academicresearchJournals

Vol. 4(6), pp. 297-320, November 2016
DOI: 10.14662/ARJASR2016.037

ISSN: 2360-7874
http://www.academicresearchjournals.org/ARJASR/Index.htm

Academic Research Journal of Agricultural Science and Research

Full Length Research

Determinations of Haricot Bean (*Phaseolus vulgaris* L.) Planting Density and Spatial Arrangement for Staggered Intercropping with Maize (*Zea mays* L.) at Wondo Genet, Southern Ethiopia

Belstie Lulie[1*], Walelign Worku[2] and Sheleme Beyene[3]

[1]Ethiopian Institute of Agricultural Research, Wondo Genet Agricultural Research Center, P.o.box, 198, Shashemene, Ethiopia

[2, 3] Hawassa University College of Agriculture, P.o.box, 05, Hawassa, Ethiopia

[*]Corresponding author's email: kbelstie@yahoo.com

Accepted 5 November 2016

Wondo Genet area, which is located in Sidama zone of south Ethiopia, is characterized by rapidly increasing human population and scarcity of arable land per household. There is a need for developing an efficient cropping system in order to use the limited land efficiently and to enhance food security. An experiment was, therefore, conducted at Wondo Genet agricultural research center experimental farm to determine the optimum proportion and spatial arrangement of haricot bean under staggered intercropping with maize and assess the biological efficiency and economic return. The trial was a 2 x 4 factorial arrangement in RCBD design consisting of ten treatments: two haricot bean spatial arrangements (single and double row) and four haricot bean densities (250000, 187500, 125000 & 62500 plants ha $^{-1}$). The analysis of variance indicated that cropping system revealed significant effect on yield and yield components of maize where significant reduction was found under intercropped plots. Sole cropped maize had highest yield (7.87 ton ha^{-1}) and intercropping with bean reduced its yield by 10 %. On the other hand, the spatial arrangement by planting density interaction significantly affected grain yield of haricot bean where the maximum (2.24 ton ha^{-1}) and minimum (0.95 ton ha^{-1}) yields were recorded at 100% haricot bean population density with a double row arrangement and 25% density with single row arrangement, respectively. The cropping system, on the other hand, significantly influenced all yield and yield components of haricot bean except seed number per pod. The highest grain yield (2.62 ton ha^{-1}) of haricot bean was obtained at sole planting compared to that of intercropping (1.58 ton ha^{-1}) with maize showing 40% loss. In general, relative yields of component crops were reduced in mixture and haricot bean showed greater degree of yield reduction than its respective maize counterpart. Additionally, intercropping of maize with haricot bean had total LER value greater than 1 which showed the advantage of intercropping over sole cropping of each crop. Intercropping of the two component crops at 100 and 75% population density (statistically at par) achieved total LER values of 1.69 and 1.61 and MAI values of 21445 and 19817 ETBha^{-1} respectively. Therefore, haricot bean with a density of 187500 plants ha^{-1} and at a spacing of either 80 *7cm (1:1) or 40 * 14cm (1:2) could be recommended for intercropping with maize 30 days after maize planting in the target area, based on its better compatibility, productivity and economic benefit.

Key words: Haricot bean, LER, MAI, maize, population density, spatial arrangement

Cite this article as: Lulie B, Worku W, Beyene S (2016). Determinations of Haricot Bean (*Phaseolus vulgaris* L.) Planting Density and Spatial Arrangement for Staggered Intercropping with Maize (*Zea mays* L.) at Wondo Genet, Southern Ethiopia. Acad. Res. J. Agri. Sci. Res. 4(6): 297-320

INTRODUCTION

Over the years, food production for a rapidly growing population from a limited farm size is a prime developmental challenge. Thus, the only way to increase agricultural production is to increase yield per unit area. Agriculture in the next decade will have to produce more food from less area of land through more efficient use of natural resources with minimal impact on the environment in order to meet the growing population demands (Hobbs *et al.*, 2008). Multiple cropping offers one of the best ways of increasing production per unit area by growing two crops of dissimilar growth habit in the same field with little intercrop competition. Intercropping, growing two or more crops at the same time on a single field, is an ancient agronomic practice still used in much of the developing world because it reduces the losses caused by pests, diseases and weeds, as well as also guarantee better yield. Traditionally, intercropping is being used by small farmers to increase the density of their products and stability of their output. Thus, intercropping has an immense importance for sustainability of farming system, which is especially true for small-scale resource poor farmers experiencing food shortage. Intercropping legumes with non-legume can be a principal means of intensifying crop production both spatially and temporally to improve crop yields for smallholder farmers. Cereal-legume mixtures have been adjudged the most productive form of intercropping since the cereals may benefit from the nitrogen fixed in the root nodules of the legumes in the current cropping year (Adu-Gyamfi *et al*., 2007; Undies *et al*., 2012). In this regard, there is a possibility of root exudates or the decay of roots and nodules causing the release of N from legumes into the rhizosphere during the cropping season. Legumes in intercropping could also provide N benefits to subsequent crops from the mineralization of N from their residues or from the N sparing effect, where a legume crop can fix atmospheric N_2, thereby reducing competition for soil NO_3^- with a non-legume crop (Tamiru, 2014).

Morpho-physiological differences and agronomic factors such as the proportion of crops in the mixture regulate competition between component crops for growth-limiting factors (Morgado and Willey, 2003). The degree of competition induced yield loss in an intercropping depending on competitive ability of the intercropped plant species, component crop density, plant arrangements, relative time of planting of the component crops and plant nutrients available in soil. Enhancing productivity of maize and bean intercrops requires improving the interspecies complementarity or reducing competition effects (Mutungamiri *et al.*, 2001). This might be achieved through manipulation of plant arrangements, plant densities, relative planting dates and planting compatible cultivars (Rao and Mittra, 1990).

Plant density is one of the most important agronomic management decisions to consider when deciding to practice intercropping. Craufurd (2000) noted that poor management of planting density could be detrimental to intercropping. Density of the component crops in the association play a significant role in influencing the level of competition, resource use and performance of the system. Plant densities that are too low limit the potential yield, and plant densities that are too high lead to increased stress on the plant, and increased interplant competition for light, water and nutrients (Ayisi *et al*., 2004) which also decreases the yield.

The other important management aspect is spatial arrangement which can improve radiation interception through more complete ground cover and determine whether an intercrop system will be advantageous or not with regard to yield gains (Heitholt *et al.*, 2005; Nthabiseng *et al.*, 2015). Row arrangements, in contrast to arrangements of component crops within rows, improve the amount of light transmitted to the lower legume. Such arrangements can enhance legume yields and efficiency in cereal/legume intercrop systems (Nthabiseng *et al.*, 2015). However, the greater challenge for researchers is to find the correct combination of intercropping pattern and planting density that will maintain or enhance growth and yield of maize under increased population of legume in the intercrop.

Smallholder farmers in Wondo Genet grow maize as an intercrops with grain legumes, mostly dry bean. Since lack of arable land is a constraint, optimizing intercropping performance can assist in effective use of space and nutrients. Thus, selection of crops that differ in competitive ability in time or space is essential for an efficient intercropping system as well as decisions on when to plant, at what density, and in what arrangement. Therefore, there is potential for higher productivity of intercrops when intra-specific competition is less than inter-specific competition for a limiting resource (Banik and Sharma, 2009).

Arrangement of crops in mixture in the traditional farming systems of Wondo Genet area is random and without any sufficient attempt to pattern the crops for effective interception of essential resources. Much of the poor crop yields obtained in traditional crop production systems of this area might be attributable in part to improper crop arrangement and relative planting time of component crops with its attendant waste of essential environmental resources. Thus, the need for reasonable cropping system under intensive cropping has become major areas of agronomic research in such an area.

In the study area, the performance of maize-haricot bean intercropping with varied planting density and spatial arrangement of the pulse under staggered planting has not been investigated. In view of the above reasons, this research was undertaken with the following objectives:

1. To determine the optimum proportion of haricot bean for maximum productivity in the mixture of the two component crops;
2. To identify suitable spatial bean arrangement for maize-bean staggered intercropping and
3. To assess the biological efficiency and economic return of the maize-bean staggered intercropping system.

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was conducted at Wondo Genet agricultural research center, southern Ethiopia under rainfed condition in 2015/2016 cropping season. The research center is located 270 km South of Addis Ababa and 14 km southeast of Shashemene. It exists within the Ethiopian Rift Valley of the Southern Nations Nationalities and People's Region (SNNPR), Sidama Zone. The geographical coordinate of the research site is $7^0$19'N and $38^0$38'E with an altitude of 1780 meters above sea level (masl). The mean annual minimum and maximum rainfall are 709 mm and 2062 mm respectively. The site has a mean maximum and minimum temperature of $26^o{}_c$ and $12^o{}_C$ respectively. The soil of the study area is clay loam in texture, neutral in reaction, low in organic matter, medium in total N, and low in available P and high in CEC (Table 1).

Wondo Genet has a bimodal rainfall distribution with two rainy seasons. Short rains occur during March-May and the long rains in July-October. The dry season extends from November to February (Dawit and Afework, 2008). The center (WGARC) is suitable for maize and haricot bean research and production.

