EFFECT OF MAIZE AND COMMON BEAN INTERCROPPING PATTERN ON YIELD AND YIELD COMPONENTS OF INTERCROPS AND PRODUCTIVITY OF THE SYSTEM AT FAFAN, SOMALI REGION, EASTERN ETHIOPIA

MSc. THESIS

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Effect of Maize and Common Bean Intercropping Pattern on Yield and Yield of the Components of Intercrops and Productivity of the System at Fafan, Somali Region, Eastern Ethiopia

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We hereby certify that we have read and evaluated this Thesis entitled "**Effect of Maize and Common bean Intercropping Pattern on Yield and Yield of the Components of intercrops and Productivity of the System at Fafan, Somali Region, Eastern Ethiopia ",** which has been prepared under our guidance by **Abdullahi Mohammed Abdi**. We recommend that it be submitted as it fulfills the requirements.

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As members of Board of Examiners of the MSc Thesis Open Defense Examination, we certify that we have read and evaluated the Thesis prepared by Abdullahi Mohamed Abdi and examined the candidate. We recommend that the thesis be accepted as it fulfills the requirements for the degree of Master of Sciences in Agriculture (Agronomy).

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DEDICATION

I dedicate this thesis to my father Mohamed Abdi and my mother Amino Ali who have been struggling to eradicate illiteracy from our family and Abdirahman Osman Arale (Assistant Professor) who helped me during thesis preparation including advice related accomplishments of establishing thesis write up and Jabarti Omar who deeply helped me during research's transportation vehicles services in Fafan experimental site. My best thank giving goes also directly to Khalid Ibrahim who assisted me during editing thesis in a good manner

STATEMENT OF THE AUTHOR

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BIOGRAPHICAL SKETCH

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ABBREVIATIONS

PCDP	Pastoral Community Development Project
ATVET	Agricultural Technical Educational Training
ACOS	Agricultural Commodity Supplies
BNF	Biological Nitrogen Fixation
CEC	Cation Exchange Capacity
CGR	Crop Growth Rate
CSA	Central Statistics Agency
EIAR	Ethiopian Institute of Agricultural Research
ESA	Eastern and Southern Africa
GNI	Gross National Income
LER	Land Equivalent Ratio
NARS	National Agricultural Research systems
NBRP	National Bean Research Program
NUE	Radiation Use Efficiency
ANOVA	Analysis of Variance
RUE	Radiation Use Efficiency
SNNPR	Southern Nations, Nationalities and People's Region
SoRPARI	Somali Regional Pastoral and Agro-pastoral Research Institute
WUE	Water Use Efficiency
TA	Technical Assistant

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ABSTRACT

Intercropping is one of the intensive cropping systems which ensure sustainable utilization of limited land resources. Maize-common bean intercropping is often considered to be the best strategic cropping system to overcome the problems of adverse effects of shortage of rainfall. Cereal-legume intercropping is common in Ethiopia but intercropping of common bean and with maize (Zea mays L.) is a recent practice in maize based cropping system of many areas in Ethiopia. The objective of this study was to to assess the effect of intercropped maize and common bean planting patterns on growth, Yield components and yield of the component of inter crops and to identify the appropriate maize and common bean intercropping pattern that can maximize the productivity of the intercrop system. Field experiments were conducted at Fafan research center during 2012. Seeding materials used experimental site was early maturing Maize Malkasa two and Common Bean Awash Melka with white colored. Treatments ware consisted of three inter row spacing (60, 75 and 90 cm) of maize and three intercropping (without and with one and two rows of common bean in maize) and sole common been arranged in randomized complete block design replicated three times. The plot size was arranged as 4.5 m x 3 m (12.15m^2) with 1 m path in between each plot and 1.2 m space in between blocks. Results indicated that for maize, plant height, Thousands grain weight, grain yield, Stover yield and harvest index were significantly affected whereas Days to tasseling, plant physiological maturity, plant stand count at both initial and at harvest were not significantly affect at maize intercropped with common bean.

Keywords: Cropping system, number of seeds per pod, Economic returns Maize equivalent yield, Land equivalent ratio, Paired row, Single row**.** And without.

1. INTRODUCTION

Maize (*Zea mays* L.) has become the third most important cereal crop in the world because of its high adaptability and productivity (Mosisa *et al*., 2002). Globally maize is grown under diverse climatic conditions but better yield is obtained under moderate temperatures with sufficient water (Aldri *et al*., 1978). However, on the African continent, it is the most important food crop and mainstay of rural diets in the eastern and southern regions (Maredia, *et al*., 2000; Pingali and Pandey, 2001; FAO, 2003). Therefore, maize occupies an important position in Africa and on the global economy where it is traded as a food, feed and industrial grain crop. On the African continent, rained agriculture is confronted with unreliable or erratic rainfall and recurrent drought with subsequent production failures..

In Ethiopia, cereals account for about 80% of the annual crop production and maize is the first in total production and yield per unit area and second in area coverage among all the cereals. In Ethiopia, it is an important crop because of its high productivity per unit area, suitability to major agro-ecologies, compatibility with many cropping systems and ease of traditional dish preparation. Maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands in the country (Kebede *et al*., 1993). Summer season post-harvest crop production survey indicated that total land area of about 12,086,603.89 ha was covered by grain crops in 2011-12, out of which 79.34% (9,588,923.71 ha) was under cereals. Of this maize covered 17% (about 2,054,723.69 ha) and gave 6069413 ton (t) of grain yield. Thus, maize has great potential in contributing to total food production in the country. Despite the large area under maize, the national average yield is about 2.95 t/ha (CSA, 2012) which is by far below the world's average yield which is about 5.21 t/ha (FAO, 2012).

Low soil fertility, limited availability of resources to farmers, nutrient mining, and drought are the main causes for low agricultural productivity in Sub-Saharan Africa. Suitable technologies that are accessible to resource-poor farmers must be affordable in terms of labor, land and capital investments. This is, however, often not the case (Sanchez, 2002). Fertilizers are essential to improve agricultural production in densely populated regions, and this was acknowledged during the Africa Fertilizer Summit held in Abuja, Nigeria in 2006. Mineral fertilizer prices continue to increase. Integrated soil fertility management (ISFM) options therefore aim at optimizing the agronomic efficiency of applied inputs (Vanlauwe et al., in press).

Major components include improved germplasm, mineral fertilizer application and organic matter management. By making effective use of resources, ISFM options maximize the profitability of investments in soil fertility. Legume integration is an important component of ISFM technologies. Legume–cereal intercropping, especially maize beans intercropping, is common throughout East and Southern Africa (Giller, 2001). In drier areas, common beans are often replaced by cowpea or groundnut. Farmers commonly intercrop to secure food production by averting risk, and to maximize utilization of land and labor. When crops are complimentary in terms of growth pattern, aboveground canopy, rooting 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.

Intercropping is one of the intensive cropping systems which ensure sustainable utilization of limited land resources. The extent and importance of intercropping increases as farm size decreases and the smaller the farm size the more complex the combinations. In tropics, cereal/legume intercropping is commonly practiced because of yield advantages, greater yield stability and lower risks of crop failure, which are often associated with monoculture (Nielsen *et al*., 2001; Tusbio *et al*., 2005). In intercropping systems, legumes can provide N for intercropped cereals through N transfer or N fixation (Rochester *et al*., 2001).

Maize-common bean intercropping is often considered to be the best strategic cropping system to overcome the problems of adverse effects of shortage of rainfall. However, varietal selection of maize and legumes in the area target only sole cropping system without considering the relative performance of varieties of varying morphologies under mixed cropping.

The main benefits of intercropping is an increase in yield and productivity per area of land, 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. Legume-cereal intercropping is a productive and sustainable system by its nutrient facilitation, and its effect to increase N uptake for intercropped cereal; via symbiotic nitrogen (N_2) fixation. The aim of this work was to test effect of maize-common bean intercropping system on the growth, nodulation, yield and N uptake.

Legumes play a significant role in soil fertility maintenance and improvement of cropping systems due to their atmospheric N fixing capacity. Growing legumes, particularly soybean and common bean, in association with cereals contribute to increased productivity of other crops when incorporated into cropping systems as intercrops (Giller and Wilson, 1991). Currently there is scarcity of land available for agricultural production. Thus, the increase in agricultural production could be achieved by improving agricultural practices, through multiple cropping (Sahota *et al.,* 1988) so as to intensify land uses aiming at achieving high yield per unit area of land.

However, finding the optimum distance between neighboring rows and plants in any intercropping systems at any particular plant density has several advantages and is another attempt to further increase biological productivity of the system. The more favorable planting pattern provided by closer rows enhances maize growth rate early in the season. Leading to a better interception of sunlight, higher radiation use efficiency and a greater grain yield (Westgate *et al*., 1997). Secondly, the maximization of light interception derived from early canopy closure also reduces light transmittance through the canopy. Thirdly, quicker shading of the soil surface during the early part of the season results in less water lost by evaporation (Karlen and Camp, 1985). This is especially important under favorable soil water conditions; because it allows maize plants to maximize photosynthesis and the proportion of water that is used in growth processes rather than evaporated from the soil (Lauer, 1994). Furthermore, earlier crop cover provided by narrower row widths enhance soil protection, diminish water runoff and hence, control soil erosion (Mannering and Johnson, 1969; Sangoi *et al*., 1998). At low densities, grain yield is limited by the inadequate number of plants whereas at higher densities, yield declines mostly because of an increase in the number of aborted kernels and/or barren plants (Swank *et al*., 1982).

