# Maize (Zea mays L.) -Common Bean (Phaseolus vulgaris L.) Intercropping Response to Population Density of Component Crop in Wolaita Zone Southern Ethiopia

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**Abstract**
Intercropping is the common types of multiple cropping which is taken as one of the best options to increase crop productivity in area with low land holding capacity. For better effectiveness of this cropping system, optimum density of the component crops should be determined. A field experiment was conducted to evaluate the growth and yield performance of maize intercropped with different population density of common bean in Wolaita Zone, Southern Ethiopia in 2013/2014. Four ranges of population density (44444 maize $ha^{-1}$ + 93750 bean $ha^{-1}$, 44444 maize $ha^{-1}$ + 62500 bean $ha^{-1}$, 44444maize $ha^{-1}$ + 0 bean $ha^{-1}$ and 0 maize $ha^{-1}$ + 125000 bean $ha^{-1}$) were arranged in a randomized complete block design with three replications. There was no significant difference between sole cropped and intercropped maize on crop phenology, days to physiological maturity, growth parameters, yield and yield components. Sole cropped common bean had significantly higher leaf area and leaf area index than intercropped bean. Population density had significant effect on yield of common bean. The analysis of partial land equivalent ratio of the component crops showed that intercropping pattern had significant ($P<0.05$) effect on the partial land equivalent ratio of the bean component and but not for maize component . Intercropping of maize with common bean having population density of 93750 $ha^{-1}$ resulted 42% yield advantage. Intercropping of maize with bean having density of 93750 $ha^{-1}$ had significantly ($P<0.05$) more economic advantage (36898.2Ebirr) than the rest. From the current investigation it is reasonable to point out that intercropping of maize with bean having density of 93750 $ha^{-1}$gave both highest agronomic and economic advantage. For better productivity of the intercropping system, further study should be done by considering other factors of production in conjunction with population density of component crops.
**Keywords**: Maize, common bean, population density

## INTRODUCTION

World population is growing exponentially and it is expected to fulfill the food requirements by setting strategies' for increasing crop productivity per unit area of available land through growing by time and space combination (Seran and Brintha, 2010). Intercropping which is an ancient practice still used in most of developing countries to maximize crop productivity (Machado, 2009 ), basically consists of cultivating two or more crops in the same area of land at the same time. The aim of this cropping system is to optimize factors and environmental resources usage, thus leading to an increased yield or output of the mixture (Li w.*, et al.,* 2005; Dwivedi *et al.*, 2015 ). In addition to maximization of crop productivity, intercropping is much less risky in that if one crop fails another or the others may still be harvested.

When crops are cultivated in multiple cropping system like intercropping result higher yield on a given piece of land by making more efficient use of the available environmental resources(Lithourgidis *et al*., 2011) using a mixture of crops with different rooting ability, canopy structure, height and nutrient requirements based on the complementary utilization of growth resources by the component crops (Dhima *et al*. 2011; Dwivedi *et al*., 2015). Complementary effects between component crops, more effective use of water, nutrients and solar energy, buffering effect of the mixture on disease and insect pest enhances intercrop productivity over sole cropping (Li *et al*.,1999 and Chen *et al*., 2004).

Maize (Zea mays L.) and common bean (Phaseolus vulgaris L.) are the major staple food crops among cereals and pulses, respectively, in high land area of Ethiopia. Maize is an important cereal crop in the family Poaceae. It is an important source of carbohydrate in human diet in the developing world and as animal feed worldwide (Undie *et al.,* 2012). As it is quick maturing and can be easily intercropped, common bean serves as a key component for intensifying production in smallholder farming systems. Its ability to fix nitrogen is much-needed for longer term improvement of soil fertility (Buruchara *et al*., 2011).

The persistent exploitation of agricultural land and fast growth of population in Ethiopia have made land an extremely expensive natural resource(CSA, 2013). Such population growth causes diminishing of arable land that in turn forced farmer to practices multiple cropping system(Ricker-Gilbert *et al*., 2014 ) in which two or more crops are produced in space and time combination(Abera *et al*., 2005). The average cropland area was found out to be 0.96, 0.48 and 0.4 hectares per household in Ethiopia, Southern regions and Wolaita Zone, respectively (CSA, 2013).

So use of intercropping which is the common types of multiple cropping is one of the best options in area with low land holding capacity since multiple cropping in a plot of land allows utilizing the available land efficiently and also it boosts crop biomass and yield as compared with sole cropping (Zhang & Long Li, 2003). For better productivity of this cropping system, population density of the component crop should be at optimum level since plant density is one of the factors which determine the degree of competition in the intercrop system (Peksen and Gulumser, 2013). Thus, this study was initiated to determine the optimum population density of common bean for better yield of maize/common bean intercropping.