Experimental Materials

Plant materials

Hybrid variety of maize namely Shala (P2859w) was used for the study. Shala (P2859w), one of the most successful hybrid varieties adapted primarily along the rift valley areas and Eastern Ethiopia, Hawassa, Melkasa, Mechara, Gurusum areas and other similar environments, is released by Pioneer Hybrid PLC in Ethiopia in 2011. It grows well at altitudes ranging from 1000 to 1700 masl with annul precipitation of 800 to 1000 mm. It needs 71 days to anthesis, 72 days to silking and 133 days to maturity and performs better under moisture limited areas and good soil conditions (MOA, 2011).

Haricot bean variety 'Hawassa Dume', which was released by SARI/AWRC in 2008, was used as the companion crop in additive series. It grows well at altitudes ranging from 1100 to 1750 masl with annul precipitation of more than 500 mm. It is adapted well in Hawassa, Amaro, Inseno, Gofa, Areka and similar areas in southern regions and southern Rift Valley areas. Hawassa Dume is determinate type in growth habit and requires 85-110 days to maturity (MOARD, 2008).

The two crops were selected for intercropping based on their adaptability in the area, differences in their morphological characteristics and yield potential.

Fertilizer materials

The land was fertilized with 20 kg P $ha^{-1}$and 92 kg N ha^{-1} as recommended for sole maize production. Split application of N (1/3 during planting and 2/3 at knee height (when the plant produced 6-8 leaves)) and full quantity of P was applied during planting. No separate fertilization was made for intercropped haricot bean.

For the sole treatment of haricot bean 20 kg P ha^{-1} was used. Separate nitrogen fertilizer was not used for the sole treatment of haricot bean. All levels of phosphorus were applied at sowing. The sources of nitrogen and phosphorous fertilizer were urea and Diammonium phosphate (DAP).

Description of Treatments and Experimental Design

The experiment was laid out in a randomized complete block design (RCBD) in 2x4 factorial arrangements with ten treatments and three replications. A uniform population of 50,000 plants ha^{-1} and a constant 80 cm by 25 cm inter and intra-row spacing, respectively, was maintained for maize in both cropping systems (sole and intercrop). In this study, plant populations of 250,000 plants ha^{-1} with 40cm by 10cm inter and intra row spacing respectively, was considered as an optimum population for sole crop of haricot bean. On the other hand, there were four different intercrop proportions of haricot bean: 25% (62,500 plants ha^{-1}), 50% (125,000 plants ha^{-1}), 75% (187,500 plants ha^{-1}) and 100% (250,000). The four levels of haricot bean populations were inter planted with maize in a spatial arrangement of 1:1 and 1:2 maize-haricot bean row arrangements. Double seeds of maize and haricot bean were used for planting and later thinned to obtain the required stand. Gross plot size of the experiment was 14.4 m^2 (4.8 *3 m) and the distance between the plots and blocks were kept at 1 and 1.5 m apart respectively. Each plot consisted of six rows of maize. The net central unit areas (3.20*2.50 m=8 m^2) of

Table 1. Descriptions of treatments

Treatments	Maize spacing		HB spacing		SA (Maize: HB)	maize rows /plot	HB rows/plot	Maize population/ ha	HB population /ha	Remark
	Intra row (cm)	Inter row (cm)	Intra row (cm)	Inter row (cm)						
T1	25	80	----	-----	-----	6	------	50000	----	Sole maize
T2	----	------	10	40	------	----	12	-----	250000	Sole HB
T3	25	80	5	80	1:1	6	6	50000	250000	100% HB
T4	25	80	6.75	80	1:1	6	6	50000	187500	75% HB
T5	25	80	10	80	1:1	6	6	50000	125000	50% HB
T6	25	80	20	80	1:1	6	6	50000	62500	25% HB
T7	25	80	10	40	1:2	6	12	50000	250000	100% HB
T8	25	80	13.5	40	1:2	6	12	50000	187500	75% HB
T9	25	80	20	40	1:2	6	12	50000	125000	50% HB
T10	25	80	40	40	1:2	6	12	50000	62500	25% HB

SA=spatial arrangement; HB=haricot bean;

each plot excluding the borders were used for data collection.

Sole and intercropped maize was planted on mid of June. The companion crop was planted four weeks after maize planting.

Experimental Procedures

Field activities and treatment application

All field activities were carried out following the standard production practices. Seeds of the main and the companion crop were sown in each plot uniformly by hand drilling in to rows at the recommended rate of 25 kg ha^{-1} for maize and different rates of haricot bean based on the treatments. All weeds were removed by hand weeding. Additionally, weeding of late-emerging weeds was done to avoid nutrient competition with the crop. Insecticides namely Endosulfan (Ethiosulfan 35% EC) and profenofos 72% EC (profit720% EC) were used to prevent the occurrences of thrips and stalk borer. The chemicals were sprayed at knee height of maize when plants were 50-75 cm tall. The rates of application were 2 L/ha for Endosulfan and 0.7 L/ha for Profenofos 72 % EC mixed with 200 L/ha of water for each chemical. They were sprayed twice within fifteen days interval. All other agronomic practices were applied uniformly for all treatments as recommended.

Soil sampling and analysis

One composite soil sample per replication, each made from five sub-samples, was collected in a diagonal pattern from 0-20 cm soil depth before planting. After harvest soil samples were taken from every plot to assess the nutrients concentrations. Uniform slices and volumes of soils were obtained in each sub-sample by vertical insertion of an auger. The samples were air-dried, ground to pass through a 2 mm sieve, except for analysis of organic carbon and nitrogen, where the samples were passed through 0.5 mm sieve. Working samples were obtained from each submitted samples and analyzed for selected physico-chemical properties such as texture, soil pH, organic carbon, total N, available phosphorus, and cation exchange capacity (CEC) using standard laboratory procedures.

Total N in the soil was determined by the Kjeldahl method (Dewis and Freitas, 1975). Organic carbon content of the soil was determined by reduction of potassium dichromate by organic carbon compound and determined by reduction of potassium dichromate by oxidation reduction titration with ferrous ammonium sulfate (Walkley and Black, 1934). Particle size distribution (texture) was determined by hydrometer method (differential settling within a water column) using particles less than 2 mm diameter (FAO, 2008). This procedure measures percentage of sand (0.05 - 2.0 mm), silt (0.002 - 0.05 mm) and clay (<0.002 mm) fractions in soils. Available P was determined following the method of Olson and Dean (1965). Cation exchange capacity (CEC) of soil was determined using ammonium acetate method at pH 7.0 (Jackson,1964).The pH of the soil was measured in 1:2.5 (weight/volume) soil samples to $CaCl_2$ solution ratio using a glass electrode attached to digital pH meter (Page *et al.,*1982). All the above physico chemical properties were analyzed at the Soils laboratory in College of Agriculture, Hawassa University.

Data Collection and Measurements

Phenological parameters

Maize

Days to tasseling was taken as the number of days required from emergence to tassel production by 50% of maize plants in the plots. Days to silking was recorded as the number of days required from emergence to silking by 50% of maize plants in the plots. Days to physiological maturity (DPM) was recorded as the number of days from emergence to the formation of a black layer in the kernel at the point of attachment of the kernel with the cob by 90% of maize plants in the plots.

Haricot bean

Days to flowering were determined as the number of days from emergence to the period when 50% of the plants in each plot produce their first flower. Days to Physiological maturity was taken as the number of days from emergence to the period when 50% of the plants in a plot are changing the foliage (turned to yellow) and pod color and seed hardening in the pods. It was indicated by senescence of the leaves as well as free threshing of the seeds from the pods when pressed between the forefinger and thumb.

Plant growth parameters

Maize

Plant height (cm) was measured as the height from the soil surface to the base of the tassel of five randomly taken plants from the net plot area using measuring stick at physiological maturity and the average was taken for analysis. Ear length (cm) was measured as the length of the ear following removing of the sheath after harvest. Leaf area (cm^2), at 50% silking, was determined from five randomly sampled plants per plot and the leaves from each plant categorized into small, medium and large leaves. Then it was calculated by multiplying leaf length and maximum breadth adjusted by a correction factor of 0.733 (i.e. 0.733 x leaf length x maximum breadth) as described by McKee (1964). Leaf area index was calculated by dividing mean leaf area per sampled ground area occupied by the plant (Radford, 1967). The ground area was calculated for both sole and intercrop as 80 cm x 25 cm=2000 cm^2.

Haricot bean

Plant height (cm) was measured as the height from the soil surface to the tip of five randomly taken plants from the net plot area at physiological maturity and the average was taken for analysis. Leaf area was measured by using portable area meter (model CI –202) from five sampled plants at 50% flowering by destructive approach. Leaf area index was calculated as the ratio of mean leaf area of sampled plants to the ground area occupied by those plants (Radford, 1967).

