping system is the principles and practices of cropping and their interaction with farm resources, technology, aerial and edaphic environment to suit the regional or global needs and production strategy (Pal *et al.*, 1985). Maize/ bean are the dominant cropping systems in most parts of Africa (Francis *et al*., 1982).

In Ethiopia, the traditional cropping systems have wide range of cropping in various maize growing areas. In most areas, mixed cropping of maize with pulses, oil crops, cereals and even trees are common. However, mono cropping of maize is the dominant feature (McCann, 2001).

The economic return or monetary gain per unit area and time is one of the major considerations for adoptions of a certain cropping system and yield is the foremost agronomic parameter to compare the importance of component crop in any type of cropping system (Francis, 1978). Soil fertility, temperature, length of rainy season and pressure on the land influence the type of cropping systems used by smallholders (Woolley *et al*., 1991). In general, in designing alternative cropping system, the common approaches to be followed are: crop intensification, crop diversification and cultivar options. However, the three approaches become inseparable and considered as a building block of a new system (Yadav *et al.*, 1998).

2.5.1. Intercropping

Though intercropping is defined by different authors differently, 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, 1982; 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 (1993), further divide intercropping in to four: mixed intercropping (growing component crops simultaneously with no distinct row arrangement); row intercropping (growing component crops simultaneously in different rows); strip intercropping (growing component crops simultaneously in different strips to permit the independent cultivation of each crop); and relay intercropping (growing component crops in relay, so that growth cycles overlap).

Crop combinations in intercropping differ with geographical location, crop morphology and growth durations. Based on geographical location 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, 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 sugar cane; 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).

2.5.2. Maize and Common Bean Intercropping

One of the main challenges in Western Ethiopia, where maize is the main stable and major producing crop, is continuous mono cropping with residue removal through burning and/or used for other purposes (Zerihun *et al*., 2014). Maize-legume intercrops yielded more and were associated with less risk than the maize legume rotations (Kamanga *et al*., 2010). Maize in association with legumes gives higher total yield and net return (Patra *et al*., 2000). If intercropping was to be practiced, there would be a higher coverage of the soil by the second crop and so, it forms a sort of green or living mulch. While it will use water for transpiration, this will also produce a crop and thus be useful water and at the same time decrease the bare soil surface evaporation. This would then also increase the water use efficiency of the combined crop (Walker and Ogindo, 2003).

A change of growth habit from bush to climbing beans in maize/bean intercrop system changes both temporal and spatial arrangements of the cropping system (Woolley and Davis, 1991).However; maize has been reported to be more competitive than beans for light. It shades the associated bean crop thus, depressing yield due to the decreased in photosynthetic in plant, which is reflected in reduced number of pods per plant and seeds per pod (Davis and Garcia, 1983). Maize was reported to depress bush bean yields by 7 to 32% (Woolley and

Smith, 1992), whereas beans caused 15 to 30% reduction in maize yield (Davis and Garcia, 1983). Reduction in bean yields may be minimized by manipulating plant density, planting pattern and relative planting dates of and beans (Niringiye *et al*., 2005).

Intercropping is being advocated as a new and improved approach to farming. However, it has been avoided because of the complications of planting and harvesting. Intercropping involves competition for light, water and nutrients. However, intercropping usually benefits from increased light interception, root contact with more soil, increased microbial activity and can act as a deterrent to pests and weeds of the other crop (Avcioglu *et al*., 2003). There is also evidence that suggests intercropping may benefit a non-legume which needs nitrogen if the other crop is a legume, since legumes will fix nitrogen in the soil (Avcioglu *et al*., 2003). Maize-bean intercropping considerably gave the highest production, increased water use efficiency and maximum net income as compared to crop rotation or continuous production in CA or farmers practices (Zerihun *et al*., 2014).

Systems that intercrop maize with a legume are able to reduce the amount of nutrients taken from the soil as compared to a maize mono crop. When nitrogen fertilizer is added to the field, intercropped legumes use the inorganic nitrogen instead of fixing nitrogen from the air and thus compete with maize for nitrogen. However, when nitrogen fertilizer is not applied, intercropped legumes will fix most of their nitrogen from the atmosphere and not compete with maize for nitrogen resources (Adu-Gyamfi *et al*., 1976).

Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Species or cultivar selections, seeding ratios, and competition capability within mixtures may affect the growth of the species used in intercropping systems in rain-fed areas (Banik *et al*., 2006; Dhima *et al*., 2007).

The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture (Mucheru *et al*., 2010). Yield advantage occurs because growth resources such as light, water, and nutrients are more completely absorbed and converted to crop biomass by the intercrop over time and space as a result of differences in competitive ability for growth resources between the component crops, which exploit the variation of the mixed crops in characteristics such as rates of canopy development, final canopy size (width and height), photosynthetic adaptation of canopies to irradiance conditions, and rooting depth. Many studies have shown a positive correlation of crop production to the amount of radiant energy intercepted by the crop (Tsubo *et al*., 2001). Intercropping has greater radiation capture potential and utilization Compared with sole cropping, because of the effect of combination of differing spatio-temporal use of radiation among component crops (Willey, 1990).

The release of biological nitrogen fixed by the legume for utilization by the cereal depends on the sowing and maturity date of the legume species. Canopy structures and rooting systems of cereal crops are generally different from those of legume crops. In most cereal– legume intercropping, cereal crops form higher canopy structures than legume crops, and the roots of cereal crops grow to a greater depth than those of legume crops. This suggests that the component crops probably have differing spatial and temporal use of environmental resources. Intercrops may make use of environmental resources such as radiation, water and nutrients more efficiently than mono crops (Willey, 1990).

When crops are complimentary in terms of growth pattern, aboveground canopy, routing system, and their water and nutrient demand, intercropping effectively enables a more efficient utilization of available resources (sunlight, moisture and soil nutrients), and can result in relatively higher yields than when crops are grown separately, as pure stands (Willey, 1979). Other benefits of intercropping are related to the better soil cover, which has advantages for weed control, and leads to reduced erosion and nutrient leaching. Because legumes can rely on atmospheric N, they are less likely to compete for N with the cereal (Fan *et al*., 2006).

Bean plant density had no influence on maize or bean yields, indicating that maize yield is not affected by bean intercropping (Tsubo *et al*., 2005). Consequently, intercropping is much less risky than mono cropping considering that if one crop of a mixture fails, the component crop(s) may still be harvested. Thus, if a single crop may often fail because of adverse conditions such as frost, drought, flood, or even pest attack, farmers reduce their risk for total crop failure by growing more than one crop in their field (Clawson, 1985).

Tesfa *et al*. (2011) found that, two released common bean varieties namely Nasir and Dimtu were confirmed to be best compatible released varieties in a maize intercropping system in the Jimma areas because of they gave high productivity in the area. They also said that, this study indicates the importance of looking for some other common bean varieties that will have better yield performance and social preferences than current local varieties in maize intercropping systems of Jimma areas.

2.6. Intercropping for Greater Production and Risk Avoidance

There are two ways of increasing crop production: the first one is through putting more land to agricultural production and the second is through increasing productivity per unit of land. The former option is finite in scope and can go only to a limited extent. The latter alternative on the other hand has more possibilities that require the generation and application of technologies especially suited to the environment and situation of the farmer (Woldeyesus *et al*., 1996). 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, 1978).

Multiple cropping system reflect farmers multiple objectives, including principal of all their need to survive. The main advantage of intercropping systems is efficient and complete use of growth resources such as solar energy, soil nutrients and water (Francis, 1978; Siva and M., 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); inexpensive weed control (Enyi, 1973); minimization and avoidance of agricultural risks (Willem, 1990; Jodha, 1981; Rao and Willey, 1980); improvements of soil fertility (Bandyopadhay and De, 1986); minimization of peak of labor and demand (Okigbo and Greenland, 1976).

The main reason for using a multiple cropping system is the fact that it involves integrating crops using space and labor more efficiently (Baldy and Stigter, 1997). Biophysical reasons for using multiple cropping include better utilization of environmental factors, greater yield stability in variable environments and soil conservation practices. Socio-economic reasons include the magnitude of inputs and out puts and their contribution to the stabilization of household food supply (Beets, 1982). Thus, there is recognition of the great potential of intercropping to increase agricultural productivity and conserve natural resource base. Intercropping presents a large level of risk reduction for the smallholder. If one crop is entirely lost to pest or drought damage, the farmer may still harvest the other crop in the field. Given the unpredictable rainy season and the different water requirements of each crop, planting many varieties of the same crop in an intercropped field gives the farmer a better chance that some crops will survive (Carlson, 2008).

2.7. Resource Use in Intercropping System

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 so make better overall use of resources than when grown separately (Willey, 1979a). In terms of competition, the component crops are not competing for exactly the same overall resources and thus inter-crop competition is less than intra-crop competition. Maximizing intercropping advantages is therefore a matter of maximizing the degree of complementarity between the components and minimizing inter-crop competition (Rezende and Ramalho, 1994). On this basis, intercropping advantages are more likely to occur where the component crops are very different. Probably the main way that complementarity can occur is when the growth patterns of the component crop differ in time so that the crops make their major demands on resources at different times. This type of complementarity has been termed by (Trenbath, 1974) as temporal.

2.8. Effects of Intercropping on Maize and Common Bean

The experiment done by Makgoga (2013) showed that shelling percentage and harvest index were not affected by cropping system for both sole maize and maize/dry bean intercropping. When maize was intercropped with dry bean followed by sole maize, maize obtained highest number of cobs per plant. Number of seeds per cob, 100 seed mass, plant height and grain yield were not significantly different between sole maize and maize/dry bean intercropping. The highest number of cobs per plant was obtained in maize/dry bean intercropping followed by sole maize. Plant height and 100 seeds mass in maize/dry bean intercropping were higher, 2.0 m and 30.8 g, respectively, followed by sole maize 1.9 m and 30.4 g. Maize/dry bean intercropping and sole maize produced high grain yield of 2156.3 kg/ha and 2093.7 kg/ha, respectively (Makgoga, 2013). Increased number of cobs per plant and grains per cobs due to maize legume intercropping, however, 1000 grain weight of maize was not significantly influenced but there was an increasing trend (Patra *et al*., 1999).

2.9. Plant Density in Intercropping System

Plant population defines the number of plants per unit area, which determine the size of the area available to the individual plant (Willey, 1979a). The intercropping population and the relative proportion of individual combined crops are very important in determining yields and production efficiencies of cereal-legume mixture (Zardari *et al.*, 2013). When the components are present in approximately equal numbers, productivity and efficiency appears to be determined by the more aggressive crop, usually the cereal (Osiru and Willey, 1972; Zardari *et al.*, 2013). They had pointed out from these data that all the component crops become relatively more competitive if they formed a larger proportion of the total population; they also stressed that as total population increased, the dominant crop become even more dominant.

2.9.1. Effect Plant Density on Growth of Maize and Common Bean

Different seeding ratios or planting patterns for cereal-legume intercropping have been practiced by many researchers (Tsubo *et al*., 2001). Competition among mixtures is thought to be the major aspect affecting yield as compared with solitary cropping of cereals. Seeding ratios and competition capability within mixtures may affect the growth of the species used in intercropping systems in rain-fed areas (Carr *et al*., 2004; Agegnehu *et al*., 2006; Banik *et al*., 2006; Dhima *et al*., 2007). Bean plant density had no influence on maize or bean yields, indicating that maize yield is not affected by bean intercropping, although bean yields will decrease in the intercropped system (Tsubo *et al*., 2005). High densities of maize maximized maize yield and calorie production, but high densities of beans maximized financial return.

Plant density determines the degree of competition among plants (Ipsilandis and Vafias, 2005; Kgasago *et al*., 2006). At low densities, grain yield is limited by number of plants, whilst at higher densities decrease due to competition (Fasoula and Tollenaar, 2005). Tsubo *et al*. (2003) have presented the yield and growth advantages of maize- bean intercropping in the study region, which is in basic agreement with previous studies in the other African regions. Concerning resource use, both RUE (radiation use efficiency) and WUE (water use efficiency) of maize-bean intercropping are equivalent to or higher than maize sole cropping, and they are higher in RUE and WUE than bean sole cropping. From those results, it follows that when farmers plan on cultivating both crops, planting maize associated with beans is more advantages than sole cropping. Plant density affects crop productivity and resource use of the intercropping (Tsubo *et al*., 2003).

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Productivity of a cropping system comprising intercrops of two or more species depends upon the degree of complementarities between them. Enhancing productivity of maize and bean intercrops requires improving the interspecies complementarities or reducing competition effects (Rezende and Ramalho, 1994). This might be achieved through manipulation of plant arrangements, plant densities and planting compatible cultivars (Rao and Mittra, 1990). Ofori and Stem (1987) proposed that the growth and yield of the legume component is reduced markedly when intercropped with high densities of the cereal component. In a maize/bean intercrop system, increasing maize density three-fold, from 18, 000 to 55, 000 plants/ha, reduced bean leaf area by 24% and seed yield by 70% (Gardiner and Craker, 1981). Spatial arrangement of component crops is one of the most important agronomic factors that determine whether an intercrop system will be advantageous or not with regard to yield gains (Natarajan and Shumba, 1980). Row arrangements, in contrast to arrangements of component crops within rows, improve the amount of light transmitted to the lower legume. Such arrangements can enhance legume yields and efficiency in cereal/legume intercrop systems (Mohta and De, 1980).

Productivity of the intercrop can be enhanced through selection of bean cultivars suitable for intercropping as they have different growth habits and growth durations, which may result in different interactions with maize in the intercrop maize cultivars with short internodes and broad leaves shade beans relatively more than cultivars of a similar height with long internodes and narrow leaves. Tall cultivars generally give more shedding to under store crops (Davis and Garcia, 1983). Plant population is the important factor in intercropping of legume-maize as it can determine the extent of competition between intercrops (Kgasago, 2006). Factors such as moisture availability, soil fertility status and cultivars to be planted determine the plant population to be planted in the specific area (Molatudi and Mariga, 2012). Optimum seeding rate results in high solar radiation interception (Jensen, 1996), and increases the rate of photosynthesis and biological nitrogen fixation in the cereal/legume intercropping system (Thobatsi, 2009).

Farmers' practice showed higher maize grain yield and lower common bean yield followed by the treatment with 100% maize and 50% common bean population densities while intercropping of 100% maize and 100% common bean population densities yielded relatively lower maize grain and higher haricot bean seed (Dagne *et al*., 2011).