Optimum plant density should be maintained to exploit natural resources, such as nutrients, sunlight and soil water fully to ensure satisfactory yields. There is no single recommendation for all conditions, because the optimum plant density varies depending on environmental factors such as soil fertility, water supply, crop management and genotype. For each production system, there is a plant density that optimizes the use of available resources, allowing the expression of maximum attainable grain yield in that environment.

Therefore, evaluating different inter row spacing for maize, and row arrangement for intercropped common bean to achieve higher yield may possibly provide improved intercropping systems as an alternative to sole cropping under limited irrigation. Thus an experiment was conducted at Fafan with the following specific objectives:

- To assess the effect of intercropped maize and common bean planting patterns on growth, Yield components and yield of the component of inter crops and
- To identify the appropriate maize and common bean intercropping pattern that can maximize the productivity of the intercrop system.

2. LITERATURE REVIEW

2.1. Adaptation and Production Potential of Maize

Maize (*Zea mays* L.) is a warm weather crop and is not grown in areas where the mean daily temperature is less than 19 ºC or where the mean of the summer months is less than 23 ºC. Although the minimum temperature for germination is 10 ºC, germination will be faster and less variable at soil temperatures of 16 to 18 ºC. At 20 ºC, maize would emerge within five to six days. The critical temperature detrimentally affecting yield is approximately 32 ºC. Frost can damage maize at all growth stages and a frost-free period of 120 to 140 days is required to prevent damage. While the growth point is below the soil surface, new leaves will form and frost damage will not be too serious. Leaves of mature plants are easily damaged by frost and hail grain filling can be adversely affected (Ghanbari and Dahmardeh, 2010). Approximately 10 to 16 kg of grain is produced for every millimeter of water used. A yield of 3152 kg/ha requires between 350 and 450 mm of rain per annum better to maintain at maturity, each plant will have used 250 l of water in the absence of moisture stress.

The most suitable soil for maize is one with a good effective depth, favorable morphological properties, good internal drainage, and an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favorable specifically for maize production. Although large-scale maize production takes place on soils with a clay content of less than 10% (sandy soils) or in excess of 30% (clay and clay-loam soils), the texture classes between 10 and 30% have air and moisture regimes that are optimal for healthy maize production (Vandermeer, 1989)

2.2. Importance and Uses of Maize

In sub-Saharan Africa, maize is a staple food for an estimated 50% of the population and provides 50% of the basic calories. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Africans consume maize in a wide variety of porridges, pastes, grits, and beer. Green maize (fresh ear) is eaten parched, baked, roasted or boiled and plays an important role in filling the gap in grain shortage after the dry season. Maize grains have great nutritional value as they contain 72% starch, 10 % protein, 4.8% oil, 8.5% fiber, 3.0% sugar and

1.7% ash. Maize is the most important cereal fodder and grain crop under both irrigated and rain fed agricultural systems in the semi-arid and arid tropics.

2.3. Adaptation of Common Bean

Common bean 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. The crop requires moderate amounts of rainfall (300 – 600 mm) but adequate amounts are essential during and immediately after the flowering stage. 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 maturity (Buruchara, 2007). Maturity period can continue up to 200 days after planting amongst climbers that are used in cooler upland elevations (Graham and Ranalli, 1997). The crop is not sensitive to soil type as long as it is reasonably fertile, well-drained and does not have suffer much from conditions that interfere with germination and emergence (Wortmann *et al*., 1998).

Common bean has been considered a high priority in recent years because of its significance in domestic consumption and as an export crop whereby dry beans are sold fresh immature beans and dry flour beans in food markets throughout Ethiopia. The largest proportion of production comes from small-holder farmers especially in central rift valley followed by southern, eastern and western part of the country (Tsedeke, 1995). Though the production share is lower, it has expanded to Afar, Amhara, Tigray, Somali, Gambella and Benshangul-Gumuz (Dawit, 2005). Apart from common bean expansion to these regions, types of common bean grown and the contribution of the regions to the export and domestic markets was not yet identified. However, the largest production which accounts for about 85 percent of the total national production comes from Oromia and the Southern Nations, Nationalities and People’s Region (SNNPR) and on average 100 to 200 thousand tons per year is produced from these regions (Ferris and Kaganzi, 2008). Among two use groups of common beans, white canning and colored food type, the white beans dominate in the Oromia region (Northeast Rift Valley), where more than 95 percent of farmers grow it and account for about 50 percent of total common bean production.

The area under common bean production tends to increase because bean intercropping with other crops like maize and sorghum is widely used (Charles *et al.*, 1998). Common bean as an export commodity and food crop is an established component of Ethiopian agriculture. It is used in crop rotation, intercropping and alley cropping systems (Firew, 1997). During the year 2001-2007, there was 11.1 percent growth rate in area and the yield accelerated rapidly to 11 percent growth rate.

Common bean and chickpea are also major legumes, with both a production of more than 200,000 m tgrain. On the world market, Ethiopia ranks 6^{th} in chickpea production and 14^{th} in production of common bean (ICRISAT, 2011). Among African countries, Ethiopia is the largest producer of both chickpea and common bean. In total, the area cultivated with the selected legumes is more than 1 million ha. Production per ha is low and far below the potential production of e.g. 2.9 t/ha for chickpea and 4 t/ha for common bean and faba bean (IFPRI, 2010)

2.4. Maize and Common bean Intercropping Research in Ethiopia

Maize and common bean co-exist in maize belt areas of western Ethiopia. Common bean is planted as intercrop, alleys and rotations with maize in mid altitude sub-humid areas of western Ethiopia where maize-legume cropping systems show considerable promise in boosting productivity and helping reverse the decline in soil fertility (Dagne *et al.,* 2012*)*. In all zones of western Ethiopia (West Wellega, East Wellega, Kelem Wellega, Horoguduru Wellega, Illubabor and Jimma), both maize and common bean were grown on a land area of 449,194 and 18,448 ha, respectively so that the crops could secure main staple and important dietary protein source (CSA, 2011).

Maize and bean co-existence could also pave the way to a strategic mitigation of mono-cropping which is drastically reducing land and crop productivity. Maize mono-cropping reduced yield by 15% and 30% with and without the use of inorganic fertilizer, respectively at Bako Agricultural Research Centre. Complete crop failure in continuous maize mono-cropping without N application was reported at Melkassa, Central Rift Valley of Ethiopia. While concluding thirty years experiment, in India it was stated that growing the same crop continuously on the same land reduced the average yields of crops, but through multiple cropping including legumes, the crops gave nearly twice as much the yields as they produced under continuous cropping (Dixit, 2007).

In Ethiopia, different maize technologies, improved varieties and management practices have been recommended for various maize agro-ecologies over the years. In research review by appropriate cropping systems for maize production regions of Ethiopia were compiled and described interactions of soybean genotypes with maize. In their review, the authors identified medium maturing soybean groups that have better performance in maize/soybean intercropping. Farmers' variety preference assessment in southern Ethiopia by resulted in selection of white pea beans for their seed size, seed colour and marketability. In Bako area, medium sized and coloured beans were preferred for better yield, smart colour and early maturity for sole production (Girma *et al.*, 2004). Hence, the works have limitations in identifying bean varieties suitable for intercropping.

In Ethiopia, an estimated total number of about 40 maize varieties which included both open pollinated and hybrids have been released until the year 2008 G.C among which 29 of them are now under production whereas 17 of them are adaptable to Bako and areas with similar agro-ecology. Similarly, over more common bean varieties have been released and many of them are under production in mid and low altitudes.

However, research on intercropping in the country has often been commonly carried out using a few crop varieties often released for sole cropping system. In the case of common bean, both varietal development and approval are primarily dependent on export market and local food preferences and less attention is given for growth habit and morphology which determine suitability for intercropping system. When choosing common bean lines tested for value of cultivation and use in different environment, Ranoel *et al.* (2009) identified growth habit as the most relevant trait. Most of the maize varieties released earlier were hybrids having deep canopy and droopy leaves that limit the growth of component crops in intercropping systems due to competition for growth factors. However, some of the maize varieties released in more recent years have leaf arrangement and canopy structure that are distinct from the early ones creating some interest among agronomists to test them under intercropping systems.

Although, maize/common bean intercropping research activities have been undertaken in Ethiopia in many places, concrete information is lacking on growth characteristics positively influencing growth of companion crops useful for use in intercropping. The focus of common bean genetic improvement program by Ethiopian Research Institutes has been on most commercially accepted varieties, pure red and white beans to support the commercial sector (Ferris and Kaganzi, 2008). Compatibility study of common bean varieties in maize/bean intercropping systems and their adaptation to various soil types and agro-ecologies is not well addressed (Tesfa *et al*., 2012). Interaction effect of variety by cropping system is expected to be arising from morphological features such as leaf arrangement, canopy size, canopy, and shape as well as growth habit. For sustainable intensification of maize and common bean in maize-based cropping system of western Ethiopia, growth and morphological characters determining suitability of varieties of the two crops under intercrop conditions need to be understood.