## METHODOLOGY

### Description of the study area

The study was conducted in Wolaita Zone Southern Ethiopia which is located at 6°34'N, 37°43'E, and 1950 m.a.s.l. The site has a bimodal rainfall distribution pattern with average annual rainfall of 1150 mm. The soil type is clay loam. The major crops produced in this area are maize, haricot bean, potato, sweet potato, cassava etc.

### Treatments and experimental design

A maize variety called BH 540 was intercropped with different population density of common bean variety called "Awassa duman". The treatments consisted of sole maize (44444 $ha^{-1}$), sole bean (125000 $ha^{-1}$), 100% maize (44444 $ha^{-1}$) + 75% bean (93750 $ha^{-1}$) and 100% maize (44444 $ha^{-1}$) + 50% bean (62500 $ha^{-1}$) which were arranged in randomized complete block design with three replications.

### Agronomic practices

The maize seeds were planted at spacing of 75 x 30 cm while seeds of common bean was sown inside the maize rows at intra-row spacing of 8.9 and 16.7 cm to get population densities of 93750 and 62500 $ha^{-1}$, respectively. Sole common bean was planted at spacing of 40x10cm. Each plot had six maize rows and five bean rows. The two extreme rows of maize were taken as border rows. Other agronomic practices were done as per the recommendation of both crops.

### Soil analysis

Soil sample before sowing was taken at representative point of the experimental field to make one composite sample. The sample was analyzed for soil texture, total N, available P, and soil pH. Soil texture was measured using the Bouyoucos hydrometer (Day, 1965). Soil pH was measured in a 1:2.5 soil to water ratio suspension using pH meter. Available P was determined using the Olsen (NaHCO3) extraction method as described by Olsen *et al.* (1954). Nitrogen was measured using the modified kjedahl method as described by Jackson (1967).

### Data collected on common bean component

For data collection, six plants were randomly selected from the central three rows by ignoring the border rows. Days to 50% flowering and physiological maturity were recorded when 50% of the plants in each plot reached these respective phonological stages. Leaf area was determined by taking six plants per plot at flowering stage. Leaf area index (LAI) was calculated as the ratio of total leaf area to area occupied by the plants. Plant height (cm) was measured at maturity stage. Number of pods per plant was recorded as the total numbers of pods per plant at maturity . Number of seeds per pod was recorded by dividing total seed number to total pod number of a plant . Hundred seed weight (g) was recorded by counting hundred seeds from a bulk of threshed seeds and weighed using a sensitive balance. Grain yield was harvested from central rows by avoiding border effects and converted to $kgha^{-1}$ after adjusting the moisture content at 10%.

### Data collected on maize component

For data collection, six plants were randomly selected from the net plot area by ignoring the border rows. Days to 50% taselling, silking and maturity were recorded when 50% of the plants in a plot reached the respective phenological stages. Leaf area was determined by measuring leaf length and width using methods described by Mckee (1964) as Leaf area (LA) = length (cm) × maximum width of leaf (cm) × 0.733. Leaf area index (LAI) was calculated as the ratio of total leaf area of plants ($cm^2$) per area of land occupied by these plants. Plant height(cm) was measured at maturity. Ear length (cm) was measured from six randomly taken plants at harvest. Thousand-kernel weight (g) was weighed using sensitive balance. Grain yield ($kgha^{-1}$) was determined from the net harvestable area .

### Productivity and economic advantage of intercrop

Land equivalent ratio was calculated to assess the productivity of the intercropping systems by the equation given by Willey (1991) as LER = Yab/ Ya + Yba/ Yb

Where: Ya = yield of component of crop 'a' in pure stand, Yb = yield of component of crop 'b' in pure stand;

Yab = yield of crop ‘a’ in intercropped with component of crop ‘b’; Yba = yield of crop ‘b’ in intercropped with component of crop ‘a’. The economic advantage of intercrop was done using Gross Monetary Values (GMV) as described by Willey (1979). To calculate the GMV of component crops, the prevailing prices at local market (5.0 Birr per kg for common bean and 7.0 Birr per kg for maize) were used.

**Statistical analysis of data**
Analysis of variance was carried out using SAS-statistical software (SAS Version 6.12, 1997). Significantly differing means were separated using the least significance difference (LSD) test at 5% level of significance as per the procedure described by Gomez and Gomez (1984).

## RESULT AND DISCUSION

**Physiochemical properties of soil :** Analysis of soil sample indicated that the chemical environment of the site was moderately acidic (pH=5.7), very low in available phosphorus (2.02 ppm) as per the rate of Olsen et al. (1954), low in total nitrogen (0.17%) as per the rate of Sahlemedhin (1999) and textural class was clay loam.