Maize grain yield rises with planting density to some maximum value and then declines. The rate that produces a maximum yield varies with varieties, environment, fertility and planting pattern. For a given hybrid, the yield of maize generally increases as density is raised until one or more factors such as water supply, available plant nutrients and other become limiting

(Vega *et al*., 2001). They also found out that, maize grain yield is more affected by variations in plant density than other members of the grass family due to its low tillering capacity. Vega *et al*. (2000) found the direct effect of increasing plant density to enhance interplant variability in several phenotypic traits (e.g. biomass, height, anthesis-silking interval, and kernel number). Sangoi *et al*. (2002) supported the results of Vega *et al*. (2000), that maize grain yield is associated with the number of kernels per area, which depend on the number of plants per area, number of ears per plant and the number of kernels per ear. Tetio-Kagho and Gardner (1988) and Tollenaar *et al*. (1992), found grain yield response to plant density to be mostly associated with number and size of kernels per unit area. Otegui (1995) found a close relationship between grain yield and kernel number for several hybrids grown under different environmental and management conditions.

2.10. System Productivity and Profitability of Intercropping Systems

Land equivalent ration (LER) is the most commonly used type of cropping index. Its inherent use is that different crops whatever their type or levels of yield, are put on a relative and directly comparable basis. To avoid bias because of differences in yield proportions, it can be calculated based on monetary values (Willey, 1979).

$$\textbf{LER} = La + Lb = \frac{Ya}{Sa} + \frac{Yb}{Sb},$$

Where, La and Lb = the LERs for individual crops in the mixture and Ya and Yb = the individual crop yields in an intercropping situations, Sa and Sb= the yield of species a and b as sole crops. For the purpose of comparing genotypes combination, it may be sensible to use the same standardizing factors for each combination, which leads to Sa and Sb being defined as the maximum or the average sole crop yields. But, each intercrop compared with its respective sole crop only at its optimum populations and spacing (Mead and Willey, 1980). While monetary advantage (MA) was calculated as yield of combined intercrop (Willey, 1979) using formula:

$$\text{yield} * \frac{(LER - 1)}{LER},$$

Tamado and Eshetu (2000) conducted field experiments at Alemaya and Babile in 1996 and 1997 to evaluate the agronomic performance and productivity of sorghum, maize, and common bean grown in row intercropping, mix cropping and sole cropping. Sorghum and common bean row intercropping gave the highest agronomic advantage (43%) at Babile and 40% at Alemaya over sole cropping of the component crops as shown by their LER values. However, sole maize gave the highest gross monetary value at Alemaya (8054 ETB/ha). Tesfa *et al*. (2002) affirmed that, in Ethiopia, LER was usually selected as a criterion to assess the agronomic advantage of intercropping systems as it already mentioned by other authors elsewhere (Willey, 1979; Mead and Willey, 1980).

3. MATERIALS AND METHODS

3.1. Description of the Experimental site

The field experiment was conducted under irrigated conditions at Jimma Agricultural Research Center (Melko) in 2013/14. The center is located at about 348 km south west of Addis Ababa, Ethiopia. The site is located at $7^0$40' latitude and 36^0 longitudes at an elevation of 1753 m.a.sl. It is situated in the tepid to cool humid-mid highlands agro-ecology of south-western Ethiopia. The soil type of the experimental area is Eutric Nitsols (Reddish brown) with a pH of around 5.2.The long-term (ten years) mean annual rainfall of the area is 1639 mm with a maximum and minimum temperature of 26.6^0C and 13.9^0C, respectively (JARC, 2008)

3.2. Description of the Experimental Materials

The below table contains maize and common bean varieties with their description used for the study

Table 1.Maize and common bean varieties used for the study

Name	Year of release	Maturity (days)	Adaptation(m asl)	Yield kg/ha	Growth type
BHQPY-545 (maize variety)	2008	120- 145	1000-1800	8000-9500	medium
Nassir(common bean)	2003	90-120	1200-1800	3000-4000	Bush
Local Asendabo (common bean)	-	-	-	-	Climbing

(MOARD, 2009; Progress Reports of the National Maize Research Project, 1988–2010).

3.3. Treatments and Experimental Design

The treatments included six component densities (100% * 17.7%, 100% * 26.7%, 100% * 53.3%, 75% * 17.7%, 75% * 26.7%, 75% * 53.3%) of hybrid maize and common bean, and two common bean varieties (Nasir and Local Asendabo) accompanied with sole Maize and sole common bean varieties. The experiment was laid out in a factorial experiment arranged in Randomized Complete Block Design (RCBD) with three replications.

Treatments

1. Sole common bean (Nasir)
2. Sole common bean (Local)
3. Sole maize
4. Maize (100%) + Common bean (17.7%) (Nasir)
5. Maize (100%) + Common bean (17.7%) (Local)
6. Maize (100%) + Common bean (26.7%) (Nasir)
7. Maize (100%) + Common bean (26.7%) (Local)
8. Maize (100%) + Common bean (53.3%) (Nasir)
9. Maize (100%) + Common bean (53.3%) (Local)
10. Maize (75%) + Common bean (17.7%) (Nasir)
11. Maize (75%) + Common bean (17.7%) (Local)
12. Maize (75%) + Common bean (26.7%) (Nasir)
13. Maize (75%) + Common bean (26.7%) (Local)
14. Maize (75%) + Common bean (53.3%) (Nasir)
15. Maize (75%) + Common bean (53.3%) (Local)

Experimental treatments detail

a. Intercropping proportion 2:1 two rows of maize and one row of common bean, respectively.

b. Maize planting pattern (spacing)

Sole maize = 75 cm x 30 cm = 44,444 plants/ha

Maize intercropped = 75 cm x 30 cm = 44,444 plants/ha (100%)

Maize intercropped= 75 cm x 40 cm = 33,333 plants/ha (75%)

c. Common bean planting pattern (spacing)

Sole common bean = 40 cm x 10 cm = 250, 000 plants/ha

Common bean intercropped = 150 cm x 15 cm = 44,444 plants/ha (17.7%)

Common bean inter cropped = 150 cm x 10 cm = 66,666 plants/ha (26.7%)

Common bean intercropped = 150 cm x 5 cm = 133,333 plants/ha (53.3%)

3.4. Experimental Procedures and Crop Management

Site selection and land preparation was done in mid-December 2013, ploughed with a tractor and hand leveled before planting. Each common bean variety was intercropped with hybrid maize. Respective sole plots of the common bean varieties and the maize were included for the study. The maize variety was sown at the (15/1/2014) by row planting and was covered by hand on the net plot size of 2.4 x 4.5 = (10.8m^2) and gross plot size of 3.6 m x 7.5 m = (27 m^2) at 75 cm inter-row by 30 cm and 40 cm intra-row spacing of maize. And also the sole maize plots were hand sown with two seeds/ hill with spacing of 75/30 cm. Number of rows/plot was 10 for maize. In dry months, the plots were irrigated using furrow irrigation. The outermost rows at both sides of plots were considered as borders. A 1.5 m wide-open strip separated the blocks; whereas the plots within a block were 1 m apart from each other. In accordance with specifications of the design, each treatment was assigned randomly to experimental units within a block. At time of maize sowing, all plots received a basal application of ammonium phosphate (DAP, 18% N, 20% P) at the rate of 100 kg/ha. The intercropped maize stand was thinned to a population of 33,333 and 44,444 plants/ha with respect to its plant spacing within row spacing; and hoeing were taken place a week after emergence. And the sole maize was thinned to a density of 44,444 plants/ ha a week after emergence. The two common bean varieties (Nasir and local) were hand sown (06/02/2014) with two seeds per hill on plots assigned for intercropping and sole common bean plots. This was done two weeks after maize emergence during second hoeing. The intercropped common bean varieties were drilled in between each two maize rows at 150 cm inter-row; and with intra-row spacing of 5 cm; 10 cm; 15 cm. The bean stand was then thinned to a population of 133,333; 66,666 and 44,444 plants/ ha a week after emergence, respectively. The sole common bean was sown with spacing of 40/10 cm and the stand was thinned to a density of 250,000 plants/ ha a week after emergence. The recommended phosphorous fertilizers were applied in the form of DAP at rate of 46 kg P_2O_5 ha^{-1} at planting for sole common bean plot. At knee height growth stage of maize, N in the form of urea (46% N) was applied at the rate of 50 kg ha^{-1}. After the crops attained full maturity stage, common bean and maize harvesting was done on 15/06/2014 and 16/06/2014 by hand at the grain moisture content of 12.5.

3.5. Data Collection

3.5.1. Soil Analysis

Soil samples were collected at random from the three replications separately within the experimental area after final ploughing at 0-30 cm depth before planting. These samples were then composited and two duplicate samples per three collected soil samples were prepared for determination of pH, organic matter, organic carbon (OC), total nitrogen, total phosphorus and available phosphorus. The soil samples were cleaned from root and other dusts, air dried thoroughly, mixed and ground to pass a 2 mm size sieve before laboratory analysis. Finally, the soil samples were analyzed in Jimma Agricultural Research Center soil laboratory. For total N content micro-kjeldahl method (Dewis and Freitas, 1970), pH by using pH meter, OM percentage by multiplying the organic carbon (obtained by wet digestion method) with a factor of 1.724, as the procedures described by (Ryan *et al*., 2001). Moreover, available P was determined using Olsen procedure as described by (Olsen *et al*., 1954)

3.5.2. Response of Maize

Growth phenology, yield and yield components of maize were recorded as described below.

Growth Phenology

Data on 50% tasseling: - were recorded when more than 50% of the plants produced tassels by counting plants in each plot.

Data on 50% silking: - were recorded when more than 50% of the plants produced silks by counting plants those bears silks in each plot.

Data on 50% maturity: Days to 50 percent maturity were recorded as the number of days from emergence to the date on which about 50 percent of the plants in a plot matured from five randomly selected plants.

Growth Parameters

Plant height (cm): - was recorded at 50% maturity from five plants randomly selected in each plot, by measuring their height from the soil surface to the tip of the terminal stem with a meter.

Leaf area (cm^2): - was determined from the same five plants used for plant height per plot randomly as leaf length (L) x maximum leaf width (W) x 0.733 as described by McKee (1964)

Leaf area index (cm^2): - LAI were calculated as the ratio of total leaf area (cm^2) of the plant to the ground area coverage of maize.

Yield and Yield Components included

Number of cobs per plant: was counted from five randomly sampled plants per plot at the end of harvest in each plot.

Numbers of kernels per cob: was taken from the same five randomly selected plants and from that, five cobs selected at the end of harvest in each plot and each of cobs kernels threshed and counted by seed counter.

Cob length (cm): was measured as the length of the cob from the tip to the bottom from the same five randomly selected cobs at the end of harvest in each plot.

Cob weight (g): The same five randomly selected cobs for cob length at the end of harvest was measured by sensitive balance in each plot

1000 Seed weight/kernel weight (TKW): The seeds were threshed from the middle of the cob and counted using electronic seed counter from each plot and measured by sensitive balance at 12.5% moisture content.

Shoot Dry biomass yield (kg/ha): Dry biomass representing oven dry weight of shoots excluding grain were measured by sensitive balance by drying the above ground parts of five randomly sampled plants in forced air circulated hot air oven at 60^0C for a minimum of 48 hours.

Total biological yield: Above ground biomass (kg) was collected and measured at harvest after sun drying from harvestable row and expressed as kg/ha.

Grain Yield (kg/ha): Grain yield were measured from the net plot area and expressed as kg/ha. Grain yield was adjusted to 12.5% moisture content using a digital moisture tester.

Harvest index (%): was calculated as the ratio of economic yield (grain yield) of harvestable row to biological yield of harvestable row multiplied by 100.

3.5.3. Response of Common Bean

Data on phenology, growth parameters and yields of common bean varieties were measured as described below.

Growth phenology:

Data on 50% crop emergence: - were counted from the date of sowing till when 50% seedling was emerged or two leafs were observed in each plot.

Data on 50% flowering: - were recorded when more than 50% of the plants produced flower in each plot by visual observation.

Data on 50% maturity: - were recorded from five randomly taken plants as the number of days from emergence to the date on which about 50 percent of the plants in a plot matured.

Growth Parameters

Plant height (cm): Plant height was recorded as the height of plant grown from the ground level from five randomly sampled plants at the end of 50% flowering in each plot.

Leaf number: leaf number was randomly taken from the same five plants used for plant height at the end of 50% flowering in each plot and the number of leaf was counted.

Leaf area: -were measured from the same five plants already earmarked for recording plant height using leaf area meter at the end of 50% flowering stage by distractive approach.

Leaf area index: - Were determined by measuring five plants canopy in each plot and dividing leaf area by their canopy.

Number of nodules per plant: - were determined at 50% flowering from the same five plants by uprooting the plants carefully and counting their nodules.

Number of branches per plant: was measured from five plants already earmarked for recording plant height at end of 50% mature in each plot.

Yield and Yield Components

Number of pod bearing branches per plant: - was taken from five randomly selected pod bearing plants at the end of harvest in each plot.

Number of pods per plant: - Number of pods was counted from the same five randomly selected plants at the end of harvest in each plot.

Number of seeds per pod: - Was taken from the same five randomly selected pods at the end of harvest and each of seeds were counted manually in each plot.

Pod length: - Was measured from the tip to the bottom of the pod from five pods randomly selected from five plants for number of seeds at the end of harvest in each plot.

100 Seed weight: Was taken from randomly selected 100 beans in each plot after adjusting the moisture content to 12% at the end of harvest.

Total Biological yield: The above ground biomass was collected and measured from the net plot area including grain yield and expressed as kg/ha.

Above ground biomass (kg) was collected and measured at harvest after sun drying from harvestable row and expressed as kg/ha.

Grain Yield (kg/ha): Bean yields were measured from the net plot area and expressed as kg/ha. Bean yield was adjusted to 12% moisture using a digital moisture tester.

Harvest index: - Was calculated as the ratio of economic yield (grain yield) of harvestable row to biological yield of harvestable row multiplied by 100.

3.5.4. Land Productivity and Economic Benefits

Productivity of the intercropping system was determined by calculating the land equivalent ratio (LER) as per (Willey 1991).

$$\textbf{LER} = La + Lb = \frac{Ya}{Sa} + \frac{Yb}{Sb},$$

Where, La and Lb = the LERs for maize and common bean crops in the mixture respectively; and Ya and Yb = the maize and common bean crop yields in an intercropping situations, Sa and Sb= the yield of maize and common bean in sole crops.