Yield components and yield

Maize

Stand count was counted at physiological maturity before harvesting. Hundred kernels weight (g) was determined by putting 100 kernels into three replications and weighting them separately using sensitive balance and finally their averaged weight was taken and adjusted to 12.5% moisture content. Grain yield per plot (g/plot) was measured using electronic (steelyard) balance and then adjusted to 12.5% seed moisture content using a digital moisture tester (model M-3G) and converted to hectare basis. Adjusted yield was calculated using Hellevang (1995) formula.

$$\text{Adjusted yield} = \frac{(100\text{-actual moisture})}{(100\text{-standard moisture})} \times \text{obtained yield}$$

Above Ground Biomass (ton/ha) was measured from the net plot area including leaves, stems and seeds which were harvested at physiological maturity just before cob removal and weighed after three days of sun drying.
Harvest index was calculated as the ratio of grain yield to aboveground biomass and multiplied by 100 and expressed as percentage (Donald, 1962). It was expressed by the following formula

$$HI = \frac{GY\ (ton/ha) \times}{AGB\ (ton/ha)} 100$$

Where, HI= harvest index; GY=Grain yield (at 12.5%

moisture base) and AGB=above ground biomass (Stover +grain yield)

Haricot bean

Stand count per plot was counted at physiological maturity before harvesting. Pods per plant were counted from five selected haricot bean plants at physiological maturity and the average was recorded for each plot. Seeds per pod was recorded from fifteen randomly sub sampled pods and the average was taken. Thousand seed weight (g) was determined from 1000 seeds randomly taken from each plot and weighed using sensitive balance and adjusted to 10% seed moisture content. Grain yield per plot was measured using electronic balance (steelyard) and then adjusted to 10 % seed moisture content using digital moisture tester and converted to hectare basis. Adjusted yield was calculated by using the following formula (Hellevang (1995),

$$\text{Adjusted yield} = \frac{(100\text{-actual moisture})}{(100\text{-standard moisture})} \times \text{obtained yield}$$

Above ground biomass (kg/ha) was determined after oven drying at 70 $^0{}_C$ through measuring its weight after consecutive one day interval before threshing till it maintains constant dry weight. Harvest index was estimated as the ratio of grain yield to above ground biomass per hectare and multiplied by 100 to express as percentage.

Analysis of Productivity and Benefit

Land equivalent ratio

The benefit of intercropping and the effect of competition between component crops were calculated by land equivalent ratio. Land equivalent ratio which verifies the effectiveness of intercropping for using the resources of the environment compared to sole planting. The LER values were computed using the following formula described by Willey *et al.* (1983)

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where, Yab and Yba are yield of maize and haricot bean in an intercropping system respectively and Yaa and Ybb are yield of maize and haricot bean in pure stand of each crop respectively.

Monetary advantage index (MAI)

The most important part of recommending a cropping pattern was the cost: benefit ratio more specifically total profit, because farmers are mostly interested in the monetary value of return. The yield of all the crops in different intercropping systems and also in sole cropping system and their economic return in terms of monetary value were evaluated to find out whether maize yield and additional haricot bean yield were profitable or not. This was calculated with monetary advantage index (MAI) which indicates more profitability of the cropping system with the higher the index value (Mahapatra, 2011). It was expressed as

$$MAI = (Pab+Pba) * \frac{LER-1}{LER}$$

Where, Pab = Pa ×Yab; Pba =Pb ×Yba; Pa = Price of maize and Pb = Price of haricot bean;
The price of maize and haricot bean seed per kg in Ethiopian birr was taken from Shashemene grain market during the cropping season. Accordingly, the prices were 6 and 5 birr kg^{-1} for maize and haricot bean respectively.

Statistical Analysis

Analyses of variances for the data recorded were conducted using the SAS GLM procedure version 9.0 (SAS, 2001). Least significant difference (LSD) test at 5% probability was used for mean separation when the analysis of variance indicates the presence of significant differences (Gomez and Gomez, 1984).

RESULTS AND DISCUSION

Physical and Chemical Properties of the Experimental Soil

Soil analysis before planting

Selected physico-chemical properties of the composite surface soil (0-20 cm) collected before planting showed that the soil was clay loam in texture based on soil textural classification triangle with neutral pH,6.92 (Table 2) indicating that these properties are favorable for both maize and haricot bean production.

Maize can grow nearly in arable areas of Ethiopia but deep and well drained soils with pH of 5.0-7.0 are better suited (Tolessa *et al*., 2001). The common bean crop is also not sensitive to such soil type and a pH greater than 5.5 is suitable for bean growth (Wortman, 2006). Additionally, it was also reported that loam or silt loam surface soil and brown silt clay loam rich in organic content are the ideal soil types for cultivation of common bean (FAO, 2013).

The organic carbon content of the experimental soil

Table 2. Selected soil physical and chemical properties of the experimental site before planting at Wondo Genet in 2015 cropping season

Physical property				Chemical properties				
Particle size distribution			**Texture class**	**pH (H_2O)**	**Total N (%)**	**Available P(mg kg^{-1})**	**OC (%)**	**CEC (cmol kg^{-1})**
clay	silt	sand	Clay					
37	25	38	loam	6.92	0.154	2.57	3.46	43.7

Source: Belstie Lulie, 2015

(3.46%) is low in accordance with Landon (1991), who classified the organic carbon content of soil <4%, 4-10%, and >10% as low, medium and high respectively. The same author classified total nitrogen content of <0.1, 0.1-0.15, 0.15-0.25 and >0.25 as very low, low, medium, and high respectively. Similarly, Tekalign (1991) also classified total nitrogen content of <0.05, 0.05-0.12, 0.12-0.25, and >0.25 as very low, low, medium, and high respectively. The total nitrogen content (0.154%) of the experimental soil was medium (Table 2) in accordance with the ratings of both authors, indicating that the nutrient was not a limiting factor for crop growth.

Available P of the experimental site was 2.57mg kg^{-1} and could be considered as low accordance with Landon (1991), who classified available P of the soil <5, 5-15 and > 15 as low, medium and high respectively. This indicated that P is limiting nutrient for optimum crop growth and yield in the experimental site. The CEC of the soil was 43.7cmol kg^{-1} soil (Table 2), which was very high (Landon, 1991) and appropriate for crop production. According to Landon (1991), CEC by sodium acetate at pH 8.2 or ammonium acetate at pH 7.0 methods with values < 5, 5-15, 15-25, 25-40, and >40 are classified as very low, low, medium, high and very high. Generally, CEC increases with increasing pH, clay and organic matter contents, since clay and organic particles have capacity to attract and hold cations. Cation exchange capacity is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. In general, the properties of the experimental soil and the weather conditions at the site were conducive for growth of both crops.

Maize Response

Phenology and growth response

The analysis of variance showed that days to tasseling, silking and maturity were not significantly (P>0.05) influenced by the main effects of common bean spatial arrangement and population density (Appendix 1). Similarly, Demessew (2002); Yesuf (2003) and Dechasa (2005) reported that days to maturity of maize from maize/common bean and sorghum from sorghum/common bean intercropping are not affected by component planting density.

However, days to tasseling and silking were significantly (P≤0.05) affected by cropping system (Appendix 1). Accordingly, sole cropped maize took longer days to tasseling and silking than intercropped maize (Table 3). This might be because of enough free space available which attributed to less competition by sole maize for water and nutrients allowing the crop in efficient utilization of soil moisture and available nutrients and extending its vegetative growth leading to delayed tasseling and silking dates.

On the other hand, days to maturity was not significantly (p>0.05) influenced by cropping system (Appendix 1). Even though non-significant difference was observed; longer days (139.0) were required in sole cropping than intercropping (137.5) (Table 3). The result agreed with the findings of Demessew (2002); Yesuf (2003) and Sisay (2004) who described that non-significant effect of cropping system on physiological maturity of maize. Similarly, Abraha (2013) mentioned that maize mono crop has a growth period of 120 days and this was not significantly different from maize intercropped with cowpea cultivars.

Plant height

The main effects of spatial arrangement and population densities were found non-significant (p>0.05) on mean plant height of maize (Appendix 1). However, cropping system significantly (P≤0.01) influenced mean plant height of maize (Appendix 1). The tallest mean plant height (209) of maize was observed from intercropped compared to sole cropping system of maize (Table 3). Intercropping increased the plant height of maize by 6% (209 vs. 196) as compared to monocropping (Table 3). This justifies the assertion that as the intra and inter row competition increases; so does the height of the plant linearly due to competition of natural resources. Similar result was reported by Adeniyan *et al.* (2007) in that plant height of maize was increased under maize with African yam bean and kenaf intercropping because of competition for light. Hailu *et al.* (2015), in line with this

Table 3. Means for phenological and growth parameters of maize as affected by spatial arrangement, population densities and cropping system under intercropping with haricot bean at Wondo Genet during 2015 cropping season

Treatments	Days to			Plant height (cm)	Ear length (cm)	Leaf area index
	tasseling	silking	maturity			
Spatial arrangement						
1:1	70.83	76.50	137.83	207.92	22.43	3.15
1:2	70.50	76.33	137.17	210.68	22.30	2.94
LSD@0.05	ns	ns	ns	ns	ns	ns
Population densities						
100%	70.5	76.33	137.33	209.20	22.03	2.87
75%	71.33	77.17	138.17	212.10	23.27	3.21
50%	71.0	76.67	137.83	207.63	22.33	3.06
25%	69.83	75.50	136.67	208.27	21.83	3.05
LSD@0.05	ns	ns	ns	ns	ns	ns
CV	1.40	1.86	1.23	3.19	4.11	13.82
Cropping systems						
Sole	72.67a	79.00a	139.0	195.67b	22.20	3.37
Intercropped	70.67b	76.42b	137.5	209.30a	22.37	3.05
LSD@0.05	1.30	1.90	ns	3.04	ns	ns
CV	1.13	1.65	1.09	3.27	2.84	12.43
SA* PD	ns	ns	ns	ns	ns	ns

*, **, *** significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant
Means in a column followed by the same letters are not significantly different at p≤5% level of significance; SA=Spatial arrangement; PD=Population density

study, also reported that under maize/tomato intercropping height of maize was increased.