2.4.1. Intercropping

Intercropping is the growing of two or more crops per unit of time and space, which is among the alternative methods used in developing countries like Ethiopia for sustainable crop production. Intercropping is a component of multiple cropping systems and can be defined as the growing of two or more crop species simultaneously in the same field during a growing season. The crops may not necessarily be sown at exactly the same time and their harvest time may be quite different, if there is a significant amount of intercrop competition during all or part of the growing period (Willey, 1979). Thus, the essence of intercropping is intensification of crop production in both space and time. Intercropping is presently a major method of crop production in tropical Africa, subtropical Asia, Central and South America, especially in countries where it is not possible to bring more land into cultivation or increase yields at the rate required by the population growth.

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, Aggarwal *et al.*, 1992); higher yield and greater land use efficiency (Andrews and Kassam, 1976; Ofori and Stern, 1987); inexpensive weed control (Enyi, 1973); minimization of agricultural risks (Norman, 1974; Fisher, 1976; Jodha, 1979; Rao and Willey, 1980), improvement of soil fertility (Agboola and Fayemi, 1972)., and minimization of peak of labor demand.

2.4.2. Intercropping and Resource use

There can be situation where a given crop would actually grow better in the presence of another crop than as a sole crop (Willey, 1979). Usually a yield advantage occurs because component crops differ in their use of growth resources in such a way that when they are grown in combination they are able to complement one another and so make better overall use of resources than when grown separately (Harderson and Danso, 1993; Wani *et al.,* 1995). In 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 complementarily between the component crops and minimizing inter-crop competition (Willey, 1979; Rezende and Ramalho, 1994). On this basis, intercropping advantages are more likely to occur where the component crops are very different. Probably the prime way in which complementarily can occur is when the growth pattern of the component crops differs in time so that the crops make their major demands on resources at different times. Common bean and maize normally have different duration of growth so that, when grown together, bean utilizes resources earlier than maize.

2.5. Efficient Resource Utilization and Yield Advantage

The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity than each sole crop of the mixture. Yield advantage occurs because growth resources such as light, water, and nutrients are 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.

Intercropping of legumes with cereals can play a major role in improving farm productivity in smallholder agriculture. They can increase plant nutrient supply in the soil (especially N) and improve soil physical characteristics, thereby improving crop yields For instance, maize intercropped with *Dolichos* spp. had the highest mean grain yield followed by maize intercropped with soybeans while pure stand of maize had the lowest yield Legumes can also provide good ground cover, thereby minimizing soil erosion through reduction of raindrop impact and runoff.

Cereal crops can be benefited from the associated legumes through immediate transfer in which fixed N travels from the legume directly to the associated crop. Giller (2001) reported that intercropped maize has been shown to benefit from associated soybean plants due to the transfer of N from the legume to the maize and therefore farmers could reduce their N inputs by growing N-fixing crops.

Legume-cereal intercropping is a productive and sustainable system by its nutrient facilitation, and its effect to increase N uptake for intercropped cereal; via symbiotic nitrogen (N_2) fixation. Most studies on intercrops systems reporting legume-cereal intercropping, a productive and sustainable system, and its resource facilitation which consist of growing, soil's fertility and yield (Ofori and Stern, 1987; Jensen, 1996). Nitrogen (N_2)-fixing legume is an important resource for intercropped cereal; Betencourt *et al*., 2012) which benefited from the nitrogen uptake and improved grain yield.

Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize alone (Ghanbari *et al*., 2010). This yield advantage occurs when the component crops do not compete for the same ecological niches and the interspecific competition for a given resource is weaker than the intra-specific competition. Asynchrony in resource demand ensures that the late maturing crop can recover from possible damage caused by a quick-maturing crop component and the available resources, e.g. radiation capture over time, are used thoroughly until the end of the growing season (Keating and Carberry, 1993). In contrast, when the component crops have similar growth durations their peak requirements for growth resources normally occur about the same time and the competition for natural recourses have been rereported in several studies in semi-arid environments. On the basis of these studies, intercropping has been advocated to increase crop yield and improve yield stability in environments where water stress frequently occurs.

2.6. Improvement of Soil Fertility and Nutrient Use Efficiency (NUE)

Common bean and maize exploit different forms of nitrogen since beans have the potential to fix atmospheric nitrogen, while maize relies on the available nitrogen in the soil Intercropped stands are known to extract more nutrients from the soil than sole stands. In experiment conducted in Trinidad involving a 1:1 proportion of maize-red gram intercropping system, it was found that intercropping system removed 30 to 63% more nutrients than the sole (Sanchez, 1976). Either crop in row intercropping was more efficient than mixed intercropping in terms of dry matter production and nutrient up take.

Legumes enrich soil by fixing the atmospheric nitrogen changing it from an inorganic form to forms that are available for uptake by plants. Biological fixation of atmospheric nitrogen can replace nitrogen fertilization wholly or in part. Moreover, because inorganic fertilizers have contributed to environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as an alternative and sustainable way of introducing N into lower input agro-ecosystems In addition, the green parts and roots of the legume component can decompose and release nitrogen into the soil where it may be made available to subsequent crops. The benefits of a legume intercrop with respect to nitrogen are direct transfer of nitrogen from the legume to the cereal during the current intercrop and residual effects when the fixed nitrogen becomes available on the sequential crops after the senescence of the legume and the decomposition of residues. Thus, the use of legumes in mixtures contributes some nitrogen to the cereal component and some residual nitrogen to the following crops (Adu- Gyamfi *et al*., 2007). The main pathway of conservation of other nutrients is through the return and decomposition of crop residues (Rahman *et al*., 2009).

2.6.1. Water Use Efficiency (WUE)

Water is a most important soil factor in semiarid and subtropical regions, where intercropping is extensively practiced in dug land farming system and inadequate rainfall may frequently limit crop production (Baker and Norman, 1975). The difference in root system, depth of rooting, lateral root spread and root density are factors that affect competition for water between component crops.

The availability of water is one of the most important factors determining productivity in cereal legume intercropping systems. Improvement of water use efficiency in these systems leads to increases the uses of other resources (Hook and Gascho, 1988), and it has been identified to conserve water largely because of early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Hulugalle and Lal (1986) found that WUE in a maize-cowpea intercrop was higher than in the sole crops, when soil water was not limiting. However, under water limiting conditions, WUE in the intercrop compared to sole cereal can be higher resulting in returned growth and reduced yield (Ofori and Stern, 1987).

2.6.2. Radiation Use Efficiency **(**RUE)

The highly productive intercropping systems compared to sole crops may be attributed to better light utilization by a crop canopy composed of plants with different foliage distribution (Willey, 1979). It also reported efficient utilization of light by intercrop and as a result higher seed yield per unit area were obtained. Through simultaneous production of more than one crop on the same piece of land, large leaf area duration is obtained by partial sequencing of the canopies and their time of assimilation (Chatterjee and Mairi, 1984). Adjustment of population density, proportion of each component in the mixture and planting pattern can be manipulated to minimize competition and to increase the light use efficiency Gardiner and Cracker (1981) reported increased light interception and decreased light reflection in bean-maize intercrop. However, the quantity of light available to the bean canopy was decreased as the maize population increased. Field experiments conducted in South Africa during the period of 1998-2000 to compare production efficiency in intercropping with sole cropping in terms of radiant energy use revealed that intercropping was more efficient in radiation harvests than sole cropping.

In intercropping between high and low canopy crops is to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller once (Seran and Brintha, 2010). For instance, it is reported that the radiation intercepted was higher in maize-bean intercropping than that of the sole crop found that intercropped bean with maize had 77% higher RUE than sole-cropped beans. Mucheru-Muna *et al.* (2010) reported that the RUE system increases maize and legume yields through higher light penetration. Keating and Carberry (1993) found that maize – soybean intercropping has better use of solar radiation than the mono-crops.

2.7. Weed Control Mechanisms

Weed growth basically depends on the competitive ability of the whole crop community, which in intercropping largely depends on the competitive abilities of the component crops and their respective plant populations (Willey *et al.*, 1983). For instance, intercropping of cereals and cowpea has been observed to reduce *Striga* infestation significantly. This was attributed to the soil cover of cowpea that created unfavorable conditions for Striga seed germination found that maize-bean intercropping reduced weed biomass by 50-66% when established at a density of 222,000 plants ha^{-1} for beans equivalent to 33% of the maize density (37,000 plants ha^{-1}).

2.8. Response of Maize to Population Density and for Grain and Biomass Yield

Maize plant population for maximum economic grain yield varies from 30,000 to 90,000 plants ha^{-1} depending on variety planting date, water availability, soil fertility and maturity. Improved endurance in high stands has allowed maize to intercept and use solar radiation more efficiently, contributing to the remarkable increase in grain yield potential. Pepper (1974) reported that increased plant densities promote utilization of solar radiation by maize canopies. However, efficiency of conversion of intercepted solar radiation into economic maize yield will decrease with high plant density because of mutual shading of plants. Dry matter production in crop plants is directly related to the utilization of solar radiation, which is influenced by canopy structure observed that total dry matter production was a maximum at the highest plant densities.