Economical advantage was assessed using gross monetary values (GMV) to evaluate the economic advantage of intercropping as compared to sole cropping (Willey, 1979). For this, the existing local market prices were 5, 7 and 8 ETB per kilogram for maize grain, Nasir and Local Asendabo bean at Jimma market at the end of May 2014.

$$\text{Gross Monitory Value (GMV)} = \text{Value of combined intercrop yield} \times \text{LER} - \frac{1}{\text{LER}}$$

3.6. Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using (Gen Stat version 13). Significance differences between treatment means were delineated using Least Significance Difference (LSD) test at 5% probability level.

4. RESULTS AND DISCUSSION

4.1. Soil Analysis

Analytical results of the composite surface soil indicated that the soil was acidic in reaction with a pH of 5.1(Table 2); It was within the suitable range for maize production as normal soil pH for maize is 5-8, with a pH of 6-7 probably being an optimal for most varieties (Martin, 1993).

As the result on table 3 indicated the low amount of organic matter in the soil and Nitrogen might be related to environmental conditions, particularly to vegetation, climate and to the history of cultivation. Practicing sequential cropping, competitive crop those highly absorb Nitrogen fertilizer in the soil, erosion and total removal of the crop residue might have contributed to the low level of organic matter and total nitrogen (Willet, 1994).

The available phosphorus of the experimental soil 0.26 ppm was low revealing that the amount of plant nutrient in the soil was deficient. According to (Foster, 1973), P response is likely in soils with less than 20 mg/kg soil of soil extractable P. (Amar, 1999) also reported that the values of available P lower than 50-55 mg/kg soil likely showed the potential yield response to P applications.

Table 2. Major characteristics of the soil of study site before planting

Soil Parameters	**Values**
Total Nitrogen (%)	1.74
pH (H_2O, KCl)	5.10
Organic carbon (%)	2.22
Organic matter (%)	3.83
Available phosphorus (ppm Bray II)	0.26
Available potassium (meq K/100g)	2.11

4.2. Response of Maize

4.2.1 Phenology and Growth Response

The analysis of variance showed that days to 50% tasseling, days to 50% silking and days to 50% maturity were not significantly (Appendix Table1) influenced by the main effect of common bean variety. Likewise, the component density and the cropping system effects were observed to be non-considerable for all phenological parameters of maize in the study. It might be from the environmental factors that did not cause influence on phenology of maize; because the experimental location of the plant was the same for all and it did not cause variation on maize phenology. Similar to this finding, Demessew (2002); Yesuf (2003) and Dechasa (2005) reported that days to 50% emergence and maturity of maize/common bean and sorghum/common bean are not affected by component planting density.

The number of days required for 50% tasseling and silking was relatively the same for all treatments and it took around 76 and 81 days, respectively in all plots (Table 3). These might be from rain fall received in the March (397.9 mm) by the crop during tussling and silking (Appendix Table 6).

The main effect of common bean varieties, component planting density as well as cropping system had no significant effect on the days to 50% physiological maturity of maize (Appendix Table1). The mean number of days required from planting to maturity was (121) days for both sole and intercropped maize (Table 3). Since maize as a main crop was not influenced by significance different on maize maturity time, indicating the more effect of genetic factors, because the variety of maize did not showed difference as it is only the same variety for all treatments. The result agreed with the findings of Demessew (2002); Yesuf, (2003); Sisay (2004) whose described that non-significant effect of cropping system was reported on physiological maturity of maize. Similarly, Wahan (1983) in Abraha (2013) mentioned that maize mono crop has growth period of 120 days and was not significantly different from maize intercropped with cowpea cultivars Glenda and Agrinaw which took 120 and 121 days to maturity.

Table 3. The main effects of common bean variety and component density on phenology and plant height of hybrid maize intercrop and sole crop at Jimma

Treatment	Days to 50%			
	Tasseling	Silking	Maturity	Plant height (cm)
M+N	75.89	81.17	120.78	237.12
M+L	75.78	81.06	120.61	238.10
SEM (±)	0.28	0.22	0.21	1.55
LSD ($_{0.05}$)	NS	NS	NS	NS
Maize and Common bean Component density				
M+C (100% *17.7%)	75.33	80.68	120.2	236.5
M+C (100% * 26.7%)	75.33	80.83	120.5	234.3
M+C (100% * 53.3%)	75.67	81.02	120.5	237.0
M+C (75% * 17.7%)	76.00	81.18	120.7	239.4
M+C (75% * 26.7%)	76.00	81.18	120.5	241.2
M+C (75% * 53.3%)	76.67	81.83	121.8	237.3
SEM (±)	0.50	0.38	0.37	1.55
LSD ($_{0.05}$)	NS	NS	NS	NS
Cv (%)	1.6	1.2	0.7	5.45
Cropping pattern				
Inter cropped maize	75.84	81.12	120.71	236
Sole Maize	76.00	81.33	121	235.7
SEM (±)	0.37	0.85	0.66	2.13
LSD ($_{0.05}$)	NS	NS	NS	NS
CV (%)	1.6	1.1	0.8	4.3

LSD=Least Significant Difference, CV=Coefficient of Variation, SEM = Standard Error of Mean, M = maize, N = Nasir, C= common bean, M + N =Maize + Nasir, M + L=Maize + Local Asendabo.

4.2.2 Growth Response

Plant height: The main effects of variety, component population density and interaction of common bean varieties and component densities of both maize and common bean had shown non-significant influence on maize plant height (Appendix Table 1). The maximum plant height 241.2 cm was recorded by 75% maize population density intercropped with 26.7% common bean population density. In contrast, the minimum plant height 234.3 cm was recorded from 100% maize intercropped with 26.7% common bean population densities (Table 3).

Also cropping system did not show significance difference with nearly equal responses in plant height between intercropped and sole plots. This might be due to efficient resource use ability of maize plant and relatively many genes that can control plant height to express across environment may be highly stable. However, plant height of maize obtained from an intercropping with local bean was greater than that of an intercropping with Nasir common bean. In accordance with the present finding, Dechasa (2005) on sorghum/bean, Sisay (2004) on sorghum/green gram, and Demesew (2002) on maize/common bean, reported that planting density had no significant effect on plant height of sorghum and maize. In another intercropping study, Wogayehu (2005) found that maize plant height was not significantly affected by the associated haricot bean varieties. Similarly, Belay *et al*. (2008) reported that no significant difference was observed between treatments in terms of plant height and diameter of maize in maize common bean intercropping. Thobatsi (2009) and Makgoga (2013) also found that intercropping of maize with grain legumes had no significant differences in maize plant height.

Leaf area: Results showed that total leaf area of maize was significantly ($P < 0.01$) affected by the main effect of common bean variety, component density and interaction of common bean variety and component density of the common bean and maize; however cropping system showed non-significant variation (Appendix Table 1). The highest leaf area (546.8 cm^2) was recorded by the interaction effect of 75% population density of maize and 17.7% local bean population density. In contrast, the lowest (444.8 cm^2) was recorded by the interaction effect of 100% population density of maize and 53.3% local common bean variety population density (Table 4). The reduction in leaf area of maize could be due to the enhanced local bean plant height and reduce leaf growth of maize with increased population density of bean from low light interception during the latter growth stages. Moreover, the time at which local common bean growth and cover the maize was the critical period at which light must be harvested by crops and greater assimilate must be supplied by the leaf in order to increase yield. In another study, Tsubo *et al*. (2003) on maize/bean intercropping reported that the photosynthetic organ (leaves) of maize becomes thinner and reduced its area due to shading effect of common bean.

Leaf area index: As indicated in (Appendix Table 1), leaf area index was significantly ($P<0.05$) affected by the interaction effect of component population density and common bean variety. The maximum leaf area index of maize 4.06 was recorded by 100% maize population density in combination with 53.3% Nasir population density. In contrast, the minimum (1.70) was recorded when 100% maize population density mixed with 53.3% local common bean variety population density (Table 5). However non-significant variation was recorded between cropping system, the results depicted that intercropped maize has lower LAI than sole maize (Table 5). The decrease in LAI in the intercropped maize could be most likely due to inter specific competitions among the higher population of the component crops for growth resources. Also the nature of local variety to climb nearby crop and canopy structures due to its larger leaf might be decrease the other crops LAI. Similarly, Pal (2004) reported that optimum LAI in crop communities is attained with adjustment of plant density and leaf area per plant. And the leaf area index per plant remained constant or unaffected until plant stand is increased above the density at which neighboring plants begin to compete for the resources. Sivaraman and Palaniappan (1995); Demesew (2002); Tolera (2005) in maize bean intercropping reported that intercropping significantly reduced leaf area index of maize at higher population of component crops. Yesuf (2003) reported that the LAI of sorghum was significantly affected due to the main effect of population density. On the contrary, Tamado (1994); Sisay (2004) reported that planting pattern and plant density or their interaction on leaf area indices of sorghum was not statistically significant. In growing canopies, foliar traits (such as leaf area index and leaf mass per unit area) are the important factors in leaf light harvesting capacity and photosynthetic potentials Niinemets and Sack (2006).

Table 4. Interaction effect of common bean variety and component density of maize and common bean on leaf area (cm^2) of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	462.2^{f}	496^{de}	511.0^{c}
Maize 100% + Nasir	508.1^{c}	530.1^{b}	488.6^{e}
Maize 75% + Local	546.8^{a}	496.0^{de}	471.1^{f}
Maize 100%+ Local	508.1^{c}	505.4^{cd}	444.8^{g}
SEM (±)	5.02		
LSD $_{(0.05)}$	10.41		
CV (%)	4.2		
Intercrop Vs Sole crop			
Inter crop	497.47		
Sole crop	504.40		
SEM (±)	3.45		
LSD $_{(0.05)}$	NS		
CV (%)	3.9		

Means followed by the same letter within a column are not significantly different from each Other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Table 5. Interaction effect of common bean variety and component density of maize and common bean on Leaf Area Index of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	3.48ab	3.48^{ab}	3.09^{ab}
Maize 100% + Nasir	3.23^{ab}	4.04^{a}	4.06^{a}
Maize 75% + Local	3.98^{a}	3.93^{ab}	3.07^{ab}
Maize 100%+ Local	4.00^{a}	3.47^{ab}	1.70^{b}
SEM (±)	0.95		
LSD $_{(0.05)}$	1.96		
CV (%)	21.6		
Intercropped vs sole cropped			
Inter crop	3.46		
Sole crop	3.78		
SEM (±)	0.61		
LSD $_{(0.05)}$	NS		
CV (%)	9.3		

Means followed by the same letter within a column are not significantly different from each Other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

4.2.3 Yield and Yield Components

4.2.3.1 Yield Components

Number of cobs per plant: The analysis of variance (Appendix Table 2) indicated that, however cropping system indicates non-significant effect, the main effect of variety, component population density and the interaction effect of them had highly significant effect ($P<0.01$) on number of cobs per plant. Accordingly, the highest cob number was recorded from 100% maize population density intercropped with 26.7% population density of Nasir common bean variety. The lowest cob number per plant was recorded from 100% maize population density intercropped with 53.3% Local bean population density (Table 6). The highest cob number might be from the low competition of crops caused from optimum combined population density of maize and common bean crops. Because high plant density reduces light interception per plant and it is likely that mutual shading affect source capacity to supply a second ear with photo assimilate. Thus, apical-ear yield seemed to be sink-limited, while source capacity seemed to limit the growth of the second ear. Edmeades *et al*. (2000) demonstrated that assimilates moved preferentially from a leaf to its nearest sink. This implies that leaves above and immediately below the primary ear supply most of assimilate for grain filling, while assimilates from the lower leaves are more likely to be translocate into the root and lower stem. The same result was obtained by Sarquis *et al*. (1998) found that plant density strongly influences the rate and duration of crop growth and ultimate fate of multiple ears. They found that a 30% reduction in light interception by the canopy during the crop cycle was enough to completely suppress the development of a second ear. Makgoga (2013) also found that number of cobs per plant significantly affected by cropping system and variety of both dry bean and lablab treatments. Maize had the highest number of cobs per plant (1.6) when intercropped with dry bean followed by optimum population. He also suggested that intercropping maize with dry bean benefitted the maize plants. Similarly, Rezaei-Chianeh *et al*. (2011) found that cob number was significantly influenced by maize and faba bean densities and their interaction.

Table 6. Interaction effect of common bean variety and component density of maize and common bean on Number of Cobs per plant of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	1.95[b]	1.45[f]	1.64[d]
Maize 100% + Nasir	1.42[f]	2.19[a]	1.72[c]
Maize 75% + Local	1.75[c]	1.13[g]	1.65[d]
Maize 100%+ Local	1.42[f]	1.56[e]	1.00[h]
SEM (±)	0.03		
LSD $_{(0.05)}$	0.05		
CV (%)	2.00		
Intercropped vs sole cropped			
Inter crop	1.57		
Sole crop	1.51		
SEM (±)	0.02		
LSD $_{(0.05)}$	NS		
CV (%)	5.90		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Number of seeds per cob: Results showed that number of kernels (seed) per cob was highly significantly affected by the main effects of variety and component population density and by the interaction effects of the main effects, but cropping system did not showed significant effect. The maximum number of kernel (557.3) per cob was recorded by 100% maize population density mixed with 26.7% Nasir variety population density and the minimum (190.8) seeds per cob was recorded by 100% maize population mixed with 53.3% Local common bean population density (Table 7). The maximum seed number might be also from the low competition of crops and the lowest caused from the high competition of crops for nutrient and moisture that leads to decrease in fertile plants to bear high seeds. Francis *et al*.

(1982) reported that, the kernels per cob differences in crop mixture are influenced by not only the presence of other crops, but also by densities and spatial arrangement of crops and levels of resource availability caused crop competition within the two crops. Buren *et al*. (1994) reported that the number of plants at low or high plant density becomes a limiting factor for the yield of maize crops. At low plant density the number of plants limit yield because of few cobs produced, whereas at high plant density yield is limited by the number of barren plants and a decrease in number of kernels per ear or both (Hashemi-Dezfouli and Herbert, 1992).