Ear length

Ear length was not significantly (P>0.05) influenced by spatial arrangement, population density, cropping system and the interaction (Appendix 1). This indicated the possibility of integration of haricot bean into maize without significant effect on its ear length, thereby complementarity of the two crops for grain formation and development of the main crop.

Leaf area index

Leaf area index was not significantly (P>0.05) affected by spatial arrangement, population density, cropping system and the interaction (Appendix 1). The non-significant effect on LAI may be due to complementary effects, i.e. enough soil moisture may be conserved by densely grown understory haricot bean. Concurrent with the results of this study, Tamado (1994) and Sisay (2004) reported that planting pattern and plant density or their interaction on leaf area indices of sorghum was not statistically significant under intercropping.

Yield components and yield of maize

Hundred kernel weight

Hundred-kernel weight was significantly (P≤0.05) affected by the interaction of spatial arrangement and population density (Appendix 2) though it was not large enough to be strikingly different from the main effects. The main effect of spatial arrangement didn't show significant (p>0.05) effect on hundred kernel weight of maize. Quite the reverse, population density had significant (p≤0.05) effect on hundred kernel weight (Appendix 2). Maximum hundred kernel weight was found at 25% population density though statistically at par with 75 % population density (Table 4). This might be due to relatively less competition of available resources at lower population densities which finally attributed formation of large seed size.

Similarly, the cropping system revealed significant (p≤0.05) variation on hundred kernel weight of maize (Appendix 2). Sole cropping gave maximum kernel weight (29.24g) compared to intercropped treatment (Table 4). The highest hundred kernel weight of maize in maize sole planting could be due to large seed size in a very low plant population per unit area which could be attributed to large accumulation of assimilate due to long tasseling and silking period. This result corroborated with the findings of Undie *et al.* (2012), who noted that hundred seed weight of maize was higher in pure stand

Table 4. Yield and yield components of maize as affected by spatial arrangement, population densities and cropping system under intercropping with haricot bean at Wondo Genet during 2015 cropping season

Treatments	100-kernel weight(g)	Grain yield (ton ha^{-1})	AGB (ton ha^{-1})	Harvest index
Spatial arrangement				
1:1	27.40	7.15	22.16	0.32
1:2	27.11	6.99	20.43	0.34
LSD@0.05	ns	ns	ns	ns
Population densities				
100%	26.98b	7.30	21.53	0.34
75%	27.31ab	7.23	22.143	0.33
50%	26.39 b	6.97	20.81	0.34
25%	28.35a	6.77	20.69	0.33
LSD@0.05	1.36	ns	ns	ns
CV	4.04	5.50	9.67	8.28
Cropping systems				
Sole	29.24a	7.87a	24.15a	0.33
Intercropped	27.26b	7.07b	21.29b	0.34
LSD@0.05	1.56	0.69	2.54	ns
CV	5.33	6.30	10.04	7.64
SA x PD	*	ns	ns	*

*, **, *** significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant
Means in a column followed by the same letters are not significantly different at p≤5% level of significance;
SA=spatial arrangement; PD=Population density

of maize than under maize/ soybean mixtures.

Grain yield

This investigation also indicated that spatial arrangement and population density did not show significant (P>0.05) yield variation (Appendix 2). This could be partly attributed to the delayed entry of bean in maize cropping systems which led to less competition of resources by the two crops due to partial overlapping of haricot bean on the critical growth period of maize. The result is in agreement with the findings of Balearic and Upadhaya (1981) who reported that population density and planting arrangement had no significant effect on sorghum yield in a sorghum/pigeon pea intercropping.

On the other hand, the cropping system showed significant (P≤0.05) effect on grain yield of maize (Appendix 2). The maximum grain yield (7.87 ton ha^{-1}) was obtained from sole cropping system of maize (Table 4) while the lower grain yield (7.07 ton ha^{-1}) was maintained for intercropped maize. The amounts of yield reduction over sole crop was 10% (Table 4).This suggests lower intra-specific competition of sole maize for natural resources (light, water and nutrients) compared to maize intercropped with haricot bean and also revealed effective utilization of applied nitrogen and phosphorus fertilizer by sole maize. The reduction in grain yield due to intercropping may be acceptable to subsistence farmers as it was in the range of a tolerable range (10-15 %) as suggested by Nnadi and Haque (1986). The smaller yield loss of maize under maize-bean intercropping could be due to delayed entry of bean in the cropping system of maize. Concomitant with this finding, Getachew *et al.* (2013) reported that maize/forage legume intercropping significantly reduced maize grain yield by 9.5% over sole maize cropping. Similarly, yield loss of maize were reported by Silwana & Lucas (2002) 34%; Morgado and Willey (2003) 32%; Peksen and Gulumser (2013) 25.77% and Tolera *et al.* (2005) 9.72 % under maize- bean intercropping compared to sole planting of maize.

However, intercropping practices are done with purpose of creating a system with higher combined yield that could benefit the farmers and enhance crop diversity as well as reduce total crop failure due to pest, disease and unusual weather conditions.

Above ground biomass

Parallel to grain yield, the spatial arrangement and population density didn't show significant (P>0.05) variation on above ground biomass (Appendix 2). On the other hand, the cropping system showed significant (P≤0.05) variation (Appendix 2).

Sole cropping gave the highest (24.15 ton ha^{-1}) above ground biomass of maize than intercropping (21.29 ton ha^{-1}) (Table 4). Thus, the sole crop was superior to the intercrop by 12%, which might be because of interspecific

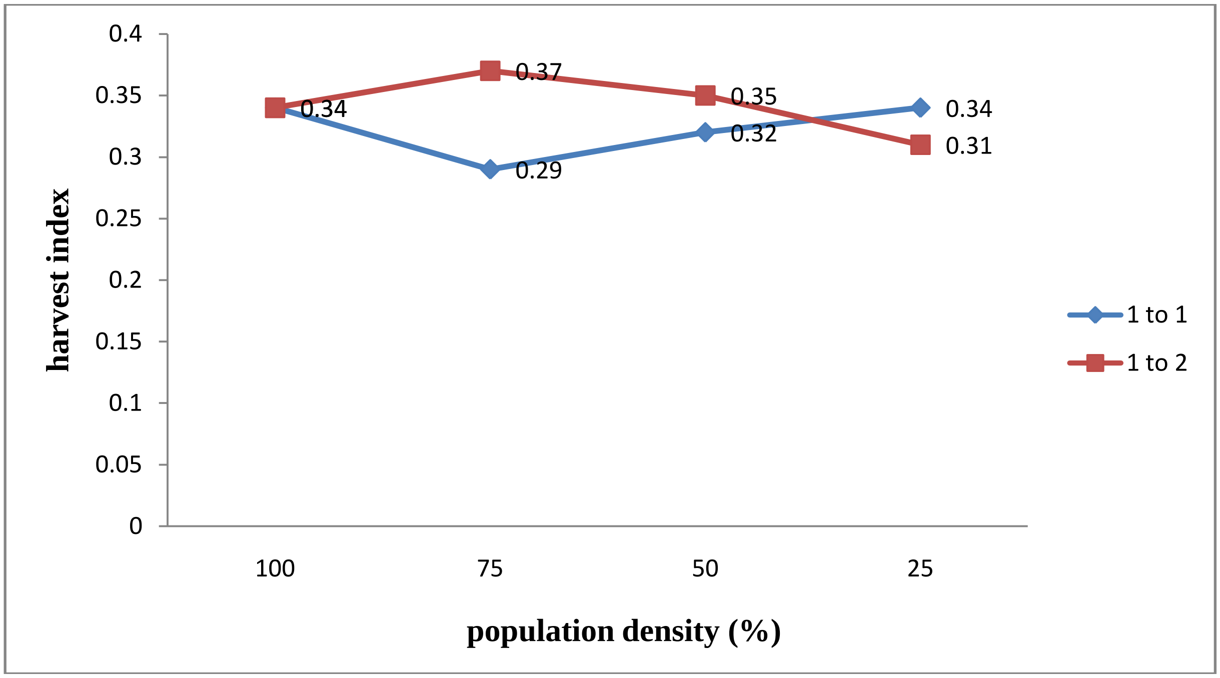

Figure 1. The interaction effect of population density and spatial arrangement of haricot bean on maize harvest index

competition on the available limited growth resources by the intercropped than the sole crop. Similarly Demesew (2002), Tolera (2003) and Tsubo *et al.* (2003), reported that intercropping practice reduced dry matter accumulation in comparison with sole cropping. In the same way, the decrease in total plant biomass of maize under maize/cowpea intercropping had been reported by Egbe *et al.* (2010).

Harvest index

The interaction effect of spatial arrangement and population density showed significant (P≤0.05) variation on harvest index (Appendix 2). The maximum harvest index (0.37) was found at the interaction of 75% population density with 1:2 spatial arrangements (Figure 1). This might be due to high competition in the 1:2 haricot bean spatial arrangements resulting in increased partitioning of dry matter to the seed and decreased the amount of biomass than the sole crop. Ludlow and Muchow (1988) similarly reported that higher transfer of assimilates to the grain would maximize the harvest index and reduce the proportion of dry matter produced early in growth that may be left as a stover.

Harvest index (HI) of the maize crop, on the other hand, was found unaffected by cropping system adopted for this study (Appendix 2). This was in agreement with Tamiru (2014) who found non- significant effect on HI of maize under maize-haricot bean intercropping system.