Plant density affects yield by influencing yield components such as number of ears, number of kernels per ear and kernel mass (Ahmadi *et al*., 1993). Low plant density results in unnecessary sacrifice of yield and higher density also lead to unnecessary stress on the via competition plants.

Plant density is dependent on both row width and intra raw spacing and under dry conditions row width should not be too narrow as this can increase competition between plants and results in yield. However, under optimum water and nutrient supply, high plant per unit area, with eventual increase in grain yields.

The ideal plant number per unit area depends on several factors, such as water availability, variety soil fertility, hybrid maturity and row spacing (Staggenborg *et al*., 1999); Under optimum water and nutrient supply, high plant density can result in an increased number of cobs per unit area, with eventual increase in grain yield Larson and Clegg (1999) also reported that full growing season hybrids could produce high yield at a high plant density under optimum water and nutrient supply. Unlike full season hybrids, short growing season (early) hybrids might improve yield stability, especially during adverse years because growth is nearer to completion before the traditional mid-summer drought begins.

2.9. Maize and Common Bean Cropping System

Common bean is grown most commonly in traditional association with maize and sorghum and occasionally grown as sole crops. They are grown in complex associations involving two or more crops, banana, maize, sweet potatoes, coffee, cassava and peas while the common is with bananas. Maturity differences between intercropped species have to be quite large to obtain the benefits of temporal separation, suitability of beans and maize intercrop indicate an advantage for early maturing beans associated with late maturing maize (Osiru, 1982). Spatial arrangement of maize/bean intercropping with two bean rows between maize rows had low *Striga* emergence with maize yield un-affected by intercropping.

Maize intercropping with common bean at planting ratio of 2:1 (maize: bean) at Adami Tullu and Siraro, eastern Shewa, resulted in low LER (1.1) due to substantial reduction in grain yield of beans attributed to faster growth of maize at an early stage resulting in smothering of the beans with low supplemental yield (Tesfa *et al.,* 2012). Similar work by the authors at Jimma and Areka exhibited LER of 1.5 whereas suitable bean varieties, spatial and temporal arrangements of bean in maize/common bean intercropping were identified. According to Dagne *et al.* (2012), at Hawasa, LER of 1.7 was obtained for intercropping of 100% common bean with

100% maize, while LER of 1.6 was realized for intercropping of 50% haricot bean with 100% maize. The result at Bako and Pawe, reported by the authors were LERs of 1.2 and 1.4, respectively.

2.10. Effect of Intercropping on Maize and Bean Growth and Yield

The grain yield of maize in maize/bean mixed planting was reduced, but this was partly compensated by the yield of bean as well as by the higher protein content of the mixed crop. A drastic reduction by 31% maize yield was reported when intercropped with climbing bean by Francis *et al.* (1982). The yield difference in crop mixtures is influenced by not only the presence of other crops, but also by densities and spatial arrangements of crops and resource availability in the two systems (Hegewald, 1991). The superiority of mixed cultivars over pure stands has been attributed generally to the significant variation in morphological characteristics, including root system, plant height and leaf orientation, which result in efficient exploitation of environmental resources, specifically, light interception, increased lodging resistance (Grafius, 1996), improved disease resistance (Wolfe, 1985), and better weed control.

The plant population of maize was kept constant and that of climbing bean was reduced in the maize/climbing bean intercropping system by Setegn *et al.* (2006) who reported that number of pods per plant was reduced by 65% and 55% when climbing bean was grown with BH-540 and Guto, respectively. The authors also emphasized that 10% yield advantage was obtained by growing climbing beans in mixture with maize as compared to sole crop yields. Yield and yield related traits of dry bean were all affected by maize/bean intercropping, but plant height, number of branches per plant and harvest index were not affected (Ciftci *et al.*, 2006).

2.11. Indices for evaluating productivity and efficiency of intercropping

Proposed LER concept to be used as an index of combined yield for evaluating the effectiveness of all forms of intercropping. Different indices have been suggested for evaluating productivity and efficiency per unit area of land of cereal-legume intercrop system (Beets, 1982; Palaniappan, 1985; Willey, 1985; . These include comparisons of absolute yield, protein yield, multiple cropping indexes, diversity index, and in economic terms, gross returns from intercrop and sole crop.

Yield advantage of intercropping can be indicated by using different methods, among which land equivalent ratio (LER) is the most commonly used to indicate the biological efficiency and yield per unit area of land as compared to sole cropping. Reddy, (1984) defined LER as the relative land areas under sole crop that is required to produce the yield achieved by intercropping. Generally, monoculture legumes have higher yields than to yields in an intercropping system. However, in most cases, land productivity measured by LER clearly shows the advantage of mixed cropping of cereals and legumes (Mandal *et al*., 1990). LER gives an indication of magnitude of sole cropping required to produce the same yield on a unit of intercropped land. Perhaps due to the adequate moisture availability to the intercrops that did not result into competitive behavior during long rains season, LER >1 was recorded (Odhiambo and Ariga, 2001).

According to Tolera *et al.* (2005) intercropping maize- common bean gave the highest yield advantage and land use efficiency of 46, 98 and 72% over sole cropping from the result of two consecutive years and combined over two years, respectively. The author also indicated that over all LER of intercropping is greater than sole cropping of component, crops meaning that LER in intercropping indicates the yield advantage both in relative yield and total LER of component crops. It is, however, important to present actual yields along with LER in reporting the results of intercropping studies (Palaniappan, 1985). Generally, the value of LER is determined by several factors including density and competitive abilities of the component crops in mixture, crop morphology and duration, and management variables that affect individual crop species. It has been suggested that in density studies of cereal–legume intercrop systems, the sole crop yield used as standardization factors for estimating LER should be at the optimum densities of the crop.

3. MATERIALS AND METHODS

3.1. Descriptions of the Experimental Site

The experiment was conducted at Somali Region Pastoral and Agro Pastoral Research Institute Center Fafan (latitude 09^{o}21′7″N; longitude 42^{o}49′7″E; elevation 1672 m above sea level) located in eastern highlands of Ethiopia. The area represents one of the excellent areas of Somali Region for the production of cereal crops and livestock. Fafan is characterized with light sandy loam soil with pH 7.0, organic matter content of 1.9%. The area has maximum and minimum temperatures of 30^{0}C and 10^{0}C, respectively, and annual rainfall of 660 mm. The annual mean minimum and mean maximum temperature is 18^0 and maximum 28^0 C, respectively with a total annual rainfall of 722 mm,. The rainfall occurs during the months of October – December (*Deyr*) and April -July (*Gu'*).

3.2. Experimental Materials

Maize variety of Melkasa-2 and common bean variety Awash Melka were used in this study. Maize variety is well adapted in Fafan area and is popular with the farmers. It is intermediate (120-140 days) in maturing. Plant height may vary up to 2 meters depending on the environmental conditions and grain color normally is white and resistant to disease. Common bean variety is white colored and is well adapted to the study area.

3.3. Treatments and Experimental Design

Treatments were consisted of three inter row spacing (60, 75 and 90 cm) of maize and three intercropping (without and with one and two rows of common bean in between two rows of maize) and sole common been arranged in randomized complete block design replicated three times.

3.4. Experimental Procedure and Crop management

Land preparation was done at the beginning of February 2015 with oxen to a fine tilth as well as to get a fine seedbed and leveled manually before the field layout was made. Both maize and climbing common bean varieties were planted simultaneously in February, 2015. After preparing the lay out the plots were manually leveled. The plot size was 4.5 m x 2.7 m (12.15m^2) with 1.0 m path in between each plot and 1.2 m space in between blocks. The intra row spacing for maize was 30 cm. Thus there were 55555, 44444 and 37037 plants /ha. There were 8, 6 and 5 rows of maize under 60, 75 and 90 cm spacing, respectively. Common bean seeds were planted in between maize rows. The treatment having one row of common bean in between two rows of maize spacing were 60, 75 and 90 cm while under two rows of common bean the spacing between common bean rows were 50cm. At harvest, three rows (2+1) in plots having 60 cm row spacing and two rows, one from each side of the plots having 75 and 90 cm spacing were border rows. Two plants one each from each end of the rows was taken as border plants. Thus the net plot size was be 3 m x 2.1 m, 3.0 m x 2.1 m and 2.7 m x 2.1 m for 60 cm, 75 cm and 90 cm row spacing which provided 55555, 44444 and 37037 plant population/ ha respectively.

For sole common bean, inter and intra row spacing was 40 and 10 cm and the net plot area was 4.5 m x 1.0 m. Planting was done at the beginning September. Two seeds per hill were placed at the specified spacing. Common bean seeds were planted in between the two rows of maize. After emergence the plants were thinned to one plant per hill. A uniform dose of recommended fertilizer (64 kg N and 46 kg P_2O_5/ha was applied. At planting 18 kg N and full dose of P_2O_5 was drilled in furrows through DAP while out of remaining N, 1/3rd and 2/3 rd dose was top dressed at knee and pre tasseling stages through urea. For sole common bean 18 kg N/ha and 46 kg P_2O_5/ha was be applied at the time of sowing through DAP. All the other recommended packages of agronomic practices were applied followed to raise the crop.