Table 7. Interaction effect of common bean variety and component density of maize and common bean on number of seeds per cob of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	471.1[c]	332.5[i]	549.4[b]
Maize 100% + Nasir	337.6[i]	557.3[a]	453.3[d]
Maize 75% + Local	414.7[e]	204.9[j]	407.3[f]
Maize 100%+ Local	356.1[h]	389.1[g]	190.8[k]
SEM (±)	0.03		
LSD $_{(0.05)}$	5.28		
CV (%)	2.10		
Intercropped vs Sole cropped			
Inter crop	388.68		
Sole crop	375.80		
SEM (±)	0.02		
LSD $_{(0.05)}$	NS		
CV (%)	5.89		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Cob length: As indicated in (Appendix Table 2) cob length of maize had statistically significance difference (P<0.01) due to the main effect of bean variety, component population density and interaction of both. The maximum number of cob length 21.73 cm was recorded by 100% maize plant population intercropped with 26.7 Nasir common bean plant populations. The minimum number of cob length was 10.72 cm, which were recorded by 100% maize plant population in combination with 53.3% local common bean plant population (Table 8). The maximum cob number per plant and the maximum seeds per cob observed in the same plot, leads to increase in the number of cob length. The lowest maize cob length might be, because of high population of Local common bean and due to vigorous nature of plant growth that leads to higher competition among crops to harvest light. Madonni *et al*. (1998) who reported that decreased incident solar radiation reduced both cob length and cob mass through reductions in biomass production.

However significant variation was not seen between cropping systems, the highest result of cob length was recorded by intercrop and the lowest were recorded by sole crop 17.78, 16.99, respectively (Table 8). Because intercropped maize get additional fertilizer from common bean legumes through biological nitrogen fixation with the use of legumes and increases soil conservation through ground coverage of intercropping. Similarly, Oljaca *et al*. (2000) found that the highest ear length of maize was obtained in intercrop than sole crop in both rain fed and irrigation.

Cob weight: The result revealed that cob weight was significantly (P<0.05) affected by the main effect of bean variety, component population density and their interaction (Appendix Table 2). Cropping system did not showed significance difference on cob weight. The maximum cob weight 0.69 kg was recorded by 100% maize plant population in combination with 26.7% Nasir common bean variety. The minimum cob weight 0.30 kg was recorded by 100% maize plant population intercropped with 53.3% Local common bean plant population. Increasing the number of kernels per cob and cob length by population densities of 100% maize intercropped with 26.7% Nasir common bean leads to increase in cob weight in the same variety and population of maize and common bean (Table 10). The decrease in the number of seeds per cob and cob length in 100% maize population intercropped with 53.3

common bean population leads to decrease in cob length in the same variety and population density of maize and common bean. In addition, the greater number of nodules by Nasir Variety might cause the maize cob weights the highest. The competition might not be between the neighboring plants only. The cobs on the same plant might be compete with themselves, in order to complete their growth, a second ear must reach a minimum stage of growth before active grain filling begins in the first ear. In a similar case Sarquis *et al*. (1998) found that, at high plant density, the equilibrium between the two ears seemed to be affected due to a stronger competition between them as evidenced by a more severe decrease in grain mass. Many researchers have reported that the plant population and the arrangement of the plants have an effect on the number and mass of the ears produced (Hatfield *et al*., 1984).

Table 8. Interaction effect of common bean variety and component density of maize and common bean on Cob length of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	17.35^{e}	18.73^{d}	20.65^{b}
Maize 100% + Nasir	15.13^{g}	21.73^{a}	16.21^{f}
Maize 75% + Local	19.39^{cd}	16.17^{f}	19.07^{cd}
Maize 100%+ Local	18.63^{d}	19.63^{c}	10.72^{h}
SEM (±)	0.51		
LSD $_{(0.05)}$	0.86		
CV (%)	2.85		
Intercropped vs Sole cropped			
Inter crop	17.78		
Sole crop	16.99		
SEM (±)	0.62		
LSD $_{(0.05)}$	NS		
CV (%)	5.70		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Table 9. Interaction effect of common bean variety and component density of maize and common bean on Cob weight of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	0.59^{b}	0.50^{e}	0.56^{bcd}
Maize 100% + Nasir	0.52^{cde}	0.69^{a}	0.49^{e}
Maize 75% + Local	0.56^{bcd}	0.49^{e}	0.48^{e}
Maize 100%+ Local	0.57^{bc}	0.52^{de}	0.30^{f}
SEM (±)	0.02		
LSD $_{(0.05)}$	0.05		
CV (%)	5.50		
Intercropped vs Sole cropped			
Inter crop	0.52		
Sole crop	0.52		
SEM (±)	0.02		
LSD $_{(0.05)}$	NS		
CV (%)	5.30		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Shoot dry biomass: There was a significant (P<0.01) effect due to the main effect of common bean variety, component density and interaction of the main effects on dry biomass of maize (Appendix Table 2). The maximum (3149 kg/ha) dry biomass was recorded by the interaction effect of 100% maize population density intercropped with 26.6% Nasir common bean population density. The minimum (2134 kg/ha) was recorded by 100% maize population intercropped with 53.3% Local common bean population density (Table 10). The main reason for this could be increasing maize density with the corresponding increment of nitrogen fertilizer by nodulation that supports the vigorous vegetative growth of maize plants besides low population of Nasir that did not compute with maize for growth resources.

Moreover, dry biomass production per hectare also showed a significant difference ($P<0.05$) between cropping system. Mean intercropping maize had 2747.92 kg/ha maximum dry biomass and the minimum 2239kg were recorded by mean sole maize (Table 10). The main reason for this could be increment of nitrogen fertilizer by nodule of common bean supports the vigorous vegetative growth of maize plants. The vigorousity of above ground part of maize plants enables them to harvest ample solar radiation, which resulted in the increment of photosynthetic rate. This higher rate of photosynthetic rate also results in higher accumulation of dry matter. In agreement with the finding of Cochran and Schlentner (1995) who reported that intercropping oat and faba bean produced high dry biomass than sole crop. Similarly, Ofosu-Budu *et al*. (1995) revealed that sorghum dry weight under mixed cropping of sorghum + soya bean gave higher dry biomass yield. Biscoe and Gallagher (1977) also reported that the rate of dry matter production in crops depend on the efficiency of the interception of photo synthetically active radiation (PAR).

Table 10. Interaction effect of common bean variety and component density of maize and common bean on shoot dry biomass of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	2606[d]	2234[f]	2975[bc]
Maize 100% + Nasir	2926[c]	3149[a]	2582[d]
Maize 75% + Local	3133[a]	2463[e]	2613[d]
Maize 100%+ Local	3014[b]	3146[a]	2134[g]
SEM (±)	82.58		
LSD $_{(0.05)}$	142.90		
CV (%)	9.17		
Intercropped vs Sole cropped			
Inter crop	2747.9[a]		
Sole crop	2239[b]		
SEM (±)	446.70		
LSD $_{(0.05)}$	643.40		
CV (%)	14.50		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Thousand seed weight: As given in Appendix Table 2 the effects of intercropping on the thousand seed weight were significantly ($P<0.01$) different due to the main effects of varieties, component population densities and interaction effect. The maximum 1000- seed weight of 431.3 g was recorded by 75% maize population densities intercropped with 53.3% Nasir common bean population density. Whereas, the minimum 1000-seed weight 352.3 g was recorded by 75% maize population density intercropped with 26.7% Nasir common bean population density (Table 11). The increased number of Nasir population density might be increase the 1000- seed weight of maize and the lower number of Nasir common bean leads to decrease in 1000-seed weight of maize. Because as Nasir variety increase in population density, number of nodules fixed also increase; further the assimilate increase in maize and grain weight increased in a similar case.

Cropping system also showed significance ($P<0.05$) difference on thousand seed weight. Sole crop had the maximum 1000- seed weight than intercropped maize (Table 11). Because the intercropped was sown with the different component population density of maize and common bean; so the deceased in 1000- seed weight in intercropped might be from the competition of different population of the component crops. The present finding was the same with that of Abraha (2013), who reported that 1000- seed weight of sole maize as compare to intercrops, where the higher was recorded from mono crop. Similarly, Thobasti (2009) indicated highest 1000-seed weight was recorded by sole crop than maize intercropped with cow pea cultivar.

Table 11. Interaction effect of common bean variety and component density of maize and common bean on 1000 seed weight (gm.) of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	405.2^{cde}	352.3^{f}	431.3^{a}
Maize 100% + Nasir	407.8^{cde}	420.1^{ab}	398.3^{e}
Maize 75% + Local	412.3^{bcde}	399.3^{de}	414.0^{bcd}
Maize 100%+ Local	418.0^{abc}	414.3^{bc}	418.2^{abc}
SEM (±)	7.36		
LSD $_{(0.05)}$	15.25		
CV (%)	2.20		
Intercropped vs Sole cropped			
Inter crop	407.59^{b}		
Sole crop	430.90^{a}		
SEM (±)	5.12		
LSD $_{(0.05)}$	14.96		
CV (%)	4.20		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Total biomass yield: The main effect of variety, component planting density and their interaction had significant ($P<0.01$) effect on total biomass yield per hectare (Appendix Table 1). The maximum 11709 kg/ha total biomass was recorded when 100% maize population density intercropped with 53.3% Local common bean population density and the minimum 3418 kg/ha was recorded when 100% maize population density intercropped with 26.6% Nasir common bean population density. The maximum total biomass yield was recorded on the plot that gave the minimum grain yield and the minimum was recorded on the plot that gave maximum grain yield. The reason might be the absorbed nutrients by crop were transferred to grain yield and reduce the dry matter production. The result of this study, agree with the findings of Ludlow and Muchow (1988), described that assimilate remobilization tends to improve yield stability by acting as a buffer against the effects of water deficits on the current assimilation. They further stated that a higher transfer of assimilates to the grain would reduce the proportion of dry matter produced early in growth that may be left as a Stover.

Table 12. Interaction effect of common bean variety and component density of maize and common bean on Total Biomass of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	8048[cd]	8177[c]	7953[d]
Maize 100% + Nasir	6880 [g]	3418 [j]	4520 [i]
Maize 75% + Local	6240[h]	10196[b]	7992[cd]
Maize 100%+ Local	7159 [f]	7397[e]	11709[a]
SEM (±)	16.10		
LSD $_{(0.05)}$	33.40		
CV (%)	5.30		
Intercropped vs Sole cropped			
Inter crop	7474.08		
Sole crop	7515.36		
SEM (±)	1436		
LSD $_{(0.05)}$	Ns		
CV (%)	11.90		

Means followed by the same letter within a column are not significantly different from each Other at 5 % level of significance. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Grain yield: The result regarding grain yield showed that there were highly significant (P<0.01) differences in grain yield of maize due to the main effect of variety and component population density as well as interaction effect (Appendix Table 2). Among intercropping the maximum grain yield (7821 kg/ha) was recorded by the interaction of 100% maize population density intercropped with 26.7% Nasir common bean population density. The minimum grain yield (2290 kg/ha) was recorded by 100% maize population density intercropped with 53.3% local common bean population density (Figure 1). This showed that among population density of maize and common bean 100% maize population density and 26.7% Nasir common bean population density gave the maximum grain yield and the other yield components revealed the same result. This occurs because short season hybrids maize are normally smaller, produce less leaves, have lower leaf area per plant and present fewer self-shading problems than the long season hybrids maize. Therefore, for short season hybrids maize it is necessary to have a greater number of plants per area to generate the leaf area index that provides maximum interception of solar radiation, an essential step to maximize grain yield. This was as a result of population density was the optimum that do not allow competition among crop for nutrient and the wide row spacing with uneven density, which seems favorable for light interception in the middle and lower canopies; also the Nasir Variety which was intercropped with maize was not computed with maize for nutrient and light. Moreover it increases nitrogen fertilizer by nodules for maize. In agreement with this, Tesfa *et al*. (2002) found the highest grain yield, when the optimum total plant density was higher than that of either sole crop.

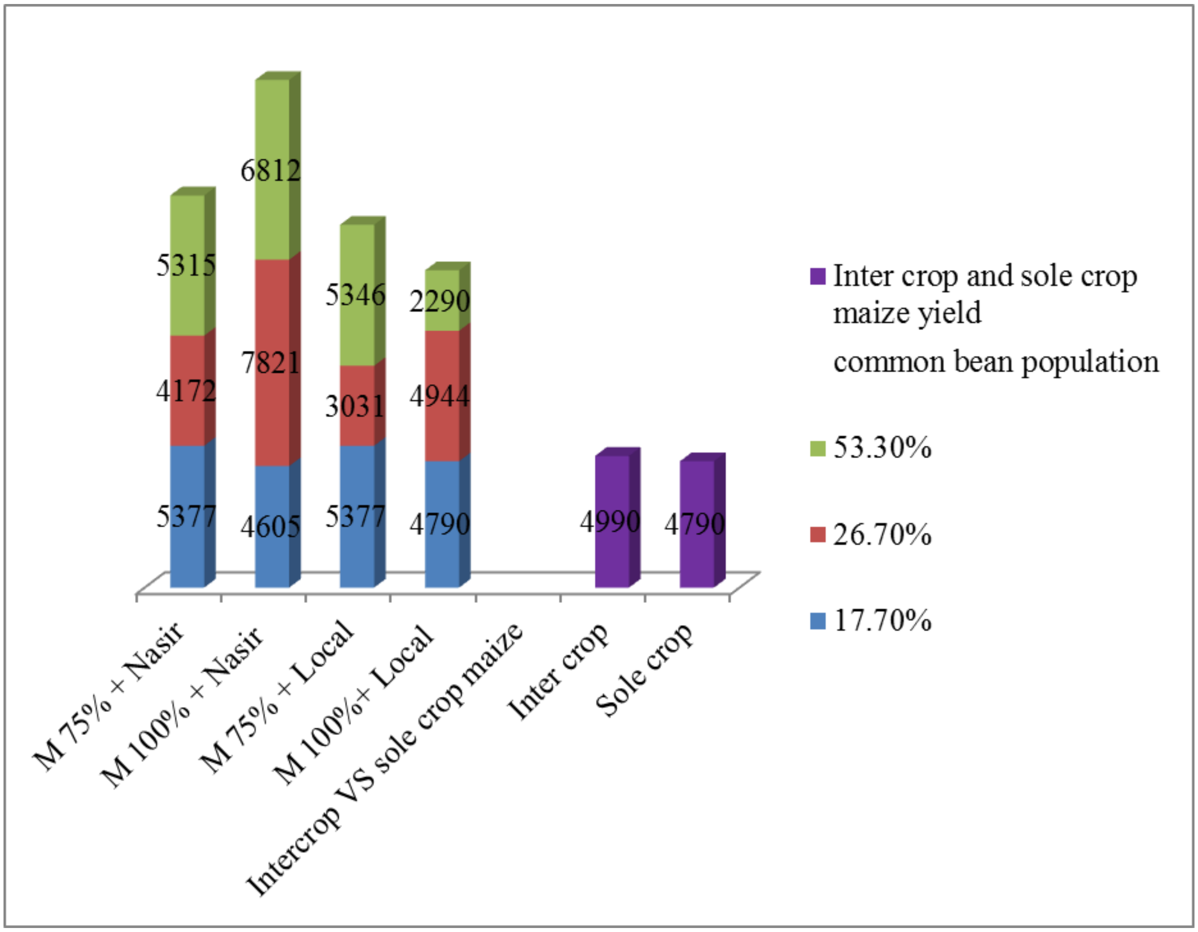
The significant variation ($P<0.05$) among cropping system indicated that, the maximum mean intercropping was 4990 kg/ha and sole crop was 4790 kg/ha (Figure1). This might be caused from Nitrogen fixed by common bean and the moisture that conserved in the soil by the canopy of the crops that helps to reduce evaporation was the main reason for the increment of grain yield of intercropped maize.