Haricot Bean Response

Crop phenology

The analysis of variance revealed that the spatial arrangement significantly (P≤0.05) affected days to flowering (Appendix 3). Similarly, population densities of haricot bean have significantly (P≤0.001) influenced days to flowering of haricot bean (Appendix 3). Flowering took more days (41.17 days) at single row spatial arrangement and at 100% haricot bean population densities (43.33 days) (Table 5). A prolonged period to flowering was observed for 1:1 spatial arrangement. This was probably due to relatively less competition between plants for sun light, space, water and nutrients at 1:1 maize to haricot bean ratio which allows the crop more vegetative growth leading to delayed flowering. Similar results were reported by Ijoyah and Dzer (2012) in maize/okra intercropping.

Days to maturity of haricot bean was also significantly (P≤0.05) affected by the interaction of the two main effects (Appendix 3). There was a tendency for 1:1 arrangement to cause relatively extended duration under increasing density while the reverse happened to 1:2 arrangements. The maximum days to maturity (81.0) was recorded at the interaction of 1:1 bean spatial arrangement and 75% haricot bean population density whereas the minimum days of maturity (78.67) was recorded at the interaction of 1:2 haricot bean spatial arrangement and 100% population density (Figure 2). This evidenced that the right intercropping pattern and

Table 5. Phenological and growth parameters of haricot bean under maize-haricot bean intercropping as affected by spatial arrangement and population densities of haricot bean at Wondo Genet during 2015 cropping season

Treatments	Days to flowering	Days to maturity	Plant height (cm)	Leaf area index
	Spatial arrangement			
1:1	41.17a	79.83	55.91b	4.22
1:2	39.75b	79.58	58.88a	4.01
LSD@0.05	1.29	ns	2.04	ns
	Population densities			
100%	43.33a	79.33	57.93a	5.75a
75%	41.33b	80.33	59.33a	5.23a
50%	39.17c	79.67	58.47a	3.66b
25%	38.00c	79.50	53.87b	1.82c
LSD@0.05	1.83	ns	2.88	0.72
CV	3.64	0.97	4.06	14.19
	Cropping systems			
Sole	41.33	80.33	62.93a	8.45a
Intercropped	40.46	79.71	57.40b	4.12b
LSD@0.05	ns	ns	2.87	0.72
CV	3.35	0.77	3.81	8.03
SA x PD	ns	*	**	ns

*, **, *** significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; Means in a column followed by the same letters are not significantly different at p≤5% level of significance; SA= spatial arrangement; PD=Population density

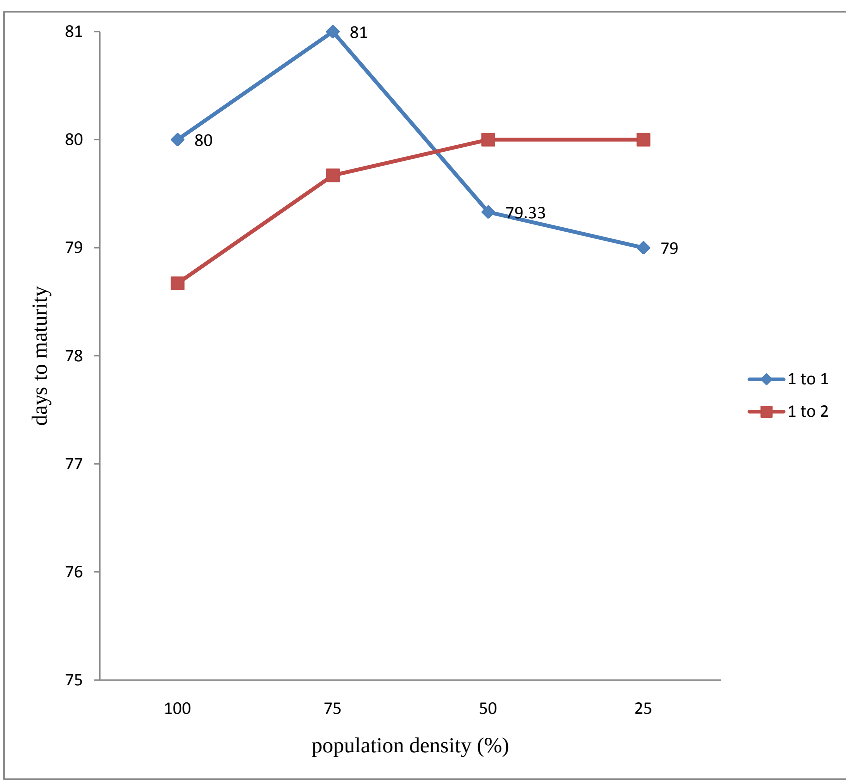

Figure 2. The interaction effect of population density and spatial arrangement of haricot bean on days to maturity of haricot bean

planting density of bean under maize-bean intercropping enhance haricot bean efficiency in utilization of resources by reducing interspecific competition which in turn resulted in delay of flowering and maturity. Similar results were reported by Ijoyah and Dzer (2012) in maize/okra intercropping and Hailu *et al.* (2015) in tomato/maize intercropping.

Unlike the main effects (bean spatial arrangement and population density), the cropping system did not show significant (P>0.05) variation on flowering and maturity date of haricot bean (Appendix 3). This may be the result of lower competition that occurred due to partial overlapping of critical growth periods of the companion crops since haricot bean was intercropped in a staggered way. This result is similar to the findings of Selamawit (2007), who reported non-significant effect of cropping system on days to flowering of potato under maize-potato intercropping. Moreover, Tamado *et al.* (2007) also reported that cropping system had no significant effect on maturity date of common bean.

Growth parameters

Plant height

Spatial arrangement, population density and the interaction of the main effects and cropping systems had significant (P≤0.01) effect on plant height of haricot bean (Appendix 3). However, the interaction effects were not large enough to cause substantial differences from the main effects.

Double row arrangement gave the highest plant height of haricot bean (58.88 cm) (Table 5). Similarly, the tallest plant height was recorded at 75% population density of haricot bean though it was statistically at par with 100 and 50% population density of haricot bean (Table 5). The difference in plant height of common bean at double row arrangement and maximum population density of haricot bean could be attributed due to higher intra and inter specific competition for natural resources particularly for light.

Sole cropping gave significantly (P≤0.05) higher plant height of haricot bean than intercropping with maize (Table 5). This probably could be due to the fact that maize causes nearly complete dominance of growth resources over haricot bean in the early growth stage of haricot bean causing poor growth. Yayeh (2014) also reported sole lupine showed the highest plant height than under cereal/lupin intercropping.

Leaf area index (LAI)

The ANOVA revealed that, the spatial arrangement did not show significant (P>0.05) effect on leaf area index of haricot bean (Appendix 3). Quite the opposite, the main effect of component population density had significant (P≤0.001) effect on leaf area index (Appendix 3).

The maximum (5.75) leaf area index was recorded at 100% haricot bean population density though at par with 75% whereas the lowest (1.82) was maintained at 25 % common bean population density (Table 5). The increase in LAI with increasing population density is due to the increased number of plants per unit area contributing more number of leaves in that given area. Tilahun (2002) also indicated that the main effects of both plant density of faba bean and planting arrangement were significant on LAI of the faba bean intercropped with maize which also followed similar trends to the present finding with respect to density.

Similarly, cropping system had significant (P≤0.01) influence on the leaf area index of haricot bean (Appendix 3). The highest (8.45) LAI was recorded at sole planting of haricot bean (Table 5). This showed that, intercropping decreases the leaf area index of the component crop; because it could be influenced by the high competition of the component crops and shading effect of maize over haricot bean that leads to decreased photosynthetic capacity of the crops (Ali *et al.*, 2003). Such a severe impact of intercropping on LAI could be one of the major factors for the low yield recorded by the bean component.

Yield components and grain yield

Number of pods per plant

Analysis of variance showed that, the main effects (spatial arrangement and population density) and the interaction did not show significant (P>0.05) effect on pod number per plant of haricot bean (Appendix 4). This finding was in agreement with Tamiru (2014) who found non-significant difference on number of pod per plant of haricot bean due to spatial arrangement and planting density in maize-haricot bean intercropping.

However, unlike the main effects, cropping system had significant (P≤0.05) effect on number of pods per plant (Appendix 4). The maximum and the minimum number of pods per plant (29.93 and 16.57) were recorded at sole planting and intercropping, respectively (Table 6). The reason for low number of pods during intercropping were, due to interspecific competition of the crops leading to low number of effective branch that can give greater number of pods. The overall highest pod/plant (29.93) in sole haricot bean might also be due to higher LAI in sole haricot bean that led to increased photosynthetic capacity of the crops. Reduction in number of pods due to intercropping was also reported by Yayeh (2014) who found that the overall highest lupine pod/plant were remarkably greater in sole lupine cropping system as

Table 6. Yield components and Yield of haricot bean under maize-haricot bean intercropping as affected by spatial arrangement population densities and cropping system of haricot bean at Wondo Genet during 2015 cropping season

Treatments	Pods per plant	Seeds per pod	1000-seed weight (g)	Grain yield (ton ha^{-1})	AGB (ton ha^{-1})
Spatial arrangement					
1:1	16.87	5.49	275.40	1.50b	7.49b
1:2	16.23	5.57	274.74	1.66a	10.33a
LSD@0.05	ns	ns	ns	0.11	1.20
Population densities					
100%	16.27	5.47	270.09	1.98a	14.64a
75%	16.43	5.65	270.02	1.79b	7.83b
50%	16.37	5.41	271.52	1.38c	7.77b
25%	17.20	5.57	288.65	1.15d	5.40c
LSD@0.05	ns	ns	ns	0.15	1.69
CV	19.25	2.98	6.81	7.74	15.61
Cropping systems					
Sole	29.93a	5.73	234.06b	2.62a	21.84a
Intercropped	16.57b	5.53	275.07a	1.58b	8.91b
LSD@0.05	4.17	ns	23.84	0.15	3.18
CV	10.91	1.43	4.56	4.18	11.45
SA x PD	ns	ns	ns	***	***

*, **, *** significant at P≤0.05, p≤.01 and p≤0.001 probability levels respectively; ns= not significant
Means in a column followed by the same letters are not significantly different at p≤5% level of significance;
SA= Spatial arrangement; PD=Population density

compared to intercropped with cereals (wheat, barley and finger millet). This also corroborates with the results of Ghosh (2004), who stated pod yield of groundnut were lower in groundnut-cereal (maize, sorghum, and pearl millet) intercropped than in monoculture.