3.5. Soil Sampling and Analysis

Soil sample was taken at a depth of 0-30 cm in a zigzag pattern randomly from the experimental field. Composite samples were prepared for analysis to determine the physico-chemical properties of the soil of the experimental site. The composited soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Soil sample was analyzed at soil laboratory. Total nitrogen was determined following Kjeldahl procedure as described by the soil pH was determined by using a digital pH meter. Organic carbon was determined following wet digestion method as described by Walkley and Black, (1934); and the available phosphorous was measured using Olson II methods (Olsen *et al.*, 1954); cation exchange capacity (CEC) was determined by ammonium acetate method and soil texture was determined by Bouyoucons Hydrometer method

3.6. Collected data

3.6.1. Phenological Parameters for Maize Component

Days to tasseling: Data on days to 50% tasseling as the number of days required from planting to emergence of tassel in 50% of the maize plants in the net plot was recorded through visual observation.

Days to physiological maturity: Days to 90% physiological maturity was recorded when in 90% of the plants the grains formed black layer at the base of the germ at the point of attachment of the kernel on the ear. However, harvesting was done when all plants in the entire plots were fully matured.

3.6.2. Growth parameters for Maize Component

Plant height: Plant height was measured from 5 randomly taken plants in the net plot area from the ground level to the apex of each plant at the time of physiological maturity.

3.6.3. Yield components for Maize Component

Stand count after thinning and at harvest:

Number of ears /plant: The number of productive ears was counted from the net plot area and was being converted into ear/ha.

Number of kernels per ear: The number of kernels per ear was determined by counting the kernels/grains from five randomly taken ears as above.

Thousand kernels weight: Thousand kernels were counted from the harvested produce of the net area and subsequently the weight (g) was recorded which was adjusted at 12.5 % grain moisture content using sensitive balance.

Grain yield: The winnowed produce from each plot was measured and adjusted to 12.5% moisture content with the help of formula:

Adjusted yield = (Actual yield x 100-M) 100-D

Where M is the measured moisture content in grain and D is the designated moisture content

Stover yield: The aboveground dry biomass of Stover (kg/ha) was determined after harvest on the basis of the samples from which the grain yield per plant was taken. This was done after the harvested Stover air dried under sun to a constant weight.

Harvest index: The harvest index was calculated as a ratio of grain yield to total aboveground dry biomass.

3.7. Common bean Component

Phenological parameters:

Days to flowering: It was recorded as the number of days from crop emergence to the time when 50% of the plants in each treatment showed a flower bud.

Days to physiological maturity: Days to physiological maturity was measured as the number of days from crop emergence to the day when 90% of plants reached physiological maturity, i.e. both pods and plants turn yellow (senescing).

Growth parameter:

Number of primary branches at maturity:

Plant height (cm): It was recorded from 10 randomly taken plants in each plot before harvest from base of plant to the tip of main stem and will be expressed as height per plant.

Yield components

Crop plant stand: The plants in the net plot area were counted at 20 days after planting and at harvest for common bean.

Number of pods per plant: Total pods in 10 randomly taken plants in each plot was counted at the time of harvest and expressed as the number of pods per plant.

Number of seeds per pod: In the above pods the total seeds were counted so that the number of seeds per pod can be determined.

100 grain weight (g): One hundred seeds were counted from harvested bulk of each plot and their weight was recorded and adjusted at 10.5% moisture content by using sensitive balance.

Aboveground dry biomass yield: It was measured at physiological maturity after cutting 10 randomly sampled plants at ground level and sun dried. This was multiplied by the number of plants per plot and was used to calculate the harvest index as the ratio of grain yield to total above ground dry biomass yield. This is necessitated because of at full maturity like in other legumes, common bean also shed almost all its leaves and under field conditions.

Grain yield (kg): This was recorded from each net plot area as in case of maize, but the yield was adjusted at 10.5% grain moisture content.

Harvest index: The harvest index was calculated as a ratio of grain yield to total above ground dry biomass.

3.8. Productivity for intercropping system

Land equivalent ratio (LER): It is the ratio of mixed crop yield to sole yield of both crops. It was calculated using a formula described by Willey (1979a).

$$\text{LER} = \frac{\text{Yield of intercropped maize}}{\text{Yield of sole maize}} + \frac{\text{Yield intercropped common bean}}{\text{Yield of sole common bean}}$$

Gross monetary value: It was calculated as the product of yields of the component crops multiplied by their respective unit price. The total value obtained from the component crops was used to indicate the gross monetary value.

Monetary advantage (MA): It was computed from the yield of maize and Haricot bean components as per the equation indicated by Willey (1979).

MA= Value of combined intercrops yield x $\frac{LER-1}{LER}$ to estimate the GMV and MA of component crops, maize grain yield was valued at an average current open market price.

Relative net return/Economic Analysis: It was calculated by taking in to account the additional input cost involved and the gross returns obtained from different weed control treatments.

3.9. Data analysis

The analysis of variance (ANOVA) was carried out using statistical packages and procedures out lined by Gomez and Gomez (1984) appropriate to Randomized Complete Block Deign using GenStat Computer Software version 13.3. Mean separation was carried out using least significant difference (LSD) at 5% probability level

4. RESULTS AND DISCUSSION

4.1. Maize Crop

Effect of spacing and intercropping pattern on days maize tasseling

Analysis of variance showed that main effects of spacing and intercropping pattern and their interaction significantly affected days to 50% tasseling of maize (Appendix Table 1). Plants grown under less spacing took significantly longer time to reach to tasseling than grown those under wider spacing (table 2). The lowest days to tasseling were recorded from the crop planted under the 90 cm spacing and two line cropping system as compared to the 75 and 90 cm spacing. On the other hand the highest numbers of days to tasseling (58.3) were registered under the spacing of 60 cm with the sole cropping (Table 2). This indicates that widened plant spacing decreased the days to tasseling for all three spacing and decreased from sole cropping to one line cropping and two line cropping. This could be associated with the lower competition effect in sole cropping in narrow spacing which allows full growth of the plant organs and delayed days to tasseling under non limited growth resources environment. Late maturing of maize in less spacing and sole cropping tend to have been taller and have more numbers of leaves. This is due to that maize plant gets favorable condition with the less spacing to continue it is growth and development of plant organs and assimilate more nutrients

Table 1: Interaction effect of maize row spacing and common bean intercropping pattern on number of days to 50% tasseling of maize

Days to 50 % tasseling			
Inter-row spacing (cm)	Intercropping pattern		
	Sole Maize	CB one row	CB two row
60	48.3^{a}	57.3^{a}	58.0^{a}
75	45.0^{ab}	56.0^{ab}	52.3^{ab}
90	53.0^{b}	53.6^{b}	57.6^{b}
Mean	48.7	55.6	55.9
LSD (0.05)	6.0		
CV (%)	11.2		

DTS=Days to tasseling, LSD = Least Significant Difference; CV = Coefficient of Variation, CB = common bean.

4.1.1. Number of days to 90% physiological maturity

This study revealed that, days to physiological maturity were significantly affected by main effect of intercropping pattern and not significantly affected by plant spacing and the interaction (Appendix Table 2).

Plant grown under less spacing took significantly longer time to reach to physiological maturity than those grown under higher spacing (Table 1). The lowest numbers of days to physiological; maturity was recorded for when the crop was planted sole cropping (88.3 days) as compared to the one line and two line cropping systems of maize with common bean. This is indicated that sole cropping required for more days to complete its growth as compared to the intercropping systems of one and two rows of common bean intercropping. The observed days to physiological maturity were not consistency among the different cropping systems. On the other hand the highest numbers of days for physiological maturity (88.9 and 89.2) were registered under the crop planted in 60 cm spacing and two line intercropping. This is indicated that, days to physiological maturity is a trait that has a relation with the maize plant spacing but not associated with the intercropping pattern

4.1.2. Plant Stand Count

Similarly, in this study showed the main effects of spacing and intercropping pattern were showed significantly ($p<0.05$) affected on stand count at thinning but not the interaction (Appendix Table 2).

Although the differences were not significant the maximum stand count (58 and 53.3) when the crop planted of 60 cm spacing at thinning and at harvest respectively as compared to 75 and 90 cm spacing. Among the cropping system the maximum stand count (59 plants/plot) were recorded from the two line intercropping (Table 1). This is shows that plant cropped in less spacing increased the stand count and wider the plant spacing may decrease the number of stand counts. Not similarly, stand count from both stages increased from sole cropping to two row cropping. On the other hand, the result of this study revealed that, plant spacing was showed significant ($p<0.05$) effect on maize intercropped on stand count at harvest bun not intercropped pattern and their interaction (Appendix Table 2).