Also Odhiambo and Ariga (2001) reported that the association of common beans and maize significantly increased the seed yield of maize in Eastern Kenya. The synergistic effect of common bean towards improvement of yield has been linked to the symbiotic fixation of atmospheric nitrogen which improved the nutrition of the plant. In addition, it has been shown that, common bean plays a positive role in the solubilization of phosphorus (P) and improves productivity by fixing the nitrogen from the air. In this respect, an increase in maize yield by 70% has been observed with association to common bean (Odhiambo and Ariga, 2001). Similarly, Kheroar and Patra (2013) reported that grain yield of maize was increased when intercropped with legumes like green gam, black gram and soybean. The yield advantage of maize in intercropping system with legumes probably occurred from the difference on the timing of utilization of resources by the different crops from different soil layers especially during peak vegetative and reproductive stage of growth, thus results in both temporal and spatial complementarities. They also increase in grain yield of maize might be resulted from maize- legume association by optimum plant density due to symbiotic nitrogen fixation by legume and current transfer of nitrogen to the association maize plants. In addition, there was bonus yield from legume component, which corroborated (Kheroar and Patra, 2013).

When we compare maize intercropped with Nasir, maize intercropped with local and sole maize with each other, the maximum 5684 kg/ha were recorded by mean maize grain yield intercropped with Nasir followed by 4790 kg/ha maize sole and the minimum 4296 kg/ha was recorded by mean intercropping of maize with local. These might be from the high competitiveness of local variety. which agree with Tesfa *et al*. (2011) whose found from an experiment carried out on farmers' fields at Jimma zone that, maize yield intercropped with local large bean (2718 kg/ha) was less than sole maize yield (3211 kg/ha) and intercrops maize yield with Nasir (3272 kg/ha). In addition, the location, variety and management system might have its own influence. Similarly Chemeda (1997) reported yield reduction of maize grain by 24% in intercropping of maize with common bean due to higher inter-specific competition for available resources such as nutrients, soil moisture and root spaces between component crops. Muoneke *et al*. (2007) reported that some soya bean varieties, which were grown vigorously affect maize grain yield. Setegn (1997) found that yield levels of maize were reduced as high as 781 kg/ha in mixture with different genotypes of climbing bean. Tolessa e*t al.* (2002); Davis and Garcia (1987); Harwood *et al*. (2000) also get the same result.

The grain yield of intercropped maize with local (climbing bean) was reduced by 494 kg/ha as compared to sole crop. It might be resulted from inter specific competition of component crops for nutrient and light and due to growth nature of this bean to climb and cover nearby crop. Similarly, Kimani *et al*. (1999) found intercropping maize with climbing bean tended to lower maize grain yield. Francis *et al*. (1982) reported maize yield decreased by 31% when intercropped with climbing bean. Besides, the yield differences in crop mixture are influenced by not only the presence of other crops, but also by densities and spatial arrangement of crops and levels of resource availability in the two systems (Francis *et al*., 1982).

Figure 1.Interaction effect of common bean variety and component density of maize and common bean on yield per hectare of sole and intercropped maize.



Interaction of variety and component density	Intercrop Vs. sole crop
SEM (±) = 71.78	SEM (±) = 203.78
LSD $_{(0.05)}$ = 124.3	LSD $_{(0.05)}$ = 293.52
CV (%) = 16.57	CV = 18.44

MY= Maize Yield, SEM= Standard Error of Mean, LSD = Least Significance Difference, CV = Coefficient of variation.

Harvest index: The result revealed that, unlike component population density and cropping system there was statistically significant ($p<0.05$) variation due to the main effect of variety and interaction of component density and variety on maize harvest index (Appendix Table 1).

The maximum harvest index was 54.64 recorded by 100% maize population densities intercropped with 26.7% Nasir variety population density. The minimum harvest index 36.27 was recorded by 100% maize population density intercropped with 53.3% Local variety population density (Table 13). The maximum harvest index might be from the increased partitioning of dry matter accumulation to seed. In addition, variations in environmental factors, genetic differences of varieties might have influenced harvest index. Similarly Ludlow and Muchow (1988) reported that a higher transfer of assimilates to the grain would maximize the harvest index and reduce the proportion of dry matter produced in early growth phase that may be left as a stover.

Table 13. Interaction effect of common bean variety and component density of maize and common bean on Harvest Index of sole and intercropped maize.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	51.34^{abcd}	49.34^{abcd}	43.50^{bcdef}
Maize 100% + Nasir	48.22^{abcde}	54.64^{a}	53.16^{ab}
Maize 75% + Local	52.64^{abc}	39.50^{ef}	54.20^{a}
Maize 100%+ Local	47.40^{abcde}	41.77^{def}	36.27^{f}
SEM (±)	3.06		
LSD $_{(0.05)}$	6.35		
CV (%)	7.90		
Intercropped vs Sole cropped			
Inter crop	47.67		
Sole crop	43.11		
SEM (±)	4.70		
LSD $_{(0.05)}$	NS		
CV (%)	12.20		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV = Coefficient of Variation.

4.3 Common Bean

4.3.1. Crop phenology

The analysis of variance (Appendix Table 3) showed that days to 50% flowering and days to 50% maturity unlike that of days to 50% emergency were not significantly affected by the main effect of common bean variety. Similarly, population density and cropping system effects as well as interaction effect were not significantly observed for all phonological parameters of common bean in the study (Table 14).

Days to 50% emergency was significantly affected by the main effect of variety. The average days to 50% emergency of intercropped local bean was 9.43 and the average days to 50% emergency of intercropped Nasir were 8.02 days. The early emergency of Nasir variety might be from the nature of variety, because different varieties have their own emergency period. However significant effect were not seen between days to 50% flowering; there were slightly earlier for intercropped bean than sole cropped bean. This might be from more efficient use of soil moisture for good germination in intercrops than in sole crops; due to high ground coverage of intercrops that conserve soil moisture. As described by Morris and Garrity (1993) water use efficiency by intercrops during *belg* greatly exceeds water use efficiency by sole crops, often by more than 18% and as much as 99%. But, during *Meher*, intercropping was not superior to sole cropping, as soil moisture is not so limiting as compared to *Belg.*

Table 14. The main effect of component density and common bean variety on phenology and growth parameters of common bean sole and intercropped with maize.

Source of Variation	days to 50% emergency	days to 50% flowering	days to 50% maturity	Number of NodulePlant^{-1}
Common bean Variety				
M+N	8.20	52.06	90.44	12.87
M+L	9.43	51.78	90.94	11.68
SEM (±)	0.11	0.22	0.27	0.06
LSD $(_{0.05})$	0.31	NS	NS	0.11
Maize and Common bean	8.85	52.00	90.17	12.25
Component density				
M+C (100% * 17.7%)				
M+C (100% * 26.7%)	8.63	51.83	90.67	12.37
M+C (100% * 53.3%)	8.50	51.83	90.83	12.13
M+C (75% * 17.7%)	9.12	51.83	90.83	12.38
M+C (75% * 26.7%)	8.95	52.00	91.17	12.10
M+C (75% * 53.3%)	8.85	52.00	90.50	12.40
SEM (±)	0.18	0.39	0.460	0.18
LSD $(_{0.05})$	NS	NS	NS	NS
Cv (%)	5.0	1.8	1.2	2.1
Inter crop Vs Sole cropped				
Inter crop	8.82	51.92	90.70	12.27
Sole L	9.53	52.33	90.00	4.07
Sole N	8.13	52.00	90.67	5.58
SEM (±)	0.37	0.79	0.97	0.20
LSD $(_{0.05})$	NS	NS	NS	0.29
Cv (%)	5.1	3.9	1.3	2.2

M = maize, N = Nasir, C= common bean, M + N =Maize + Nasir, M + L=Maize + Local Asendabo, SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

Table 15. The main effect of component density and common bean variety on Leaf number and Number of branch per plant of common bean sole and intercropped with maize.

Source of Variation	Leaf number	Number of branches per plant
Common bean Variety		
M+N	30.40	13.63
M+L	29.36	13.46
SEM (±)	0.40	0.45
LSD ($_{0.05}$)	NS	NS
Maize and Common bean component density		
M+C (100%*17.7%)	30.70	12.78
M+C (100%*26.7%)	27.95	13.97
M+C (100%*53.3%)	31.45	12.93
M+C (75%*17.7%)	31.52	13.38
M+C (75%*26.7%)	27.40	14.77
M+C (75%*53.3%)	30.25	13.42
SEM (±)	0.70	0.79
LSD ($_{0.05}$)	2.04	NS
Cv (%)	5.7	14.2
Inter crop Vs Sole cropped		
Inter crop	29.88	13.54
Sole L	26.63	14.97
Sole N	28.20	16.00
SEM (±)	1.46	1.49
LSD ($_{0.05}$)	NS	NS
Cv (%)	5.8	13.2

M = maize, N = Nasir, L= Local Asendabo, M + N = Maize + Nasir, M + L = Maize + Local Asendabo, C = Common bean, M+C = Maize +Common bean, Sole L = Sole Local, Sole N = Sole Nasir. SEM = Standard Error of Mean, LSD=Least Significant Difference, CV= Coefficient of Variation.

4.3.2. Growth Parameters

Plant height: As indicated in (Appendix Table 4), the main effect of variety, component population density and the interaction effect of component density and variety had significant ($P<0.05$) effect on plant height of common bean. The maximum plant height 186.3 cm was recorded by 26.7% local common bean population density intercropped with 75% maize population density. The minimum plant height (92.3 cm) was recorded by 75% maize population density intercropped with 17.7% Nasir common bean population density (Table 16). The difference in plant height of the varieties could be attributed to the difference in their genetic makeup and due to the population density of combined crops. In agreement with this, Shahzad *et al*. (2007) reported that, height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors. The result obtained from this study was agreed with Tilahun (2002), who reported plant height was significantly affected by planting arrangement and the interaction of planting density and plant arrangement but not due to the main effect of plant densities. In the report of Kanda and Nishizawa (1967) whose revealed that dense planting promoted plant height to a certain level at the early stage of growth, while elongation was depressed at later period in rice crop. Similarly, Toaima *et al*. (2000) reported that, plant height was significantly decreased as seed rate increased in wheat crop. Baloch *et al*. (2010) also reported that; the maximum plant height (103.3 cm) was observed with seed rate of 150 kg/ha followed by 175 kg seed/ha which produced plants of 93.2 cm in wheat.

Leaf number: Statistically no significant variation was noticed in leaf number due to variety and component density interaction but, the main effect of component density and common bean variety showed significant ($P<0.01$) variation (Appendix Table 4). The maximum leaf number 31.52 was recorded by 17.7% common bean population density intercropped by 75% maize population density. The minimum leaf number was 27.40, was recorded by 26.7% common bean population density intercropped with 75% maize population density (Table 15). The reason might be, higher number of common beans cause decrease leaf number and the lower population number leads to many leaf number. Because when plants increased in number on per unit area of land, the scarcity of nutrient and moisture will be raised resulting decrease in number of effective branch. Similarly Woolley and Davis (1991) reported leaf number of common bean did not show a significance difference due to interaction effect of variety and population density.

Leaf area: The main effect of variety and population density showed significant ($P<0.01$) in affecting the leaf area. Likewise interaction effect and cropping system showed a significant variation in leaf area. The maximum (436.8 cm^2) leaf area was recorded by 17.7% population density of local bean intercropped with 100% maize population densities and the minimum (214.5 cm^2) were recorded when 53.3% Nasir common bean variety intercropped with 100% maize population density (Table 17). As indicated in the result the lower leaf area was observed in the higher population density that might be resulted from interspecific competition between plants, and the lower population density results higher leaf area.

The significant ($P<0.01$) difference between cropping system indicated that intercropping had the maximum leaf area as compared to sole cropping (Table 19). Because intercropping increase water uses efficiency of the combined crop that leads to faster growth of leaves and also, the competition among crops to sun light cause greater leaf area of intercrops than sole crop. Similarly, Walker and Ogindo (2003) found that, intercropping increase the water use efficiency of the combined crop. The process whereby the soil surface is shaded quicker under the intercropping system is due to the faster growth of the leaves due to competition. This has been shown from the leaf area measurements of the maize-bean intercropping system where the intercrop had higher leaf area index by 40 days after planting (Walker and Ogindo, 2003). This earlier closure of the crop canopy reduced the amount of solar radiation reaching the soil surface. The reduction in soil evaporation due to earlier higher leaf area then resulted in there being 2-7% more transpiration in the intercrop than in the sole cropping systems. Also Wogayehu, (2005), found variety had significant effect on leaf area of common bean.

Leaf area index: The result evidenced that, the main effect of component density and variety as well as their interaction had significant ($P<0.01$) effect on leaf area index (Appendix Table 3). The maximum 4.66 leaf area index was recorded by 53.3% Nasir common bean population density intercropped with 75% maize population density. The lowest 1.48 was recorded by

53.3% Nasir common bean population density intercropped with 100% maize population density (Table 18). This showed that, as the maize population density intercropped with common bean increase in population density the leaf area index decrease; because it might be influenced by the high competition of the component crops that leads to decrease the in photosynthetic capacity of the crops.

However non-significant difference was observed between cropping system, the highest mean LAI (3.04) was recorded for sole common bean which was higher than the mean LAI (2.87) of intercropped common bean. These showed that the maximum leaf area index was recorded by sole crop and the lowest was recorded by intercrop. The main reason for the differences in leaf area index of common bean was due to density differences of sole and intercrops population, so that sole crops resulted in higher LAI because of lower density of crops that leads to lower competition between crops. Similarly Demesew (2002) obtained a significant variation on leaf area index of haricot bean intercropped with maize. Moreover, the intercropping had significant effect on leaf area index (LAI). In a similar trend, Tilahun (2002) indicated that the main effects of both plant density of faba bean and planting arrangement had a significant effect on LAI of the faba bean intercropped with maize. Similarly, Wogayehu (2005) found that the leaf area index of Common bean significantly affected due to the difference in inherent character of the varieties.