**Effect of crop mixture on maize**
**Crop Phenology**: Population density of component crop had non-significant ($P< 0.05$) effect on days to 50% tasseling, days to 50% silking and days to physiological maturity of maize (Table 1). This may be attributed to less competitive effect of bean on maize which use environmental resources dominantly over bean. Similar result was reported by Temesgen *et al*. (2015). Furthermore, Muoneke *et al*. (2007) indicated that tasseling and silking of maize weren't influenced by intercropping of maize with soybean.
**Growth parameters**: Analysis of variance showed that plant height, leaf area and leaf area index weren’t significantly ($P< 0.05$) influenced by population density of common bean (Table 2). Worku (2008) reported that variatin on population density of bean didn't influence growth of maize which may be attributed to less aggressive nature of bean over maize. Similarly, Muoneke *et al.* (2007) reported that plant height and leaf production of maize weren't significantly influenced by its association with soybean.

Table 1. Effects of component crop density on days to 50% tasseling, days to 50% silking and days to physiological maturity of maize intercropped with common bean and grown under sole crop

| Treatments | Days to 50% tasseling | Days to 50% silking | Days to physiological maturity |
|---|---|---|---|
| Intercropping Pattern | | | |
| Sole Maize | 82.33 | 88.08 | 119.75 |
| Maize+75% Bean | 82.17 | 87.83 | 119.42 |
| Maize+50% Bean | 82.00 | 87.58 | 118.75 |
| LSD (0.05) | NS | NS | NS |
| CV (%) | 2.56 | 2.84 | 3.53 |

**Table 2. Effects of component crop density on plant height, leaf area and leaf area index of maize intercropped with common bean and grown under sole crop**

| Treatments | Plant height(cm) | Leaf area($cm^2$) | Leaf area index |
|---|---|---|---|
| Intercropping Pattern | | | |
| Sole Maize | 177.22 | 763.71 | 2.85 |
| Maize+75% Bean | 175.26 | 752.67 | 2.67 |
| Maize+50% Bean | 179.22 | 767.23 | 2.73 |
| LSD (0.05) | NS | NS | NS |
| CV (%) | 21 | 10.1 | 11 |

**Yield and yield component parameters**: Population density of bean hadn't significant ($P< 0.05$) effect on ear length, 1000 kernel weight and grain yield of maize (Table 3). However, grain yield and yield component of sole maize were higher than intercropped maize which might be attributed to the fact that crops under sole cropping system have better resource utilization than under intercropping system (Gebru, 2015).

**Table 3. Effects of component crop density on ear length, 1000 kernel weight and grain yield of maize intercropped with common bean and grown under sole crop.**

| Treatments | Ear length (cm) | 1000 kernel weight (g) | Grain Yield (kg $ha^{-1}$) |
|---|---|---|---|
| Intercropping Pattern | | | |
| Sole Maize | 15.55 | 374.91 | 4437.1 |
| Maize+75% Bean | 15.95 | 363.75 | 4380.4 |
| Maize+50% Bean | 15.55 | 375.58 | 4197.5 |
| LSD (0.05) | NS | NS | NS |
| CV (%) | 7.03 | 3.96 | 6.72 |

**Effect of crop mixture on common bean :**

**Growth parameters**: Analysis of variance showed that plant height and leaf area weren't significantly($P< 0.05$) influenced by variation on population density while leaf area index showed significant($P< 0.05$) difference (Table 4). The higher leaf area index was recorded from intercropping pattern of 100% maize with 75% common bean. The higher leaf area index as the population density of common bean increased may be attributed to the lower area occupied by a given plant as the population density increased or more number of plant per a given area as compared to lower population density. Additionally, common bean under sole cropping pattern had significantly($P< 0.05$) higher leaf area (1771.86$cm^2$) and leaf area index (4.25) than intercropped bean. The higher leaf area and leaf area index of common bean under sole cropping pattern may be related to the absence of shading effect of main crop(maize), and then plants can intercept light to their potential and grow vigorously opposite to intercropped bean. In line with this result, kassahun (2013) reported that sole common bean had significantly higher leaf area and leaf area index than intercropped bean.

**Yield and yield component parameters:**

Population density had non- significant($P< 0.05$) effect on yield component parameters of common bean but seed yield $ha^{-1}$ showed significant($P< 0.05$) variation due to difference in intercropping population (Table 5). The higher seed yield (1413.2 kg$ha^{-1}$) was obtained from intercropping pattern of 100% maize+75% bean. The significant increase of seed yield as common bean population in the intercropping system increase from 50 to 75% may be related to more number of plant per a given area. Seed yield of common bean in sole cropping was significantly ($P< 0.05$) higher than intercropped one. This result may be related to the fact that plants in sole cropping system are more advantageous than when they are intercropped since they have better opportunity to capture environmental resources like water, light and nutrients and also no inter-specific competition under sole cropping system (Gebru, 2015).