Table 2: Effect of maize row spacing and common bean intercropping pattern on days to 90 % physiological maturity of maize and stand count at both at thinning and at harvest

Treatments	Days to 90 % physiological maturity	Initial crop stand count	Crop stand count at harvest
Spacing (cm)			
60	88.9[a]	54013[a]	51789[a]
75	88.8[a b]	41975[ab]	40062[ab]
90	88.6[b]	36675[b]	33473[b]
Mean	88.7	58961.3	41774.6
LSD(0.05)	NS	NS	1364
Cropping System			
SCB	88.3[a]	44397[a]	42077[a]
CB One row	88.7[a b]	44362[a b]	41751[a b]
CB Two rows	89.2[b]	43904[b]	41495[b]
Mean	88.7	44221	41774.3
LSD(0.05)	NS	NS	NS

LSD = Least Significant Difference, SCB = sole common bean, CB = Common bean

4.1.3. Plant height

Main treatment effects of spacing and intercropping pattern did not significantly ($p<0.05$) affected plant height while their interaction significantly affected plant height (Appendix Table 1). Plant grown under 75 spacing were significantly taller than compared to the shorter and wider spacing mono-cropping and intercropping pattern. The highest plant high (149 cm)m was recorded when the crop planted under 75 cm spacing with mono-cropping whereas the shortest plant height (123 cm) was recorded under the 95 cm spacing with the one line intercropping (Table 2). Among the spacing the highest mean height (148 cm) was recorded under the spacing of “75 cm” followed by “60 cm” spacing and the shortest “90 cm”. This indicates that medium plant spacing is the most appropriate of the plant growth which allows normal development of plant tissues and organs. Less spacing may increased the competition between the plants for nutrients, moisture, solar radiation and space. On the other hand wider spacing might be create moisture evaporation for the expose solar radiation between widened rows

Table 3: Interaction Effect of spacing and intercropping pattern on maize plant height (cm)

	Plant height in (cm)		
Spacing (cm)		intercropping pattern	
	MC	OLINCR	TLINCR
60	146[a b]	142.3[a b]	146.7[a b]
75	149[a]	147[a]	148[a]
90	129[b]	123[b]	138[b]
Mean	128	141	141
LSD(0.05)	6		
CV (%)	25		

MC = maize crop, OLINCR =one line intercropping, TLINCR= two line intercropping; LSD = Least Significant Difference; CV = Coefficient of Variation;

4.1.4. Maize ear number per plant and number seeds per plant

The result of this study revealed that, maize intercropping pattern and the interaction were significantly ($p<0.05$) affected on number of ears per plant but not the main effect of spacing (Appendix Table 1).

The number of ears per plant obtained when maize planted at middle spacing was significantly higher than the other two spacing “60 & 90 cm” (Table 3). The highest and the lowest number of ears (1.23 and 1.53) were recorded from 60 and 75 cm spacing respectively. The number of ears per plant is increased from mono-cropping to one line and two line cropping from “90 cm” spacing but not consistent increase from the other spacing (Table 3). This shows that the increase of spacing has no relation with the increase of ear number per plant

Table 4: Interaction effect of row spacing of maize and common bean intercropping pattern on number of ears plant^{-1} and seeds per ear of maize

	Number of ears plant^{-1}			Number of seeds ear^{-1}		
	Intercropping pattern			Intercropping pattern		
Spacing (cm)	Sole maize	Common bean (one row)	Common bean (two rows)	Sole maize	Common bean (one row)	Common bean (two rows)
60	1.33^{a}	1.23^{b}	1.33^{b}	450.3^{a}	486.1^{a}	458.2^{a}
75	1.33^{a}	1.43^{a}	1.53^{a}	489.9^{a}	477.9^{a}	534.5^{a}
90	1.26^{a}	1.30^{ab}	1.52^{a}	412.2^{b}	430.7^{b}	468.9^{a}
Mean	1.31	1.13	1.46	451	465	487.2
LSD(0.05)	0.2			42		
CV (%)	12.8			9.2		

LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation

Similarly, the study showed that maize intercropping pattern and the interaction were significantly ($p<0.05$) affected on number of ears per plant but not the main effect of spacing (Table 3, Appendix 1). As a result the maximum number of seeds per ear (534.5) was counted when the crop planted at “75 cm” spacing with the two line intercropping (Table 3). More over the lowest number of seeds (412.2) per ear was recorded from “90 cm” spacing with the mono-cropping. This is showed that either the increase of plant spacing or cropping system have no relation with increase or the decrease of number of seeds per ear.

4.1.5. Maize thousand grain weight (g) and grain yield per plot

The analysis of variance showed that maize intercropping pattern and the interaction were significantly ($p<0.05$) affected on thousand grain weight but not the main effect of spacing (Appendix Table 4).

As a result revealed, the maximum thousand grain weight (301g) measured when the crop planted in one line intercropping with the “75 cm” spacing (table 4). This showed that one line intercropping with the middle spacing of "75 cm" is the most appropriate for the crop production to produce higher weight grains. With regards of spacing the highest mean thousand grain weight (286.4g) was recorded from "75 cm" spacing followed by 60 cm spacing and 90 cm (Table 4). However, it was in contrast with Ketema (1983), who argued that, varying in spacing has no significant effect on 1000-kernel weight.

Table 5: Interaction effect of row spacing of maize and common bean intercropping pattern on thousand kernel weight (g) and grain yield (kg ha^{-1}) of maize

	Thousand kernel weight (g)			Grain yield (kg ha^{-1})		
	Intercropping pattern			Intercropping pattern		
Spacing (cm)	Sole maize	Common bean (one row)	Common bean (two rows)	Sole maize	Common bean (one row)	Common bean (two rows)
60	237.0^{b}	274.2^{ab}	268.5^{a}	15623^{b}	16041^{b}	16821^{b}
75	288.3^{a}	310.0^{a}	261.0^{a}	20410^{a}	21285^{a}	19372^{ab}
90	265.7^{a}	258.0^{b}	247.7^{b}	21264^{a}	18776^{ab}	20712^{a}
Mean	5.5	27.3	259.1	19,100	18,700	18,967
LSD(0.05)	38.15			1301		
CV (%)	14.3			7		

LSD = Least Significant Difference; CV = Coefficient of Variation

Similarly, this study showed that maize intercropping pattern and the interaction were significantly ($P<0.05$) affected on maize grain yield whereas the main effect of spacing was not showed any significant effect (Appendix Table 4). The result showed that the maximum yield per plot (21285 kg/hectare) was measured from two line intercropping with the "75 cm" spacing whereas the lowest grain yield (15623 kg/hectare) was from the "60cm spacing' with sole cropped maize crop (Table 4).l This is showed that grain yield increased with the increase of intercropping that means from mono-cropping to one line intercropping to two line intercropping. According the spacing the highest mean yield (20356 kg/hectare) was recorded from "75 cm" followed by "90 cm "and "60 cm". This is indicated that wider spacing may effect maize grain yield production due to the moisture availability.

4.1.6. Maize Stover yields (kg) and harvest index

The result of this study revealed that, maize intercropping pattern and the interaction were significantly ($p<0.05$) affected on Stover yield per hectare but not the main effect of spacing (Table 4, Appendix 1). The maximum Stover yield (21920 kg/hectare) was recorded from “75 cm” spacing with one line intercropping while the lowest Stover yield (16670kg/hectare) was recorded from “90 cm” with one line intercropping also (Table 4). This is indicated that plant favorite to grow at the middle spacing of “75 cm” and one line intercropping as well. Regarding mean biomass yield for the three spacing “60, 75, and 90 cm” were “17193, 21319 and 20280 kg/hectare respectively (Table, 4). The highest mean Stover yield recorded from the “75 cm” spacing which related to its bigger stocks resulting in more dry matter accumulation for relatively longer growth period of maize intercropped.

The data analysis for revealed that, the main effects of spacing and intercropping pattern and their interaction caused significant ($p<0.05$) variation in harvest index (HI) (Table 5, Appendix 1). The highest HI value 0.5 was recorded from “75 cm” spacing with one line intercropping (Table 5). The mean harvest index value recorded for the three spacing “60 cm”, “75cm” and 90 cm” spacing were 0.48, 0.5 and 0.48 respectively (Table 5) showing that the spacing of “75 cm” having the highest mean harvest index than the other smaller and wider spacing

Table 6: Interaction effect of row spacing of maize and common bean intercropping pattern on Stover yield (kg ha^{-1}) and harvest index of maize

	STY			HI		
Spacing (cm)	intercropping pattern			intercropping pattern		
	Sole maize	CB (one row)	CB (two rows)	Sole maize	CB (one row)	CB (two rows)
60	16670 [b]	16928 [b]	17982 [b]	0.47 [a b]	0.48 [ab]	0.49 [a]
75	21382 [ab]	21920 [a]	20656 [a]	0.50 [a]	0.52 [a]	0.48 [a b]
90	21674 [a]	19181 [ab]	20012 [ab]	0.47 [a b]	0.47 [b]	0.49 [a]
Mean	19,908	13,343	19,550	0.48	0.49	0.487
LSD(0.05		5.9			0.015	
CV (%)		28.3			2.12	

STY= Stover yield, HI= Harvest index, LSD = Least Significant Difference; CV = Coefficient of Variation, CB =Common bean

4.2. Common bean Component

4.2.1. Phenological Parameters

Analysis of variance of this study revealed that days to flowering and physiological maturity were significantly ($P<0.05$) affected by spacing and intercropping pattern and their interaction between the two factors (Appendix Table 1).