Table 16. Interaction effect of common bean variety and component density of maize and common bean on Plant Height of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	92.3[d]	124.5[c]	121.4[c]
Maize 100% + Nasir	148.3[bc]	138.3[c]	130.2[c]
Maize 75% + Local	182.5[a]	186.3[a]	180.5[a]
Maize 100%+ Local	176.2[a]	176.5[a]	171.9[ab]
SEM (±)	5.56		
$LSD_{(0.05)}$	11.16		
CV (%)	10.5		
Intercropped vs Sole cropped			
Inter crop	152.41		
Sole crop	155.00		
SEM (±)	25.98		
$LSD_{(0.05)}$	NS		
CV (%)	10.10		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table 17. Interaction effect of common bean variety and component density of maize and common bean on Leaf Area of sole and intercropped common bean.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	231.7^{gh}	239.5^{g}	274.2^{d}
Maize 100% + Nasir	304.3^{de}	421.8^{a}	214.5^{h}
Maize 75% + Local	324.7^{cd}	298.9^{e}	367.5^{b}
Maize 100%+ Local	436.8^{a}	331.5^{c}	330.3^{c}
SEM (±)	1.283		
LSD $_{(0.05)}$	2.66		
CV (%)	4.40		
Intercropped vs Sole cropped			
Inter crop	314.64^{a}		
Sole crop	273.00^{b}		
SEM (±)	9.96		
LSD $_{(0.05)}$	20.47		
CV (%)	3.00		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table 18. Interaction effect of common bean variety and component density of maize and common bean on Leaf Area Index of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	2.60^{cd}	3.13^{bc}	4.66^{a}
Maize 100% + Nasir	3.23^{bc}	2.75^{cde}	1.48^{e}
Maize 75% + Local	2.60^{cd}	2.94^{bc}	3.14^{bc}
Maize 100%+ Local	4.50^{a}	1.79^{de}	1.64^{cd}
SEM (±)	0.37		
LSD $_{(0.05)}$	1.07		
CV (%)	12.6		
Intercropped vs Sole cropped			
Inter crop	2.87		
Sole crop	3.04		
SEM (±)	0.37		
LSD $_{(0.05)}$	NS		
CV (%)	13.3		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Number of nodules per plant: No significant effect was observed due to common bean variety and component population density interaction on number of nodules per plant. However, cropping system and the main effect of common bean variety indicated significant ($P<0.05$) effect on number of nodules. The result showed the lowest (4.83) number of nodules per plant was recorded by sole common bean plants while the highest (12.27) was recorded by intercrop common bean (Table 14). This might be from the moisture conserved in the soil because of the upper canopy of maize and the lower canopy of common bean that limit evaporation of moisture from the soil and prevent the direct sun light to reach the ground also the competition among plant might be initiate nodulation.

Among varieties the maximum number of nodules was recorded by Nasir common bean (Table 16). Because different varieties have different nodule fixing ability; so the above result might depend on the genetic makeup of the common bean. In agreement with this, Santalla *et al*. (2001) reported that higher number of nodules per plant was recorded by intercropped varieties of common bean than sole cropped. Also Abraha (2013) found that, the intercropped Lablab-maize registered higher nodules per plant (12.11) and low was sole lablab which was 5.33 nodules per plant. In addition, the result between cowpea-maize intercropping and mono crop cowpea were statistically significant ($P<0.01$), where cowpea-maize registered 13.44 nodule per plant and sole cowpea 8.77 nodules. Also he said that, this might be attributed that crop competition stimulates nodulation. Thobasti (2009) reported that, the intercrops cow pea cultivar Glenda and Agrinawa had significantly more nodules per plant than compare to sole crops.

Number of branches per plant: In the present study, neither the interaction effects of common bean varieties and component density, nor their main effects showed significant variation on number of branches per plant of common bean (Appendix Table 4). However the maximum numbers of branches per plant (14.97) was recorded for sole cropped as opposed to the minimum number (13.54) was recorded from the intercropped common bean (Table 15). The main reason of the maximum number of branch per plant for sole crop might be from the low competition and the lowest might be from the high competitiveness of maize crop than common bean. This observation agreed with that of Yadav and Yadav (2000), who reported a reduction in the number of branches of Custer bean cultivars mix-cropped with pearl millet compared to their pure stand.

4.3.3 Yield Components and Grain Yield

4.3.3.1. Yield Components

Number of pods per plant: Analysis of variance showed that, cropping system and the interaction effect of component population density and variety had significant ($P<0.01$) effect on number of pods per plant. The maximum number of pods per plant 18.60 was recorded by 17.7% local common bean population density intercropped with 75% maize population density and the lowest 12.40 was recorded by 53.3% local common bean population density intercropped with 100% maize population density (Table 19). The reason in low number of pods were, due to interspecific competition of crops, the number of effective branch that can give greater number of pods was decreased so that the number of pods per plant was ultimately decreased.

Regarding the cropping system, the highest 22.01 pods per plant was recorded by average sole common bean, whereas the lowest 15.89 was recorded by average intercropped common bean. This result showed that, number of pods per plant decreased with the increasing planting density. This decrease in pods per plant at higher density was attributed to increased competition among plants for growth factors like light and nutrient, which ultimately reduced the number of effective branches. This finding is in agreement with Demesew (2002); Wogayehu (2005) on maize/common bean intercropping reported that, number of pods per plant was significantly affected by common bean varieties and planting density. Adem (2006) on sorghum-cowpea found a significant difference on number of pod per plant due to planting density. Turk *et al*. (2003) confirmed that number of pods per plant was negatively related to plant density. Similarly the result obtained from this study was in agreement with (Kheroar and Patra (2013) who reported that number of pods per plant in green gram, black gram, soybean and groundnut were significantly reduced due to intercropping. Also Abraha (2013) reported that intercropping significantly ($P<0.01$) affected number of pods per plant where the higher 43.11 was recorded by mono crop averages and the lower 40.77 was recorded by intercrop.

Number of seeds per pod: ANOVA result indicated that the main effects of component density, variety and interaction of the main effects as well as cropping system had significant ($P<0.05$) effect on number of seeds per pod (Appendix-Table 4). The highest number of seeds per pod 6.20 was recorded by 53.3% local bean population density intercropped with 75% maize population density, and the minimum number of seed per pod 4.00 was recorded by 53.3% Nasir common bean density intercropped with 100% maize population density (Table 20). The difference in number of seeds per pod might be because of inherent characteristics of the varieties and due to the population density of the plant.

By comparing intercrop with sole crop the highest seed per pod 6.25 was recorded by average sole crop and the lowest 5.33 was recorded by average intercrop, which showed sole crop common bean had the maximum number of seeds per pod. This might be most likely due to competition for soil nutrient and light. The same result was recorded by Yesuf (2003) on sorghum-haricot bean and Adem (2006) on sorghum-cowpea intercropping found significant difference was seen as a result of planting density effect. This showed that the highest number of seed per pod was recorded by sole crop and the minimum is recorded by intercropping. In agreement with this Niringiye *et al*. (2005) revealed that, Values for number of seeds per pod and mean grain weight intercrops were slightly lower than in sole crop. Similarly Kheroar and Patra (2013) reported that number of seeds per pod was significantly reduced in leguminous crops like green gram, black gram, soybean and ground nut due to intercropping.

Pod length: Statistically significant ($p<0.01$), variation were noticed in pod length due to variety and component population density interaction (Appendix Table 4). Among intercropping the maximum 15.63 pod length was recorded by 17.7% local bean intercropped with 100% maize population density. The minimum 10.93 was recorded by 26.7% Nasir common bean population density intercropped with 100% maize population density. The higher the number of pod per plant and number of seeds per pod in the sole crops due to lower competition caused the highest number of pod length in the sole crop.

Regarding cropping system significant ($p<0.01$) effect was observed for pod length, the maximum pod length 16.59 was recorded by mean sole common bean and the minimum 12.5

was recorded by mean common bean intercropping. Also as overall treatment, the maximum pod length 17.80 was recorded by sole local common bean. Definitely, the main reason for this lower Pod length of the intercropped bean plants could also be due to the higher plant population per unit area of the component crops that could compete for the scarce resources to reduce the Pod length of the bean plant. In agreement with this result Thobasti (2009) found cowpea cultivar Agriwana intercrop produced the shortest pod length 2.66 cm. and there was significance reduction in pod length in intercropping condition.

Table 19. Interaction effect of common bean variety and component density of maize and common bean on Number of pods per plant of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	16.47[c]	17.77[b]	17.30[b]
Maize 100% + Nasir	14.87[d]	16.20[c]	12.50[f]
Maize 75% + Local	18.60[a]	14.00[e]	16.27[c]
Maize 100%+ Local	18.22[a]	16.13[c]	12.40[f]
SEM (±)	0.25		
LSD $_{(0.05)}$	0.51		
CV (%)	4.90		
Intercropped vs Sole cropped			
Inter crop	15.89 [b]		
Sole crop	22.04 [a]		
SEM (±)	0.28		
LSD $_{(0.05)}$	0.58		
CV (%)	7.10		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table 20. Interaction effect of common bean variety and component density of maize and common bean on Number of seed per pod of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	5.4c[e]	5.07[d]	4.67[e]
Maize 100% + Nasir	5.00[d]	6.00[a]	4.00[f]
Maize 75% + Local	5.07[d]	5.67[b]	6.20[a]
Maize 100%+ Local	5.67[b]	5.33[c]	5.87[b]
SEM (±)	0.11		
LSD $_{(0.05)}$	0.24		
CV (%)	2.6		
Intercropped vs Sole cropped			
Inter crop	5.33[b]		
Sole crop	6.25[a]		
SEM (±)	0.11		
LSD $_{(0.05)}$	0.22		
CV (%)	2.4		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table 21. Interaction effect of common bean variety and component density of maize and common bean on pod length of sole and intercropped common bean.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	11.37[ef]	11.67[de]	12.30[c]
Maize 100% + Nasir	12.27[c]	10.93[g]	11.47[ef]
Maize 75% + Local	12.03[cd]	11.93[cd]	14.50[b]
Maize 100% + Local	15.63[a]	11.27[fg]	14.63[b]
SEM (±)	0.18		
LSD $_{(0.05)}$	0.37		
CV (%)	1.7		
Intercropped vs Sole cropped			
Inter crop	12.50[b]		
Sole crop	16.59[a]		
SEM (±)	0.18		
LSD $_{(0.05)}$	4.00		
CV (%)	5.60		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significant. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Hundred seed weight: Analysis of variance showed that the main effect of variety, component density and interaction effect of component density and variety had highly significant (P<0.01) effect on 100 seed weight (Appendix Table 3). The maximum 100 seed weight 60.91gm was recorded by 17.7% local common bean population density intercropped with 75% maize population density. The minimum 41.63gm was recorded by 53.3% local common bean population density intercropped with 100% maize population density (Table 22). This result showed that as local bean decrease in population density, 100 seed weight increase, and as the population density increase 100 seed weight of local bean decrease. The higher hundred seed weight obtained from Local common bean could be most likely due to its larger seed size. Dechasa (1996) also found significant difference on the number of pods per plant, number of seeds per pod and hundred seed weight due to different bean genotypes. Wogayehu (2005) on maize-common bean intercropping found that, hundred seed weight was significantly ($P<0.05$) different between varieties.

Concerning cropping system, there was a significance ($P<0.01$) difference between common bean cropping system, where the maximum (51.49) hundred seed weight was recorded from sole crop as compared to the minimum (49) value recorded on intercropped plot (Table 22). Because the nitrogen that fixed by sole beans might not absorbed by other crop, rather it was used by bean itself that leads to higher hundred seed weight.

In accordance with the present finding, Adem (2006) reported that the highest hundred seed weight of intercropped cowpea was obtained from a planting ratio of sorghum 100%*25% cow pea than sorghum 100% * 50% cowpea. Similarly Turk *et al*. (2003) reported that the lowest plant density produced the highest seed weight. Demesew (2002) also reported similar result from the intercropping of maize with bush bean.

Above ground dry biomass: The cropping system and interaction effect of variety and component planting density, as well as the main effects showed highly significant ($P<0.01$) difference for above ground dry biomass production. The common bean sole crop had the highest above ground dry biomass as compared to intercropped common bean.

Among intercropping the highest above ground dry biomass of 2732 kg/ha was obtained from 17.7% Nasir population density intercropped with 100% maize population density and the lowest 749 kg/ha were obtained from 26.7% local variety intercropped with 100% maize population density (Table 23). The maximum above ground dry biomass of common bean might from the well utilization of nutrient and light by crops that increase the vegetative growth of common bean.

The maximum 4861kg/ha (Table 24) increase in dry biomass production in sole cropped bean is most likely either due to absence of inter-specific competition between the component crops or due to the increase in light interception or both. (Biscoe and Gallagher, 1977) reported that the rate of dry matter production in crops depend on the efficiency of the interception of photo synthetically active radiation (PAR). Similar to the present finding, Wogayehu (2005) on maize-haricot bean; Sisay (2004) on sorghum/green gram and Yesuf (2003) on sorghum/haricot bean; intercropping reported that sole cropped bean produced the highest dry biomass per hectare than intercropped bean.

Grain yield: Results revealed that grain yield was significantly (P<0.01) affected by the interaction effect of component plant population and variety as well as cropping system.The main effects also showed significant variation on grain yield. Among intercrops the maximum grain yield (1462 kg/ha) was, recorded for 53.3% Nasir common bean population density intercropped with 75% maize population density. The minimum grain yield (186 kg/ha) was, recorded for 53.3% Nasir common bean population density intercropped with 100% maize population density (Figure 2). The high population of the bean and maize component crops per unit area of land might cause crops to compute with each other for growth resources like nutrient and light that leads to decrease yield of crops.

As overall treatment the maximum 2306 kg/ha was recorded by sole Nasir common bean followed by 2048kg/ha recorded by sole local common bean. The mean intercropped Nasir 784.17kg/ha was greater than the mean intercropped yield of local 608.67kg/ha. These present result was similar with Tesfa *et al*. (2011) whose found the mean Nasir yield 742kg/ha was greater than the mean intercropped local yield, which was 720kg/ha at Jimma.