**Table 4. Effects of crop density on plant height, leaf area and leaf area index of common bean intercropped with maize**

| Treatments | Plant height(cm) | Leaf area per plant ($cm^2$) | Leaf area index |
|---|---|---|---|
| Intercropping Pattern | | | |
| Maize+75% Bean | 40.81 | 1465.53 | 2.41 |
| Maize+50% Bean | 40.97 | 1492.32 | 1.62 |
| LSD (0.05) | NS | NS | 0.18 |
| Cropping system | | | |
| Sole crop mean | 46.39 | 1771.86a | 4.25a |
| Intercrop mean | 40.51 | 1478.93b | 2.02b |
| LSD (0.05) | NS | 183.81 | 1.44 |
| CV (%) | 9.8 | 12.8 | 8.9 |

**Crop productivity and monetary advantage**

Land equivalent ratio and gross monetary value were used to evaluate the productivity and economic advantage of maize -bean intercropping, respectively. The analysis of the partial land equivalent ratio of the component crops showed that variation on density of common bean had significant ($P<0.05$) effect on the partial land equivalent ratio of the bean component and but not for maize component (Table 6). Since 42% yield advantage was obtained from intercropping of maize with bean at density of 93750 $ha^{-1}$ as compared to sole cropped one, intercropping was more efficient in land use than sole cropping. Intercropping advantage may come from better resources (moisture, light and nutrient) utilization with low interspecific interaction and better complementary effect.

**Table 5. Effects of crop density on pod length, pod number, seed weight, seeds number and seed yield of common bean intercropped with maize**

| Treatments | PL | PN | HSW | SP | SY |
|---|---|---|---|---|---|
| Intercropping Pattern | | | | | |
| Maize+75% Bean | 10.07 | 10.29 | 30.67 | 4.44 | 1413.18a |
| Maize+50% Bean | 8.94 | 10.56 | 30.38 | 4.47 | 1167.73b |
| LSD (0.05) | NS | NS | NS | NS | 126.44 |
| Cropping system | | | | | |
| Sole crop mean | 7.32 | 11.9 | 31.8 | 4.99 | 2282.6a |
| Intercrop mean | 9.5 | 10.4 | 30.0 | 4.78 | 1365.5b |
| LSD(0.05) | NS | NS | NS | NS | 734.2 |
| CV (%) | 33.0 | 15.65 | 4.38 | 5.7 | 11.45 |

PL(cm)=pod length, PN= pod number, HSW=hundred seed weight, SP= seeds per pod, SY= seed yield kgha$^{-1}$

Intercropping of maize with common bean at density of 793750 ha$^{-1}$ had significantly ($P<0.05$) more economic advantage(36898.2Ebirr) than the other crop combination (Table 6). Common bean under sole cropping had significantly($P<0.05$) higher economic advantage than when it was intercropped with maize that may be related to more number of population, absence of interspecific interaction and better resource utilization under sole cropping system than when it was intercropped. In line with this result, Niringiye *et al.*(2005) reported that intercropping of maize with different population density of bean resulted more yield and economic advantage than sole cropping of the component crops.

**Table 6. Land Equivalent Ratio (LER) and Monetary Value (MV) of maize and common bean grown in intercropping and sole cropping.**

| Treatments | Maize LER | Bean LER | Total LER | GMV |
|---|---|---|---|---|
| Intercropping Pattern | | | | |
| Sole Maize | | | | 30663.1b |
| Maize+75% Bean | 0.897 | 0.58 | 1.42 | 36898.2a |
| Maize+50% Bean | 0.84 | 0.51 | 1.40 | 36448.5a |
| LSD (0.05) | NS | 0.04 | NS | 1709.9 |
| CV (%) | 10.4 | 12.8 | 11.4 | 12.3 |
| Cropping System(GMV) | | | | |
| Sole common bean | | | | 11413.1a |
| Intercrop | | | | 6452.3b |
| LSD (0.05) | | | | 2180.9 |
| CV (%) | | | | 10.5 |

## CONCLUSION

The aim of this study was determining the optimum population density of common bean for better yield of maize/common bean intercropping. The statistical analysis of data revealed that non-significant variation was observed between intercropped and sole maize on crop phenology, days to physiological maturity, growth parameters, yield and yield components. Sole cropped common bean had significantly higher growth and yield performance than intercropped bean. Intercropping pattern had significant effect on the partial land equivalent ratio of bean component but not for maize component. From this investigation it can be conclude that intercropping of maize with common bean having density of 93750 ha$^{-1}$ gave both highest agronomic and economic advantage. For better productivity of the intercropping system, further study should be done by considering other factors of production in conjunction with population densities of component crops.

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