Plants grown under lower spacing took significantly longer time to reach flowering and physiological maturity than grown under those crop planted higher spacing (Table 1). The lowest numbers of days to flowering and physiological maturity (45.2 and 63 respectively) were recorded from “90cm” spacing with the two line intercropping with maize as compared to both other spacing of “60cm” and “75cm”. On the other hand the highest numbers of days to flowering and physiological maturity (49.7 and 70.3 respectively) were registered from the “60cm” with the mono-cropping of the crop as compared to the one line and two line intercropping with maize (Melkasa-2) (Table 1)

This indicates that increased plant spacing decreased days to flowering and physiological maturity of all three spacing. This could be associated with the lower competition effect in less plant population attributed the wider spacing which allows full growth of plant organs and delayed days to flowering and physiological maturity under non-limited growth resource environment.

Table 7: Interaction Effect of spacing and cropping systems of common bean production on 50% days to flowering and 75% physiological maturity

	50%DTF			DTPM		
Spacing(cm)	Intercropping pattern			Intercropping pattern		
	SC	OLINCR	TLINCR	SC	OLINCR	TLINCR
60	49.7[a]	47.7[a]	45.8[a]	70.3[a]	67 [a]	65.3[a]
75	48.5[ab]	46.7[ab]	45.5[a]	68.3[ab]	66 [ab]	64.3[ab]
90	47.8[b]	46[b]	45.2[a]	67[b]	65 [b]	63[b]
Mean	48.7	46.8	45.5	68.5	61	64.2
LSD(0.05)	1.33			3.8		
CV (%)	2.12			2.12		

SC= Solo Cropping, OLINCR =one line intercropping, TLINCR4= two line intercropping

4.2.2. Plant height

The result of this study revealed that, haricot bean spacing and the interaction were significantly ($p<0.05$) affected on plant height but not the main effect of intercropping pattern (Appendix Table 4).

Plants grown under relatively lower spacing were significantly ($p<0.05$) taller as compared to those grown under the wider spacing in sole cropping all intercropping patterns. The highest plant height (0.72 cm)was recorded from the “60cm” spacing grown plants with the mono cropping whereas the shortest plant height (0.47 cm) was recorded from “90 cm” spacing with the two line maize intercropped (Table 8). Among the spacing the highest mean plant height was recorded the shortest spacing followed by the middle and the widest once. This is indicated that increased plant spacing decreased plant height due to the unfavorable condition of plant growth.

4.2.3. Number of pods per plant

The analysis of variance revealed that, haricot bean intercropping pattern and the interaction were significantly ($p<0.05$) affected on number of pods per plant but not the main effect of spacing (Table 4, Appendix 1).

Among the spacing the maximum number of pods/plant (7.2) was recorded from “60cm” spacing as compared to the “75 cm” and “90 cm” spacing (Table 2). Among the intercropping pattern the highest mean number of pods per plant (6.3) was recorded when the crop planted with the intercropping pattern of one line intercropping (Table 10). The observed number of pods/plant was not consistency with the plant spacing. This is indicated that that, number of pods/plant is a trait that has no relation with the plant population attributed by the different plan spacing but more of associated with the crop variety and conditions.

Table 8: Interaction Effect of spacing and intercropping pattern of common bean production on Plant height (cm) and number of pods per plant

Spacing (cm)	Plant height			Number of pods /plant		
	intercropping pattern			intercropping pattern		
	SC	OLINCR	TLINCR	SC	OLINCR	TLINCR
60	0.72[a]	0.63[a]	0.6[a]	5.9 [a]	7.2[a]	5.6[b]
75	0.6[ab]	0.59[a]	0.49 [ab]	5.7[ab]	6.8[ab]	6.4[a]
90	0.55[b]	0.52[a]	0.47[b]	5.6 [b]	4.9[b]	6.2[ab]
Mean	0.64	0.58	0.52	5.7	6.3	6.1
LSD(0.05)	0.1			1.5		
CV (%)	11.6			25.8		

SC= Solo Cropping, OLINCR =one line intercropping, TLINCR4= two line intercropping

4.2.4. Plant Stand Count

Analysis of variance showed the main effects of spacing and intercropping pattern and interaction were showed significantly ($p<0.05$) affected on stand count at thinning (Appendix Table 9). The maximum stand counts (123.3 plant/plot)) when the crop planted 90 cm spacing and sole crop as compared to 60 and 75 cm spacing and the minimum (99.7 plant/plot). This is shows that plant cropped in wider spacing increased the stand count and less the plant spacing may decrease the number of stand counts. Not similarly, stand count from both stages increased from sole cropping to two line cropping.

Table 9: Interaction Effect of spacing and cropping systems of common bean production on stand count at harvest (plant number/ plot)

	STC			
Spacing(cm)	Cropping system			
	SC	OLINR	TLINCR	Mean
60	121.0[ab]	112.0[a]	108.0[a]	113.7
75	99.7[b]	109.7[b]	112.3[a]	107.2
90	123.3[a]	110,0[a]	93.3[b]	108.9
mean	114.7	111	104.5	
LSD(0.05)	20.2			
CV (%)	2.12			

4.2.5. Number of seeds/pod

Analysis of variance revealed that, number of seeds/pod was significantly ($p<0.05$) affected by the main effects of the treatments as well as their interaction (Table 3, Appendix 2). As a result the maximum number of seeds/pod (5.9seeds/pod) was counted from the "75 cm" spacing with the one line intercropped with maize (Table 3). This is showed that, the middle spacing and one line intercropped are the most favorites that crop can produced the maximum required seeds. With regard to the different spacing the highest mean number of seeds/pod (5.6) was recorded from the "75 cm spacing" followed by "90cm" and "60cm" spacing (table 3). This indicated that the increase of number of seeds/pod has no relation with the increase of plant spacing.

4.2.6. Hundred grain weight (g)

The result of this study showed that hundred grain weight was not significantly by the main effects of spacing and Intercropping pattern whereas their interaction was significantly ($p<0.05$) affected (Table 3, Appendix 2). The maximum hundred grain weight (20.5g) was recorded when the crop planted under the "75 cm spacing" with the one line i9ntercropped with maize (Table 3). The minimum hundred grain weight (18.2g) was recorded under the crop plantation of "90cm spacing" with the mono-cropping system. On the other hand, the maximum hundred mean weights (19.9g) was recorded under the "75cm spacing" followed by "90cm" and "60cm"

Table 10: Interaction Effect of spacing and Intercropping pattern of common bean production on Number of seeds per pod and hundred seed weight (g)

	NSPO				HDSW			
Spacing (cm)	Intercropping pattern				Intercropping pattern			
	SC	OLINCR	TLINCR	Mean	SC	OLINCR	TLINCR	Mean
60	5.1 [b]	5.3[b]	5.5 [a]	5.3	18.7 [b]	20.3 [a b]	19.3 [a]	19.5
75	5.6[a]	5.9 [a]	5.3 [a b]	5.6	19.3 [a]	20.5 [a]	20 [b]	19.9
90	5.2 [a b]	5.5 [a]	5.5 [a]	5.53	18.2 [b]	19.2 [b]	19.2 [a]	19.3
Mean	5.3	5.7	5.43		18.8	19.7	19.5	
LSD(0.0)	0.42				1.6			
CV (%)	7.7				8.3			

NSPO= Number of seeds/pod, HDSW = Hundred grain weight

4.2.7. Grain yield and

Analysis of variance showed that, grain yield was significantly ($p<0.05$) affected by the main effects of the treatments as well as their interaction (Table 4, Appendix 2). The maximum grain yield (1.6 kg/plot) of common bean intercropping pattern was recorded when the crop planted under the "75cm spacing" with the one line intercropped pattern whereas the minimum grain yield (1.3 kg/plot was recorded from "60cm spacing" with sole cropping (Table 12). This is indicated that the increase of plant spacing yield was not consistently increase among all intercropping patterns except the sole cropping. Among the spacing the highest mean grain yield (1.5 kg/plot) from the "75cm spacing" followed by "90cm spacing" and "60cm spacing". This is indicated that yield increase of common bean intercrop patterns is a trait which has no relation with the increase or decrease the plant spacing.

4.2.8. Above ground weight

The result of the study showed that, above ground weight was significantly ($p<0.05$) affected by the main effects of the treatments as well as their interaction (Table 11, Appendix 2).