Number of seeds per pod

Consistent with number of pods per plant, number of seeds per pod revealed non-significant (P>0.05) variation by the main effects (population density and spatial arrangement) and the interaction (Appendix 4).Similarly, the cropping system, inconsistent with number of pods per plant, showed non-significant (P>0.05) effect on seed number per pod (Appendix 4). Tamiru (2014) similarly reported non-significant (P>0.05) influence of different proportions of maize/haricot bean intercropping on seed number in each pod of haricot bean. Shahidullah and Hosain (1987) also showed non-significant variation of seed number per pod among various plant densities of soybean.

Thousand seed weight

The analysis of variance showed that spatial arrangement, population density and the interaction did not show significant (P>0.05) influence on 1000- seed weight of haricot bean (Appendix 4). This result is in agreement with the research findings of Aziz *et al. (*1988) who did related work on chick pea and reported non-significant variation among different plant densities.

Thousand seed weight, on the other hand, was significantly (P≤0.05) higher in the intercropping than sole cropping (Appendix 4). Greater (275g) and smaller (234g) thousand seed weights were observed in the intercropped and sole cropped crops, respectively (Table 6). In agreement with this finding, Tamiru (2014) reported hundred seed weight of haricot bean grown in differential mix proportion was significantly affected, whereby all the intercrop treatments produced higher grain weight than the sole stand. Yayeh, (2014) also reported sole cropped lupin revealed lower thousand seed weight than small cereal/lupin intercropping system which was in agreement with this finding. On the other hand, Wright (1981) reported that higher hundred seed weight of soybean was recorded under intercropping than sole cropping.

Grain yield

In this study, grain yield was significantly (P≤0.001) affected by the interaction effect of spatial arrangement and population density (Appendix 4). The maximum grain yield (2.24 ton ha^{-1}) was recorded at 1:2 bean spatial arrangements with 100% haricot bean population density (Figure 3). The minimum grain yield (0.95 ton ha^{-1}) was recorded at 1:1 bean spatial arrangement with 25 %

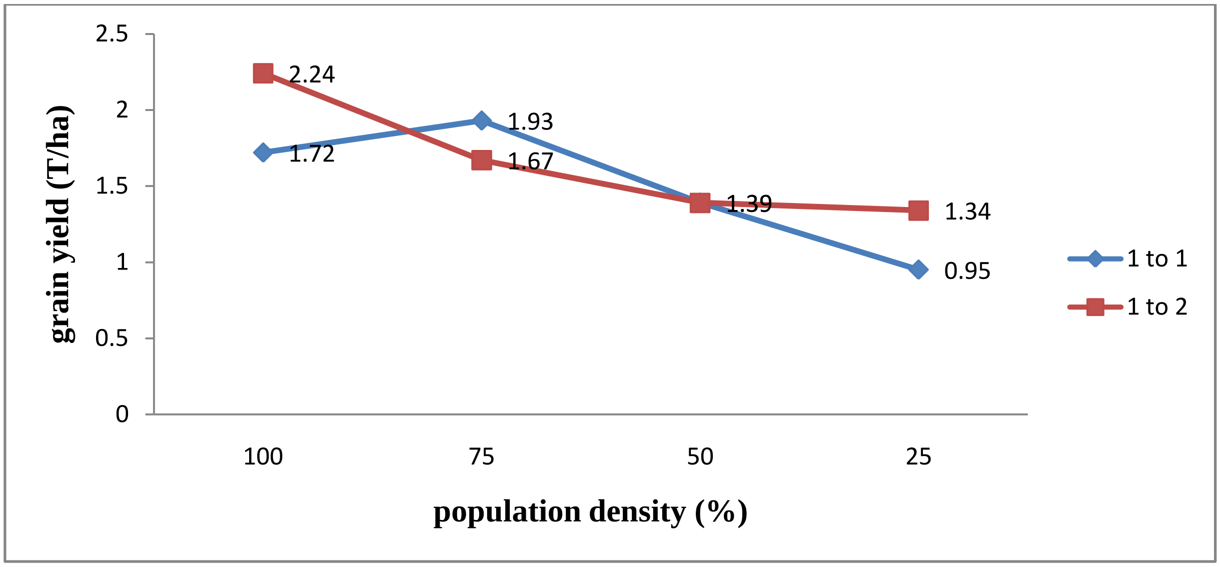

Figure 3. The interaction effect of population density and spatial arrangement of haricot bean on haricot bean grain yield

common bean population density.

Generally, an increase of grain yield of haricot bean was more evident at 1:2 spatial arrangements when bean plants were closer to maize rows. It seems that beans probably benefited from the N applied to maize rows as the plants got closer to maize rows. As the bean population density increased from 25% (125,000 haricot bean/ha) to 100% (250,000 haricot bean/ha), grain yield of haricot bean increased. This might be due to efficient utilization of resources such as light as a result of total ground coverage by higher plant populations per unit area of land. Similar result was reported by Dorais *et al.* (1991) in that the use of high plant density improved the utilization of the high level of Photosynthetic Photon Flux Densities (PPFD) and yields were greater at the high (3.5 plants m $^{-2}$) densities than at the traditional 2.3 plants m^{-2}. The study of Muoneke and Mbah (2007) also agreed with the current result in that more number of plants per unit area produced a greater yield per hectare than under low plant densities.

Correspondingly, cropping system significantly (P≤0.01) influenced the grain yield of haricot bean (Appendix 4). The highest grain yield (2.62 ton ha^{-1}) of haricot bean was obtained at sole planting compared to intercropping (1.58 ton ha^{-1}) of haricot bean with maize (Table 6). Yield of haricot bean decreased under intercropping by 40% (2.62 vs. 1.58). The high population of the bean and maize component crops per unit area of land might cause greater inter-specific competition for growth resources like nutrient and light that leads to decreased yield of the component crops. Furthermore, yield reduction of haricot bean in an intercropping could be due to a more extensive root system; particularly a larger mass of fine roots of maize which compete more for soil nutrients. Kheroar and Patra (2013), in line with this finding, reported that yield of intercrops were reduced by intercropping with maize that was caused due to receipt of lower amount of solar radiation. Also agreed with the results of this study, Rezaei-Chianeh *et al*. (2011) showed reduction in the yield of faba bean under intercropping system.

Above ground biomass

Above ground biomass was significantly (P≤0.001) affected by spatial arrangement, population density and the interaction (appendix 4). However, the interaction effects were not large enough to cause markedly differences from the main effects. The maximum above ground biomass was obtained at double row arrangement (10.33 ton ha^{-1}) and at 100 % population density (14.64 ton ha^{-1}) of haricot bean (Table 5). This might be due to proportional relationship of above ground biomass to the number of plants per unit area of land and also may be due to canopy density as it has positive influence in moisture conservation and water use efficiency.

The cropping system also revealed significant (P≤0.01) biomass reduction at intercropping system (Appendix 4). According to the present finding, above ground biomass at sole cropping was about three times higher than that under intercropping (Table 5). The high population of the bean and maize component crops per unit area of land might cause crops to compete with each other for growth resources like nutrient, water and light that lead to decrease biomass of crops. Presumably, lower intra-specific competition due to the lower population density at sole crop per unit area might have provided a better soil resource condition with higher light availability for bean plants to grow vigorously. Consistent with this finding, Legesse *et al.* (2015) reported that the highest biomass yield (kg/ha) was obtained from sole faba bean. Additionally, Getachew *et al.* (2013) under maize/legume intercropping concluded that aboveground dry biomass yield was significantly reduced by 74 % in the intercropping as compared to the sole cropping system.

Productivity of Maize-Haricot Bean Intercropping

Land equivalent ratio

Partial LER

Partial LER of maize was non- significantly (P>0.05) affected by spatial arrangement, population density and the interaction (Appendix 5). The maize partial LER values range between 0.86 and 0.93 among the densities (Table 7).

In contrast to partial LER of maize, the interaction effect showed significant (P≤0.001) variation on partial LER of haricot bean (Appendix 5). The highest partial LER of haricot bean (0.86) was found at double row bean arrangement with 100% haricot bean population density (Figure 4).

Over all, partial LER of haricot bean increased as haricot bean population density increased in all maize-haricot bean combinations probably due to efficient utilization of resources. This was in agreement with Yayeh (2014) who reported highest partial LER of lupine in lupine-finger millet combinations at 75:100 seeding ratio, while the lowest was recorded in lupine-barley combination at 25:100 seeding ratios.