Thus, the general observation in this study is that yields of common bean component are significantly depressed by maize component in intercropping. This is most likely due to competition for soil nutrient and the reduction in transmitted photo synthetically active radiation (PAR) to the common bean as a result of shading. Similarly, Kheroar and Patra (2013) revealed that yield of intercrops were reduced by intercropping with maize that caused due to receipt of lower amount of solar radiation. Also the result was in agreement with Rezaei-Chianeh *et al*. (2011) showed that, the effects of maize densities and the interactions of maize and faba bean densities on grain yield of faba bean was significant. There was a general reduction in the yield of faba bean under intercropping system and also he said, the highest grain yield of faba bean was recorded in mono-cropping. The result found by Tesfa *et al*. (20011) confirmed that sole Nasir and Dimtu had top growth performance and produced significantly higher mean yield of 2,302 and 2,223 kg/ha, respectively during main season at Jimma. Niringiye *et al*. (2005) who reported that, mean bean yield intercrop was less in intercrop as compared to sole bean yield and also they revealed that intercropping with maize reduced bean grain yield by 63 and 71% in season 1 and 2 respectively. Yield was mostly affected in the short statured under sown leguminous crops and the main reason for reduction in yield was probably due to the receipt of lower amount of incoming solar radiation which affected the rate of photosynthesis and thereby translocation of photosynthesis from source to sink. Also, Pal *et al*. (1993) reported that grain yield of sole cropped maize; sorghum and bean were higher than the intercropped yield of these crops.

Harvest index: It is clear that in (Appendix Table 3), statistically significant ($p<0.01$) variation was observed by cropping system, the main effects variety and component population density and interaction effects of the main effects on harvest index of common bean. The maximum harvest index among intercropping, (63.87) was recorded by 26.7% Nasir common bean population density intercropped with 75% maize population density. By contrary, the minimum results of (32.79) were recorded for 53.3% Nasir common bean population density intercropped with 100% maize population density (Table 24). The minimum harvest index might be directed from the low nutrient and light use efficiency of the crops caused from the high population density.

However, the higher harvest index of common bean was recorded by mean sole crop as compared to the minimum 45.20 was from the mean intercropped. Because it might be from the efficient light interception and utilization of sole crop than intercrop and also the good partitioning of dry matter to grain yield. Ludlow and Muchow (1988) reported that a higher transfer of assimilates to the grain would maximize the harvest index and reduce the proportion of dry matter produced early in growth that may be left as a stover.

Table 22. Interaction effect of common bean variety and component density of maize and common bean on 100 seed weight of sole and intercropped common bean.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	52.78[b]	48.20[c]	48.53[c]
Maize 100% + Nasir	48.87[c]	56.15[b]	41.83[d]
Maize 75% + Local	60.91[a]	46.85[c]	48.81[c]
Maize 100% + Local	46.06[c]	47.38[c]	41.63[d]
SEM (±)	1.72		
LSD $_{(0.05)}$	3.57		
CV (%)	4.30		
Intercropped vs Sole cropped			
Inter crop	49.00[b]		
Sole crop	51.49[a]		
SEM (±)	1.16		
LSD $_{(0.05)}$	2.46		
CV (%)	4.00		

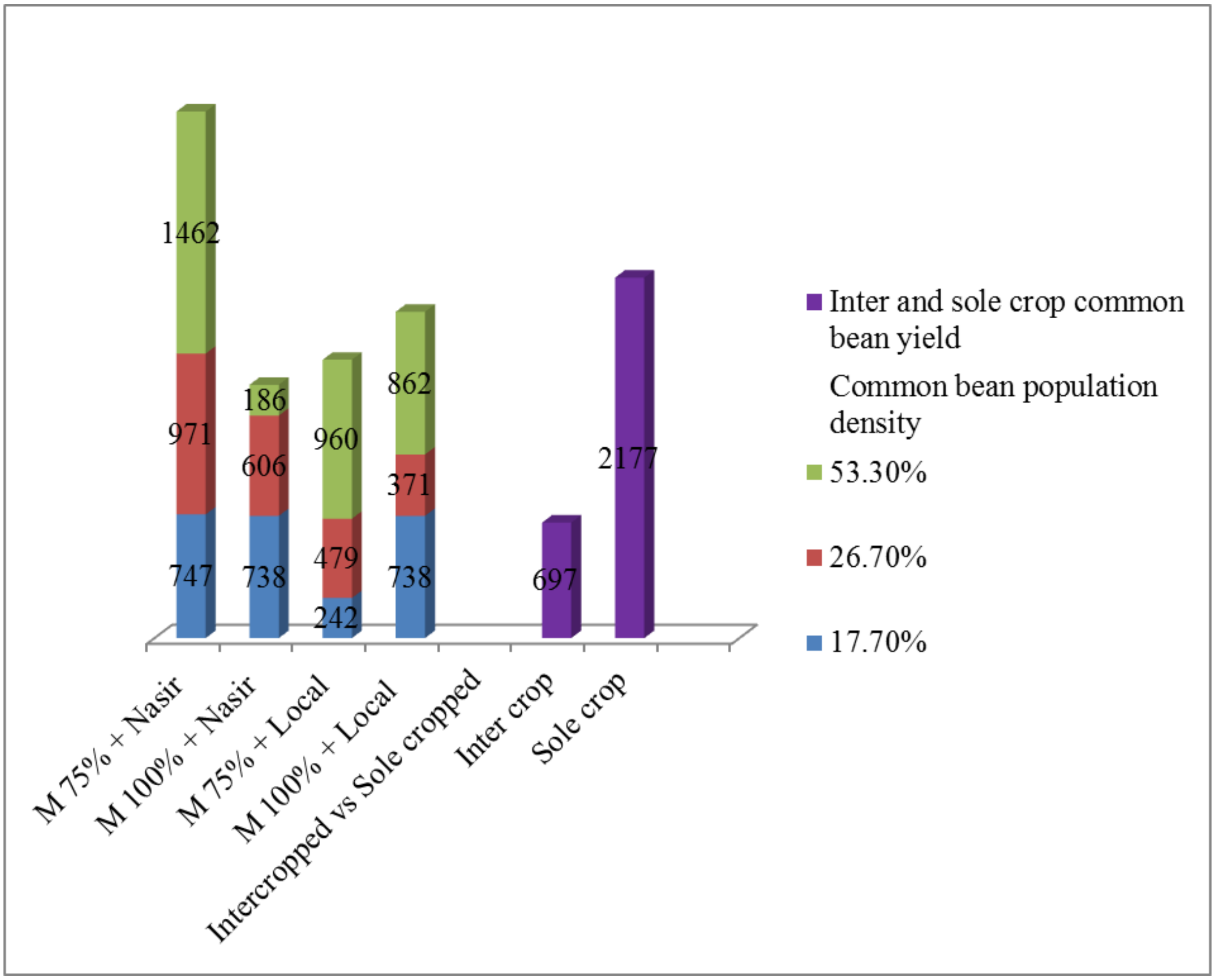
Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Table 23. Interaction effect of common bean variety and component density of maize and common bean on above ground biomass of sole and intercropped common bean.

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	1703[e]	1086[h]	2525[b]
Maize 100% + Nasir	2732[a]	1496[f]	853[i]
Maize 75% + Local	1294[g]	1085[h]	2219[c]
Maize 100% + Local	1087[h]	749[j]	2116[d]
SEM (±)	22.20		
LSD $_{(0.05)}$	119.80		
CV (%)	36.70		
Intercropped vs Sole cropped			
Inter crop	1412.08[b]		
Sole crop	4861.00[a]		
SEM (±)	57.70		
LSD $_{(0.05)}$	157.00		
CV (%)	5.80		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

Figure 2. Interaction effect of common bean variety and component density of maize and common bean on yield per hectare of sole and intercropped common bean.



Interaction of variety and component density	Intercrop vs. sole crop
SEM (±) = 14.10	SEM (±) = 15.35
LSD $_{(0.05)}$ = 38.50	LSD $_{(0.05)}$ = 44.64
CV (%) = 8.30	CV = 11.2

M= Maize, SEM= Standard Error of Mean, LSD = Least Significance Difference, CV = Coefficient of variation.

Table 24. Interaction effect of common bean variety and component density of maize and common bean on Harvest Index of sole and intercropped common bean

	Bean population density		
Maize population with common bean variety	17.7%	26.7%	53.3%
Maize 75% + Nasir	47.17^{cd}	63.87^{a}	54.41^{b}
Maize 100% + Nasir	36.72^{e}	45.98^{cd}	32.79^{f}
Maize 75% + Local	37.70^{e}	47.94^{c}	46.46^{cd}
Maize 100% + Local	44.31^{d}	39.83^{e}	45.26^{cd}
SEM (±)	1.09		
LSD $_{(0.05)}$	3.21		
CV (%)	3.70		
Intercropped vs Sole cropped			
Inter crop	45.20^{b}		
Sole crop	71.33^{a}		
SEM (±)	2.37		
LSD $_{(0.05)}$	22.80		
CV (%)	6.70		

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. SEM = Standard Error of Mean, LSD = Least Significant Difference, CV= Coefficient of Variation.

4.4. Economic Benefits and Monetary Advantages from Maize/Bean Intercropping

LER of both maize and common bean statistically showed, significance ($P<0.01$) difference due to interaction of the main effect of variety and component population density (Appendix Table 5). The highest maize PLER (1.64) recorded when 100% maize mixed with 26.7% Nasir common bean variety population density. The lowest (0.48) was recorded when 100% maize population density intercropped with 53.3% Local common bean variety population density (Table 25).

The highest common bean PLER (0.63) was obtained from 75% maize mixed with 53.3%) Nasir common bean population density and the lowest (0.08) were obtained when 53.3% Nasir common bean population density mixed with 100% maize population density.

The result showed that the interaction effect of variety and component population density gave significant ($P<0.01$) effect on total LER of maize and common bean (Appendix Table 5). The highest mean total LER values of 1.90 were achieved when 100% maize population density intercropped with 26.7% Nasir common bean population density. The minimum mean total LER values 0.86 was recorded when 75% maize population density intercrops with 26.7% local common bean population density (Table 25).

Intercrop system had LER value of 1.36 (Table 26) that was greater than sole crop. The value of LER above 1 indicates that, the intercropped utilize the available resource efficiently than sole cropped. From the present LER result, we can conclude that intercropping has 26.5% yield advantage as compared to sole crop. Therefore, the calculated total LER enlightened that intercropping of maize and common bean was productive and had yield advantage over cropping either maize or common bean in sole. This could be happened due to 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, Tsubo *et al*. (2004) the intercropping maize-bean system was more effective and more efficient relative to the individual plantings. Chemeda (2003) found, up to 28% higher total productivity increase of maize-bean intercropping compared with pure stand. Willey and Osiru (1972) reported that

55% yield advantage was obtained when 85 day beans intercropped with 120 day sorghum and 38 % yield advantage was obtained when 85 day beans intercropped with 120 day maize (Osiru and Willey, 1972). Baker (1979) also pointed out that, both early and slow maturing crops are combined to ensure efficient utilization of the whole growing resource.

Gross Monetary Value which indicates the economic advantage of the cropping system showed that, significant (P<0.01) effect were seen on maize and common bean due to the interaction effect of common bean variety and component density. On maize plot the maximum 39104 ETB/ha GMV observed by the component density of 100% maize population density and 26.7% Nasir common bean population density. The minimum 11452 ETB/ha were seen by the combination of 100% maize population density and 53.3% local population density. On common bean plot 10234 ETB/ha the maximum GMV was seen on the plot contains 53.3% Nasir bean population density and 75% maize population density. The minimum 1302 value were observed by the plot that contains 53.3% Nasir population density with 100% maize population density.

Total Gross Monetary Value revealed that the interaction effect of common bean varieties and component population densities had a significant (P<0.01) effect on the TGMV of intercropped maize and common bean (Appendix Table5). The highest total gross monetary value of 43,346 ET B/ha were obtained from maize population density of 100% intercropped with Nasir common bean variety of 26.7% population density. The lowest 18,348 ETB/ha were obtained from maize population density of 100% intercropped with local common bean variety of 53.3% population density (Table 25).

Among the sole cropped common bean varieties, the GMV of 16,384 and 16,142 ETB/ha was obtained from Local common bean and Nasir varieties respectively. Whereas GMV of 23,950 ETB/ha was obtained from Sole maize (Table 25). Because of Local common bean was mostly preferred by consumers its GMV was the highest.

Concerning Monetary Advantage significant (P<0.01) effect were seen on maize and common bean due to the interaction effect of common bean variety and component density. The maximum GMA 3710.73 ETB/ha was recorded on maize when 100% maize population density were intercropped with 26.7% Nasir bean population density. Whereas the minimum -477.56 ETB/ha were from 75% maize population density intercropped with 26.7% local bean population density. The minimum value of monetary advantage was observed in the plot that showed minimum LER less than 1. This value indicated that, intercropping did not show yield advantage; no potential in increasing total land productivity and no efficient use of limited land resources. This might be from less population of maize crop as well as common bean crop to give high yield.

The result obtained indicated maize common bean intercropping adds extra income and warrants insures against food security and income to farmers particularly during the summer season when production during main season is running out and shortage of food supply occurred, rather than single cropping of maize and beans as there is scarcity of land and need to diversify production.

In general, the value observed from the LER and the GMA evidently showed that intercropping of maize and common bean is advantageous than sole cropping of either maize or common bean.