The maximum above ground mass (1.8 kg/plot) of common bean intercropping patterns was recorded under the crop spacing of “75cm” with the one line intercropped pattern whereas the minimum weight (1.55 kg/plot) was recorded under the plant spacing of “60cm” with the sole cropping pattern of the crop (Table 12). This is indicated that the above ground mass of common bean intercropping pattern was not consistently increased with the increase of plant spacing. The highest mean above ground mass was recorded under the “75cm spacing” followed by “90cm” and “60cm” spacing (Table 11)

Table 11: Interaction Effect of spacing and intercropping pattern of common bean production on grain yield (kg) per plot and above ground weight (kg) per plot

	GY				AGW			
Spacing (cm)	Intercropping pattern				Intercropping pattern			
	SC	OLINCR	TLINCR	Mean	SC	OLINCR	TLINCR	Mean
60	1.3^{b}	1.47^{a}	1.43^{b}	1.4	1.55^{a}	1.75^{ab}	1.6^{b}	1.63
75	1.33^{ab}	1.6^{b}	1.55^{a}	1.5	1.73^{a}	1.8^{a}	1.7^{a}	1.7
90	1.53^{a}	1.47^{a}	1.47^{ab}	1.49	1.6^{b}	1.72	1.64^{ab}	1.65
Mean	1.4	1.51	1.45		1.62	1.73	1.97	
LSD(0.05)	0.1				0.11			
CV (%)	6.3				2.12			

GY = grain yield, AGW= above ground weight

4.2.9. Harvest index (HI)

The data analysis for revealed that, the main effect of intercropping pattern as well as the interactions, caused significant ($P<0.05$) variation in harvest index (HI) but not the spacing (Table 12, Appendix 2).

The highest HI value of 0.48 was recorded from “75cm spacing” and “90cm spacing” with one line intercropping pattern at both treatments, whereas the lowest HI recorded under the was recorded from the 0.45 was recorded from the “60cm spacing” with the sole cropping pattern (table 11). Among the spacing the highest mean HI (0.47) was recorded from both “75cm spacing” and “90cm spacing” followed by “60cm spacing”. The mean harvest index values recorded for the three spacing “0.46cm”, “0.47cm” and “0.47cm” spacing respectively (Table 12)

Table 12: Interaction Effect of spacing and intercropping patterns of common bean production on harvest index

HI				
Spacing (cm)	Intercropping Pattern			
	SC	OLINCR	TLINCR	Mean
60	0.45 [b]	0.46 [b]	0.46 [b]	0.46
75	0.46 [a]	0.48 [a]	0.473 [a]	0.47
90	0.46 [a]	0.48 [a]	0.452 [a]	0.47
mean	0.46	0.48	0.47	
LSD(0.05)		0.02		
CV (%)		4.3		

HI= harvest index

4.3. Total Land Productivity and Gross Monetary Evaluation

The productivity of this experiment was evaluated by calculated total land equivalent ratio (LER) and gross monetary Value (GMV).

4.3.1. Land Equivalent Ratio (LER)

The land equivalent ratio (LER) was calculated by adding up partial land equivalent ratio of maize and climbing common bean. The partial land equivalent ratio (PLER) of maize was highly significantly ($P<0.01$) affected by planting date also PLER of climbing common bean was highly significantly ($P<0.01$) affected by varieties, planting date and cropping system. The interaction was not significantly affected by time of planting and cropping system The LER was highly significantly ($P<0.01$) affected by date of planting and variety and significantly ($P<0.05$) affected by cropping system. However the interaction of both PLER and LER was not significant as the results of this study indicated. The highest LER (1.76) and lowest LER (0.95) were scored from 14 DAPM and simultaneous planting, respectively. The highest LER (1.76) indicates that the combination of 100% maize and 14 days after planting of maize gave 76% yield advantage than planting maize or climbing common bean independently as sole crops and increased trend of growth parameters and yield and yield components of maize with delaying time of climbing common bean intercropping. This result was in agreement with the report of Kidane*et al.*, (1990), Muoneke*et al.*, (2007) and Allen and Obura (1983) where the LER of maize/soybean intercrops ranged from 1.2 to 1.8.The LER of all varieties was more than one. The LER of variety type was significantly higher than others.

The LER of intercropping was showed 44% yield advantage and efficient land utilization by intercropping as compared to the sole cropping. This higher value of LER in intercropping treatments compared to sole cropping of climbing common bean might be due to better utilization of land, light, nutrients and water

5. SUMMARY AND CONCLUSIONS

Intercropping is the growing of more than one crop species more or less simultaneously and at different time of planting in the same field during a growing season and commonly used cropping practice which aims to match efficiently crop demands to the available growth resources and labor. Sowing of component crops in different times is an important agronomic approach in intercropping systems. The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops.

In view of this, the experiment was conducted in 2015 cropping system at fafan Somali region pastoral and agro pastoral research center of Somali Region to assess the effects of varieties and relative planting date of climbing common bean in intercropping with maize on yield and yield components related traits of the component crops and productivity of the system. The treatment consists of three climbing common bean varieties (awash malka) and four date of planting (simultaneous planting, 7 days after maize planted, 14days after maize planted and 21days after maize planted) were arranged in factorial randomized complete block design in three replication by including sole of maize (malkasa 2)and each of the three climbing common bean varieties.

The result indicate that date of planting had significant effect of phenology of maize and growth parameters of maize leaf area, leaf area index and plant height but variety and interaction were not affected significantly. The main effect of date of planting and varieties had significant effect on stand count of maize at harvest but no significant effect of cropping system. Date of planting was significantly affected number of ears per plant, thousand kernel weight and harvest index. Number of ears per plant, thousand kernel weight and harvest index of maize were increased as date of planting increased from 7, 14 and 21days after maize planted. The highest number of ears per plant (1.20) recorded from 21 days after maize planted (DAMP) and the highest thousand kernel weight of maize was good yield obtained from the combinations of 7 DAMP of climbing common bean awash malka variety while the lowest thousand kernel weight of obtained from combination of simultaneous planting variety. The highest number of harvest index was recorded from 14 DAMP and lowest was recorded from simultaneous planting. The highest maize grain yield ha^{-1} was obtained from 21 DAMP and the lowest t ha^{-1} was obtained from the simultaneous planting and yield of maize gradually increased with delaying sowing of climbing common bean.

The total land equivalent ratio showed significant differences due to varieties, date of planting, cropping system. The highest LER (1.76) was obtained from date of planting of 14 DAMP and climbing common bean Awash malka variety. The LER of intercropping indicated that, there were higher yield advantage and land use efficiency of maize/climbing common bean intercropping than the sole cropping. This showed that, intercropping of maize/ climbing common bean gave 42% efficient land utilization and yield advantage as compared to their respective sole cropping.

Thus, the results showed that proper decision should be given while practicing intercropping of maize and climbing common bean. In this regard, planting climbing common bean 14 days after planting of maize variety was the best in intercropping system to maximize the productivity and compatible variety. Common bean was the best relative variety in intercropping with maize. However, since this study is for one year at one location, it is difficult to conclude and give valuable recommendation. To reach better conclusive recommendation, it needs further investigation on the selection of additional best compatible maize and climbing common bean varieties, date of planting and repetition of this study on more locations and seasons

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7. APPENDACES

Appendix 1: Mean squares of phenological, growth parameters, Yield and Yield components of maize production

Sources of variance	Df	DST	DSPM	PH	EPP	STCAT	STCAH	NSPE	TGW	GY	SY	HI
Replication	2	8.5	1.9	1462	0.003	101140	85.3	391	1436	77.3	81	0.0003
Spacing	2	150*	0.26^{NS}	493.4^{NS}	0.00^{NS}	710388211^{*}	774596505^{*}	193^{NS}	121^{NS}	9^{NS}	6.3^{NS}	0.002*
Intrcr Pattern	2	38*	1.8*	393.7^{NS}	0.08*	681094*	765083^{NS}	5250*	1172*	51*	53.2*	0.00014*
Spacing X Intrcr Pattern	4	25.5*	1.1^{NS}	752*	0.04*	1484078^{NS}	342895NS	7153.5*	2162*	58.1*	55*	0.0005*
Error	16	576	38.8	18285	0.5	787692	1862915	28447	23313	607	551	0.004
CV (%)		11.2	1.8	25	0.2	2.01	3.3	9.2	14.1	31.5	28.3	3.13

Appendix 2: Mean squares of phenological, growth parameters, Yield and Yield components of common bean production

Sources of variance	Df	DTF	DTPM	PH	NPPP	STC	NSP0	HDSW	GY	AGM	HI
Replication	2	0.48	0.33	0.002	0.67	112	0.3	3.4	0.03	0.02	0.001
Spacing	2	3.6*	24.1*	0.02*	0.77^{NS}	108.3^{NS}	0.2*	0.4^{NS}	0.03*	0.03*	0.0002^{NS}
IntrcrPattern	2	7.15*	22.1*	0.002^{NS}	1.9*	228^{NS}	0.17*	1.1^{NS}	0.034*	0.038*	0.001*
SpacingXIntrcrPattern	4	7.8*	11.7*	0.03*	3.9*	354.7*	0.19*	6.3*	0.04*	0.02*	0.0007*
Error	16	28.4	232.7	0.1	37	6531	2.82	41	0.13	0.2	0.01
CV (%)		2.84	5.82	11.6	25.8	18.4	7.7	8.3	0.1	6.4	0.02

Sole common bean vs intercropped common bean, Sole common bean, Intercropped common bean