Furthermore, the partial LER of maize and haricot bean was higher than 0.5 in all spatial arrangement and population density indicating that there was an advantage for both crops in these intercropping systems. But comparing the two partial LER values of the two combined crops, partial LER of maize was higher than partial LER of haricot bean in all cropping systems. Thus, the results ascertain that maize were the major contributor to the mixture yield which also confirms the presence of greater competitive capacity of maize against haricot bean and farmers' justification of growing the haricot bean as an intercrop. According to Gitonga *et al.* (1999) during intercropping C_4 plant (maize) with C_3 plant (bean), those species that have C_4 photosynthetic pathway derives more resource efficiently than C_3. Besides, maize had a relatively larger upper canopy structures and the roots grow into larger area compared to bean.

Total LER

The total LER in all cases was more than unity (Table 7) showing that intercropping of haricot bean with maize is more advantageous than sole cropping of maize. However, spatial arrangement and the interaction did not show significant variation on total LER (Appendix 5). Though spatial arrangement was statistically at par, higher total LER (1.52) was obtained at double row arrangements of haricot bean (Table 7).

On the other hand, population density of 100 and 75% haricot bean in an intercropping revealed significantly higher (P≤0.001) total LER (Appendix 5) which justifies mutualistic and complementarity of the two component crops. The highest total LER 1.69 was recorded when haricot bean was row-sown at 100% population density of its sole followed by 75% population density (1.61) (Table 7). These values indicated that intercropping gave a 69 and 61% yield advantages and land use efficiency than planting sole crops which was similar with Tolera *et al*. (2005) who observed more yield and higher land use efficiency by intercropping of maize with climbing bean.

Furthermore, in line with the partial LER of each crop, total LER showed an increasing trend as the population density of haricot bean increased from 25 to 100% (Table 6). The yield advantage could be due to a possible efficient utilization of growth resources by the intercropped crops or the intercropping advantages of weed reduction, nitrogen fixation and increased light use efficiency (Willey, 1985; Reddy, 2000). Ofori and Stern (1987) pointed out that the value of LER follow the density of the legume component. However, it is obvious that the optimum plant density could be achieved at certain points; to this effect optimum plant density was achieved at 100% of the sole population density of haricot bean. Land equivalent ratio greater than unity, has been reported in maize/faba bean (Tilahun, 2002) intercropping. Higher LER in intercropping also reported in maize/soybean by Ullah *et al*. (2007).

Monetary advantage index (MAI)

Similar to total LER, spatial arrangement and the interaction did not show significant (P>0.05) variation on MAI (Appendix 5). Population density, on the other hand, revealed significant effect (P≤0.001) on MAI. Population density of 100 and 75% of haricot bean in an intercropping gave the maximum MAI (21445 and 19817 ETB respectively) (Table 7). Therefore, intercropping of maize with haricot bean at 1:1 or 1:2 bean spatial arrangements and 75% population density gave effective land utilization efficiency and more profitability to farmers especially with limited land holding.

Since intercropping adds extra income and warrants insurance against a risk to the farmers, intercropping of

Table 7. Productivity measurement of intercropping of maize as affected by population densities and spatial arrangement of haricot bean at Wondo Genet during 2015 cropping season

Treatments	Partial LER of maize	Partial LER of haricot bean	Total LER	MAI
		Spatial arrangement		
1:1	0.91	0.57b	1.48	16590.4
1:2	0.89	0.63a	1.52	17234.0
LSD@0.05	ns	0.043	ns	ns
		Population densities		
100%	0.93	0.76a	1.69a	21445a
75%	0.92	0.69b	1.61a	19817a
50%	0.88	0.53c	1.42b	14966b
25%	0.86	0.44d	1.29c	11420c
LSD@0.05	ns	0.06	0.09	2779.4
CV	5.48	8.15	4.95	13.27
SA x PD	ns	***	ns	ns

*, **, *** significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant Means in a column followed by the same letters are not significantly different at p≤5% level of significance; SA=spatial arrangement; PD=Population density; LER=land equivalent ratio

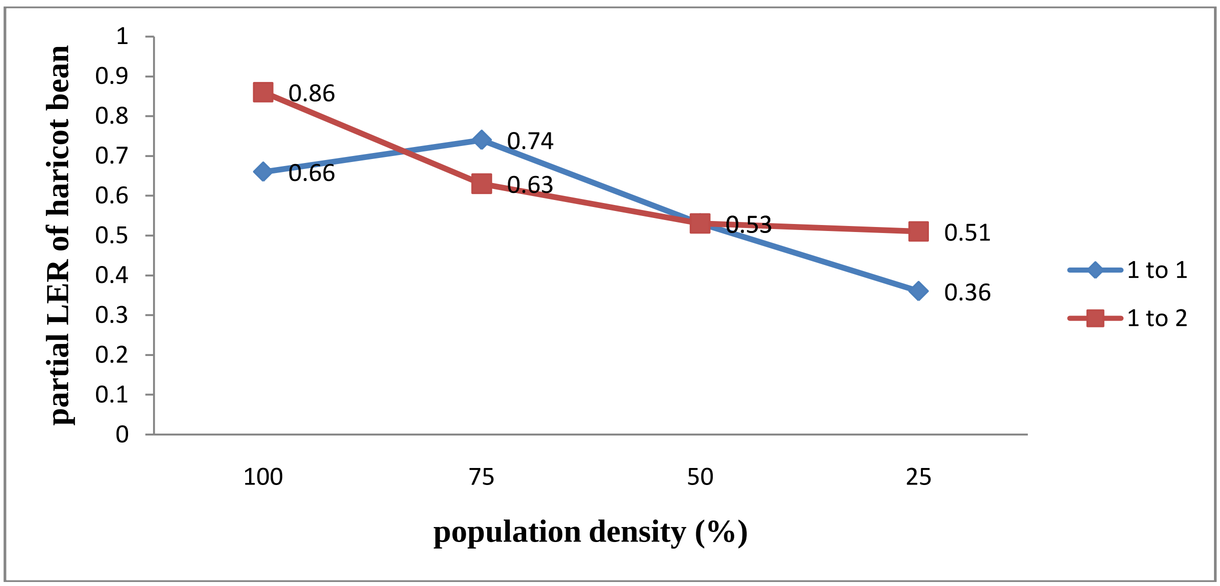

Figure 4. The interaction effect of population density and spatial arrangement of haricot bean on partial LER of haricot bean

maize component was found to be advantageous than single cropping of maize as there is a scarcity of land and a need to diversify production. Therefore, the inclusion of haricot bean under maize intercropping scheme raised yield advantage of intercropping over the single crop per year as revealed by the highest total LER and monetary advantage index.

Influence of Intercropping on Soil Properties

Soil pH

Analytical results of soil samples collected before planting and after harvest indicated that all soils are in a neutral range, and hence the pH level did not show significant difference due to spatial arrangement, population densities, their interaction and by the adopted cropping

Table 8. pH, Total N, CEC, Available P and organic carbon content of the soil under sole and intercropped treatments at Wondo Genet, in 2015 cropping season

Treatments	pH	Total N (%)	OC (%)	Avai. P Mg kg^{-1}	CEC Cmolkg^{-1}
Before planting	6.92	0.15	3.46	2.57	43.70
		After harvest			
		Spatial arrangement			
1:1	6.81	0.17	2.47	2.68	37.23
1:2	6.80	0.20	2.21	1.93	36.27
LSD@0.05	ns	ns	ns	ns	ns
		Population densities			
100%	6.82	0.19	2.25	2.96[a]	36.98
75%	6.82	0.19	2.23	1.66[b]	36.61
50%	6.77	0.21	2.66	2.84[a]	37.17
25%	6.81	0.15	2.22	1.75[b]	36.25
LSD@0.05	ns	ns	ns	1.07	Ns
CV	1.42	33.56	15.41	36.42	4.59
		Cropping systems			
Sole	6.77	0.11[b]	2.99	2.37	36.62
Intercropped	6.80	0.19[a]	2.34	2.08	36.75
LSD @0.05	ns	0.07	ns	ns	Ns
CV	1.37	27.26	5.32	30.71	4.68
SA x PD	ns	ns	ns	ns	Ns

*, **, *** significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant
Means in a column followed by the same letters are not significantly different at p≤5% level of significance;
SA=spatial arrangement; PD=Population density; Total N=total nitrogen; CEC=cation exchange capacity; Avai. P= available Phosphorous; OC= organic carbon content

system (Appendix 6). The soil samples under sole and intercropped treatments were also under neutral range with similar pH values of 6.8 (Table 8) implying that the cropping systems of maize and haricot bean did not influence the pH values of the soil. Similarly, Ariel *et al.* (2013) reported that pH values of the rhizosphere soil remained fairly constant during the cropping cycles of intercropping maize with soybean. Ossom and Rhykerd (2007), in the contrary, have reported that sole field bean had greater effect in raising the soil pH over pure maize.

Organic Carbon and Total N

The organic carbon and nitrogen contents of the soil did not significantly (P>0.05) varied among spatial arrangement and population densities of haricot bean whereas cropping system had shown significant (p≤0.05) effect (appendix 6) on total nitrogen. Intercropping treatments had higher total N (0.19%) than sole maize treatments (Table 8). The improvement of soil N in plots where haricot bean was grown in an intercrop in the present study could be due to a possibility of root exudates or the decay of roots and nodules causing the release of N from the legume components into the rhizosphere during the cropping season (Szumigalski and Van Acker, 2006).