Table 25. Effect of variety and component density on yield advantages of maize/common bean intercropping

Treatment number	Component density of maize and common bean varieties	Yield kg/ha		Partial LER		TLER	GMV and MA in ETB/ha			
		Maize	CB	maize	CB	TLER	M	CB	TGMV	MA
1	M+NB (100% +17.7%)	4605^{g}	738^{d}	0.96^{f}	0.32^{d}	1.28^{h}	23023^{i}	5166^{f}	28189^{g}	1007.44^{i}
2	M+NB (100% + 26.7%)	7821^{a}	606^{e}	1.64^{a}	0.26^{e}	1.90^{a}	39104^{a}	4242^{g}	43346^{a}	3710.73^{a}
3	M+NB (100% + 53.3%)	6812^{b}	186^{i}	1.42^{b}	0.08^{g}	1.50^{d}	34059^{b}	1302^{k}	35361^{c}	2272.66^{b}
4	M+NB (75% +17.7%)	5377^{cd}	747^{d}	1.12^{c}	0.32^{d}	1.44^{e}	26884^{d}	5229^{e}	32113^{d}	1653.16^{e}
5	M+NB (75% + 26.7%)	4172^{h}	971^{b}	0.87 ^{g}	0.42^{c}	1.29^{g}	20862^{j}	6797^{d}	27659^{h}	940.59^{h}
6	M+NB (75% + 53.3%)	5315^{d}	1462^{a}	1.11^{c}	0.63^{a}	1.74^{b}	26575^{f}	10234^{a}	36809^{b}	2267.41^{c}
7	M+LAB (100%+17.7%)	4790^{f}	738^{d}	1.00^{e}	0.36^{d}	1.36^{f}	23952^{h}	5904^{d}	29856^{gh}	1268.85^{f}
8	M +LAB (100% + 26.7%)	4944^{e}	371^{g}	1.03^{d}	0.18^{f}	1.21^{j}	24720^{g}	2968^{i}	27688^{f}	861.94^{j}
9	M +LAB (100%+ 53.3%)	2290^{j}	862^{c}	0.48^{i}	0.42^{c}	0.90^{k}	11452^{l}	6896^{c}	18348^{j}	-251.91^{k}
10	M +LAB (75%+ 17.7%)	5377^{cd}	242^{h}	1.12^{c}	0.12^{e}	1.24^{i}	26885^{d}	1936^{j}	28821^{e}	1034.28^{g}
11	M +LAB (75% + 26.7%)	3031^{i}	479^{f}	0.63^{h}	0.23^{e}	0.86^{l}	15154^{k}	3832^{h}	18986^{i}	-477.56^{l}
12	M +LAB (75% + 53.3%)	5346^{cd}	960^{b}	1.12^{c}	0.47^{b}	1.59^{c}	26728^{e}	7680^{b}	34408^{c}	1981.09^{d}
13	SM	4790	-	1.00	-	1.00	23,950	-	23,950	-
14	SNB	-	2306	-	-	-		16142	16142	-
15	SLAB	-	2048	-	-	-		16384	16384	-
SEM (±)		203.78	15.35	0.001	0.006	0.007	48.37	155.87	119.26	137.65
LSD ($_{0.05}$)		293.52	44.64	0.003	0.012	0.014	81.90	323.25	349.77	403.70
CV		18.44	11.2	4.2	2	0.6	0.2	11.5	0.6	12.2

Means followed by the same letter within a column are not significantly different from each other at 5 % level of significance. LER = Land Equivalent Ratio, TLER = Total Land Equivalent ratio, GMV = Gross Monetary Value, TGMV = Total Gross Monetary Value, MA = Monetary Advantage, ETB/ha = Ethiopia Birr per hectare, CB = Common bean, M = Maize, NB = Nasir, LAB = Local Asendabo, SM = Sole Maize, SNB = Sole Nasir, SLAB = Sole Local Asendabo.

5. SUMMARY AND CONCLUSION

The increasing population in one hand and shortage of arable land in the other leads to intercropping in Jimma, western Ethiopia. Inter cropping helps to diversify production and answers against risk for subsistence farmers and intensifies and diversifies production in time and space dimension in this area. Therefore, the study was conducted to determine the effects of component density of maize and common bean varieties on growth, yield and yield components of the associated crops and on their productivity at off-season and to identify the best performed common bean variety with component population density that maximizes productivity under Jimma conditions, southwest Ethiopia. The experiment contains six component densities (100% * 17.7%, 100% * 26.7%, 100% * 53.3%, 75% * 17.7%, 75% * 26.7%, 75% * 53.3%) of hybrid maize and common bean, and two common bean varieties (Nasir and Local Asendabo) accompanied with sole maize and sole common bean varieties in randomized complete block design with three replications.

In this intercropping mixture of maize and common bean experiment: phonological, growth, yield and yield parameters, economic analysis and productivity of the system as a whole were examined. With the exception of days to 50% emergency of common bean, all phonological parameters of maize and common bean did not affected by the main effects as well as the interaction effect of variety and population density.

Among maize growth parameters, plant height and leaf area index was not affected by the main effect of varieties and component population densities. However interaction effect showed significant variation on leaf area index, plant height showed non-significant difference. Similarly, the main effect of variety, population density and their interaction indicated significant difference ($P<0.05$) on maize leaf area, biological yield and harvest index. But, population density did not show significant difference on harvest index of maize.

Result indicated that cropping system and common bean varieties showed a significant ($P<0.05$) difference on number of nodules per plant and number of pod bearing branch per plant of common bean. But, population density and the interaction of the main effects did not showed significant difference. Likewise, significance difference (P<0.01) was seen on leaf area and leaf area index as a result of the main effect of common bean variety, component population density and interaction effect of the main effects.

Regardless of yield and yield components of maize, significant effects were observed due to common bean variety, component population density and interaction on seed number per cob, cobs per plant, number of seeds per row, thousand seed weight, dry biomass yield, cob length, cob weight and yield per hectare of maize. Also in a similar case, concerning yield and yield components of common bean: number of pod per plant, number of seed per pod, pod length, hundred seed weight, above ground biomass and yield per hectare showed statistically significant (P<0.05) difference due to cropping system. As overall treatment the maximum 2306 kg/ha was recorded by sole Nasir common bean followed by 2048 recorded by sole local common bean.

The ANOVA result on partial land equivalent ratio (PLER) of maize and common bean indicated that, interaction effect of variety and population density had highly significant effect on PLER of maize and common bean. Likewise, the main effect of common bean variety and component density confirmed that, highly significant variation had observed on (PLER) of maize and common bean. Besides the TLER, GMV and MV, results indicated from the experiment revealed that, significant variation were obtained due to the main effect of common bean variety, component population density and due to the interaction of the main effects on maize and common bean.

Moreover, LER and monetary values result indicated, additive intercropping mixture of maize and common bean had significant effect on many maize and common bean phenology, growth, yield and yield components. From these result clearly indicated that, proper attention should be given while practicing maize and common bean intercropping. The economic assessment of intercropping is expressed in terms of increased value per unit area of land indicated that the main effect of common bean variety and component density showed significant effect on GMV of maize and common bean. And hence the highest GMV of 43346 ETB/ha were obtained from maize population density of 100% intercropped with Nasir common bean variety of 26.7% population density. And the lowest 18348 ETB/ha were obtained from maize population density of 100% mixed with 53.3% local common bean variety population density.

In general maize 100% population density intercropped with 26.7% population density of Nasir common bean variety, and as an alternative, maize with 75% population density intercropped with 53.3% population density of both varieties of common bean are recommended to make farmers benefited from the system. The calculated result also confirmed that the largest LER and the largest MV was obtained from population densities of 100% and 26.7% intercropped maize and Nasir common bean variety.

Though selecting and practicing intercropping of best food crops varieties maximize yield of crops and maximize food security of the farmers. Mainly during off-season based on their agro-climatologic environment and performance, released new varieties and best local varieties should be evaluated and tested by farmers. In the present study, the selected maize variety (BHQPY-545) which was early maturity and best yielder and the intercropped bean varieties performed better in the area.

Generally, increasing intercropping practice is used to maximize the grain yield from the same space at the same time and the system is more appropriate in terms of soil fertility improvement. Intercropping practice, mainly in the off-season by irrigation is used to secure family food and cash security; because, the present result indicates the yield obtained from sole and intercropped maize and common bean was not inferior to the yield obtained from maize and common bean at the main season as the some authors reported. So far, no research work had been made on the cropping system and proportion of maize and common bean productivity during off-season in the study area; so it needs further research on cultivars of maize and common bean intercropping combination that maximize production during off-season . As a final, it is difficult to conclude and give valuable recommendation in one year experiment at one site, hence further investigation on the selection of best compatible maize and common bean varieties and proportion of planting density should be studied.

Future direction

- More research is needed to better understand how intercrops function and to develop intercropping systems that are compatible with current farming systems
- Soil analysis after sowing and before harvest
- Different varieties of combined cropped must be tested at different cropping season and at different agro ecology
- Economic aspect of the green and dry cob of maize and pod of common bean must be tested

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7. APPENDIX

Appendix Table 1. Phenology and growth parameters of intercropped maize as influenced by common bean variety and planting density.

		Mean squares							
Source of variation	D f	DFT	DFS	DFM	PH	LA (cm^2)	LAI	TBY	HI
Replication	2	13.231	6.2564	4.6410	8.52	14.22	0.178	164635	0.39
Intercrop Vs. sole	1	0.077	0.137	0.259	0.68	242.67	0.313	1904277	28.80
Common bean variety (A)	1	0.094	0.1239	0.2543	51.26	305.24**	0.482	12987025*	129.72*
Maize and Common bean component densities (B)	5	1.278	0.8148	1.6898	39.86	646.80**	0.587	11782585**	39.62
A x B	5	1.472	0.9722	1.8125	5.06	6509.98**	3.319*	9292651*	198.82*
Error	22	1.453	0.8675	0.8632	21.53	36.23	1.11	3092702	33.16

DF = degree of freedom, DFE, DFT, DFS, DFM, PH,LA, LAI, BY, HI= days to 50% emergency, days to 50% tussling, days to 50%silking, days to 50%maturity, plant height, Leaf area, Leaf area index, Biomass yield, Harvest index respectively

* = significant at 5 % probability level**= highly significant at 1% probability level.

Appendix Table 2.Growth parameters of intercropped maize as influenced by common bean variety and planting density

		Mean squares								
Source of variation	D f	SNPC	Cobs plant $^{-1}$	N. of Rows cob $^{-1}$	N. of seeds/row	1000 seed weight in gm.	Yield ha^{-1} in kg	DBMY/ha in kg	Cob length in cm	Cob weight
Replication	2	139.59	0.003	0.220	1.287	100.89	84441.4	154964	0.1321	0.0002
Intercrop VS Sole	1	228.14	0.001	0.113	3.723	753.72**	674831.51*	1139691**	1.095	0.000002
Common bean variety (A)	1	110285.25**	0.406**	0.370**	422.533**	1220.52**	609436.4**	402181**	9.5790**	0.023**
Maize and Common bean component densities (B)	5	58824.69**	0.309**	0.717**	244.747**	1363.85**	586026.5**	3546435**	39.1686**	0.026**
AxB	5	36249.15**	0.202**	0.782**	163.090**	927.31**	75851.8**	118063**	16.1038**	0.016**
Error	22	64.93	0.001	0.068	0.694	78.77	15458.7	20458	0.2555	0.0008

DF = degree of freedom, CV= Coefficient of variance, SNPC and DBMY=Seed number cob^{-1}and Dry biomass yield respectively,

* = significant at 5 % probability level, **= highly significant at 1% probability level

Appendix Table 3.Phenology and growth parameters of intercropped common bean as influenced by population density of maize and common bean variety.

		Mean squares								
Source of variation	D f	DFE	DFF	DFM	NNPP	DWNPP	HSW	LA	LAI	HI
Replication	2	0.172	0.095	0.500	0.013	0.057	4.471	230.3	3.2808	6.198
Intercrop Vs sole	1	0.454	0.956	1.176	0.243*	0.180	2.048**	12.66*	1.606	35.294*
Common bean variety (A)	1	5.544**	0.394	1.196	100.467**	7.956**	68.767**	56090.8**	2.8243**	408.432**
Maize and Common bean Component densities (B)	5	0.244	0.042	0.579	0.087	0.351**	66.358**	12190.7**	3.5654**	348.674**
A x B	5	0.071	0.951	1.312	0.122	0.624**	168.974**	12308.4**	2.5450**	696.979**
Error	22	0.45	0.97	1.182	0.246	0.171	2.003	12.20	0.3671	1.963

DF = degree of freedom, CV= Coefficient of variance, DFE, DFF, DFM, NNPP, NPBB, DWNPP, HSW, LA, LAI=Days to 50% emergency, Days to50% flowering, Days to 50% maturity, Number of nodules plant^{-1}, Number of pod bearing branch plant^{-1}, Dry wait of nodule per plot, Hundred seed weight, Leaf area and Leaf area index respectively, * = significant at 5 % probability level, **= highly significant at 1% probability level

Appendix Table 4.Phenology and growth parameters of intercropped common bean as influenced by component density and bean variety.

		Mean squares							
Source of variation	D f	LN	NBPP	NPPP	NSPP	PH	PL	Y	AGBM
Replication	2	6.801	0.235	0.1031	0.005	24.6	0.025	5408	58207
Intercrop Vs sole	1	1.816	1.796	0.353*	0.1324*	15.25	0.2172*	26.28**	278.2*
Common bean variety (A)	1	14.883**	7.086	64.086**	7.665**	10760.6**	52.725**	16504800**	153853588**
Maize and Common bean component densities (B)	5	15.828**	2.667	16.113**	0.243**	2222.2**	6.305**	394969**	2090528**
Ax B	5	7.036	5.408	12.609**	1.989**	1173.2**	3.811**	397139**	3966095**
Error	22	1.704	1.825	0.348	0.134	15.48	0.217	52.85	275.5

DF = degree of freedom, CV= Coefficient of variance, LN, NBPP, NPPP, NSPP, PH, PL, Y, ABM, DBM= Leaf number, Number of branch plant^{-1}, Number of pod plant^{-1}, Number of seed pod^{-1}, plant Height, Pod length, Yield/ha, Above ground biomass, Dry biomass yield,* = significant at 5 % probability level, **= highly significant at 1% probability level

Appendix Table 5. Effect of variety and component density on yield advantages of maize/common bean intercropping.

		Mean squares						
Sources of variation	DF	PLER		Total LER	GMV and MV in ETB/ha			
		maize	Common bean	LER	maize	Common bean	GMV	MV
Replication	2	2.737	0.0008	0.0008	1.570	10230	9.477	8.260
Common bean Varieties (A)	1	7.381**	0.0187**	0.5220**	4.234**	132902	4.385**	3.247**
Maize and Common bean Component densities (B)	5	2.326**	0.0210**	0.2386**	1.334**	25711495**	1.475**	1.535**
AXB	5	2.455**	0.0137**	0.1603**	1.408**	16961383**	7.302**	7.914**
Error	22	4.079	0.00005	0.0001	2.340	36442	4.267	5.684

DF=degree of freedom, CV= Coefficient of variance, PLER, LER, GMV, MV, ETB/ha=Partial land equivalent ratio, Land equivalent ratio, Gross monitory value, Monitory value, Ethiopian Birr per hectare respectively, **= highly significant at 1% probability level, NS= Non-significant

Appendix Table 6.Rainfall and temperature distribution at Jimma during production season of 2014.

Month	Rainfall (mm)	Min. Temp. (°C)	Max. Temp. (°C)	Mean Temp. (°C)
January	6.1	11.3	25.6	18.45
February	21.3	10.7	26.2	18.45
March	397.9	10.4	23.8	17.1
April	258.5	11.6	25.6	18.6
May	262.2	11.9	25.5	18.7
June	142.8	10.6	26	18.3
Mean	181.5	11.1	25.5	18.3

Source: (Jimma Agricultural Research Centre Metrology Station)