Comparing the soil analytical results before planting and after harvest, the total N decreased under sole cropping, but increased under intercropping systems (Table 8). The higher N content of intercropped treatments might be attributed due to the contribution of N to the rhizosphere by the legumes root from atmospheric fixation. In line with this, Santalla *et al.* (2001) reported that exudates produced by maize may also stimulate nodulation in haricot bean and increases in nodulation leading to better N under intercropped treatments. Intercropping legumes with cereals have potential to fix 6-300 kg N ha^{-1} as described by several authors (Sanginga and Woomer, 2009; and Matusso, 2014). According to Ofori and Stem (1987) the variations in N fixation under legume cereal intercropping systems depend on genotypes, plant morphology, density of component crops and type of management.

On the other hand, the organic C content of the soil was not affected by the spatial arrangement, population densities and cropping systems (Appendix 6). Further, the organic C content decreased during the growth period despite the release of exudates and supply of mucilage layer indicating high decomposition by microorganisms. Similar observation was also made by Ossom and Rhykerd (2007).

Available P and CEC

Available phosphorous was significantly ($p \leq 0.05$) affected by population densities but not by spatial arrangement, cropping system and the interaction (Appendix 6). Soil samples collected from 100% population density had significantly ($p \leq 0.05$) higher P levels than others though it was statistically at par with 50% density (Table 7). However, the trend was inconsistent to give further justification.

Available P content of the experimental soil (2.57 mg kg^{-1}) at planting declined to 2.37 and 2.08 mg kg^{-1} after harvesting under sole cropping and intercropping respectively (Table 8). The reason for the reduction of soil available P might be due to removal of soil P by grains and other plant parts. Legumes including haricot bean have high P requirements due to the need for high amount of P in the process of N_2 fixation and the production of protein containing compounds, and hence P concentration in legumes is generally much higher than that of cereals. Mandal *et al.* (2014) correspondingly showed that available P content was reduced in post-harvest soils of all plots in which maize was intercropped with soybean and groundnut at varying row proportion compared to the initial and sole maize.

Cation exchange capacity (CEC) of the soil was not affected by bean spatial arrangement, population densities, cropping systems and the interactions (Appendix 6). However, the CEC of the experimental soil (43.7 cmol kg^{-1} at planting) decreased to 36.6 and 36.8 cmol kg^{-1} soil after harvest under sole cropping and intercropped, respectively. The reduction in CEC might be due to the reduction of organic matter among treatments. Ossom and Rhykerd (2007) also reported the non-significant variation on CEC in intercropping of maize with field bean.

CONCLUSION

The increasing human population on one hand and shortage of arable land in the other led to practice of multiple cropping in Wondo Genet area, south Ethiopia. Hence, maize/haricot bean intercropping could increase incomes obtained by smallholder farmers at Wondo Genet area of Southern Ethiopia, through enhancing efficient utilization of land. Farmers can achieve greater benefit from their land by growing the main crop (maize) and in association with an increased plant population of the haricot bean, which maintains at least 75% of the sole stand. Hence, maize/haricot bean intercropping could increase incomes obtained by smallholder farmers at Wondo Genet area of Southern Ethiopia, through enhancing efficient utilization of land. According to the result of this study, maize with 187500 haricot bean ha^{-1} density either 80 * 7cm (1:1) or 40*14cm (1:2) spacing of haricot bean after 30 days of maize planting could be recommended for intercropping in the target area, based on the observed productivity and economic benefit.

ACKNOWLEDGMENT

I acknowledge the Ethiopian Institute of Agricultural Research for their financial support to accomplish this study. Special thanks extend to Wondo Genet agricultural research center for allowing me to use the experimental site and other facilities for field experiment. Further special thanks go to staff members of Wondo Genet agricultural research center for their direct and indirect involvement in the achievement of this research. And I also would like to thank Mr. Amrachu, Beshir and Ms Tadelech (Assistants, soil laboratory in College of Agriculture at Hawassa University) for their support and cooperation in analysis of soil sample.

REFERENCES

Abraha L. 2013. The effect of intercropping maize with cowpea and lablab on crop yield. *Herald J. Agric. and Food Sc. Res.* 2 (5): 156- 170.

Adeniyan O.N., Akande S.R., Balogun M.O. and Saka J.O. 2007. Evaluation of crop yield of African yam bean, maize and kenaf under intercropping systems. *American-Eurasian Journal of Agricultural and Environmental Science*, 2 (1): 99-102.

Adu-Gyamfi JJ, Myaka F.A., Sakala W.D., Odgaard R., Vesterager J.M. & Hogh-Jensen H. 2007. Biological nitrogen fixation and nitrogen and phosphorus budgets in farmer- managed intercrops of maize-pigeon pea in semi-arid Southern and Eastern Africa. *Plant and Soil, 295:127-136*.

Ali K., Gemechu A., Beniwal M., Makkouk S. & Halila M. 2003. Food and forage legumes of Ethiopia: Progress and Prospects on food and forage legume proceeding of the workshop, Addis Ababa, Ethiopia.

Ariel C.E., Eduardo O.A., Benito G.E., Lidia G. 2013. Effects of two plant arrangements in corn (*Zea mays* L.) and soybean (*Glycine max* L. Merrill) intercropping on soil nitrogen and phosphorus status and growth of World J. Agric. Sci. 076 component crops at an Argentinean Argiudoll. American J. Agric and For., 1(2):22-31.

Ayisi K.K., Whitebread A.M., Mpangane P.Z.N. 2004. Growth and symbiotic activities of cowpea cultivars in sole and binary cultures with maize. Tropical legumes for sustainable farming systems in Southern Africa and Australia, edited by Whitebread A.M., Pengelly BC, ACIAR Proc, 115 P.

Aziz A., Aslam K. and Salim M., 1988. Chickpea seed yield as influenced by seeding densities. *Pak. J. Agric.*

Res., 9: 346-348.
Balearic S.S. and Upadhaya U.C. 1981. Crop geometry studies in sorghum in association with pigeon pea varieties. *Indian Journal of Agricultural Sciences* 15 (11): 77.
Banik P. & Sharma R.C. 2009. Yield and resource utilization efficiency in baby corn-legume intercropping system in the eastern plateau of India. *Journal of Sustainable Agriculture,* 33, 379-305. http://dx.doi.org/10.1080/10440040902834970
Craufurd P.Q. 2000. Effect of plant density on the yield of sorghum–cowpea and pearl millet–cowpea intercrops in northern Nigeria. *Experimental Agriculture, 36: 379-395.*
Dawit Kassa and Afework Bekele 2008. Species composition, abundance, distribution and habitat association of rodents of Wondo Genet, Ethiopia. *SINET: Ethiop. J. Sci., 31(2):141–146*
Dechasa H. 2005. Effect of moisture conservation methods and Plant Density of Component Crops on Performance of Sorghum/bean intercropping in Meiso district, West Hararghe. M. Sc. Thesis, Alemaya University. 78 pp.
Demesew Mengesha 2002. Effect of plant density of haricot bean and nitrogen fertilization on productivity of maize and haricot bean additive intercrop system. *M.SC. Thesis. Alemaya University, Alemaya, 105 pp.*
Dewis J. and Freitas, P. 1975. Physical and chemical methods of soil and plant analysis.
Donald C. M., 1962. In search of yield. Journal of Australian Institute of Agricultural Science, 28: 171-178.
Egbe O., Alibo s. and Nwueze I. 2010. Evaluation of some extra-early and early maturing cowpea varieties for intercropping with maize in Southern Guinea Savanna of Nigeria. *Agriculture and Biology Journal, 1:845-458.*
FAO (Food and Agriculture Organization of the United Nations). 2008. FAO fertilizer andPlant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Rome, Italy. 203p.
FAO (Food and Agricultural Organization). 2013. Food and Agriculture Organization. www.fao.org (accessed date 12 May 2013).
Getachew Bekele, Ketema Belete and Sharma J.J. 2013. System Productivity of ForageLegumes Intercropped with Maize and Performance of the Component Crops in Kombolcha, Eastern Ethiopia. *East African Journal of Sciences, 7 (2): 99-108*
Ghosh P.K. 2004. Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. *Field crop Research 88:227-237*
Gitonga N., Shisanya C., Hornetz B., Maingi J. 1999. Nitrogen fixation by *vigna radiata* L. in pure and mixed stands in south eastern Kenya. *Symbiosis, 27: 239-250.*
Gomez A. and Gomez A. 1984. Statistical procedures for agricultural research. 2nd ed., Willey J. and Son I., New York, USA, PP: 97-107
Hailu Gebru, Kebede W/Tsadik & Tamado Tana 2015. Effect of planting patterns in tomato (*Lycopersicon esculentum* Mill) and Maize (*Zea mays* L.) intercropping on growth, yield and yield traits of the crops in Wolaita Zone, Southern Ethiopia. 5 (1):39-49
Heitholt J.J., Farr J.B., Eason R. 2005. Plant configuration and cultivar environments. *Crop Sci., 45:1800-1808.*
Hellevang Kenneth 1995. Grain Moisture Content Effects and Management. North Dakota State Extension Publication AE-905. http://www.ag.ndsu.edu/extension-aben/documents/ae905.pdf. [accessed Sep 2014]
Hobbs P.R., Sayre K., Gupta R. 2008.The role of conservation agriculture in sustainable agriculture. Philos. *Trans. R. Soc. B., 363: 543-555.*
Ijoyah M. O. and Dzer D. M. 2012. Yield Performance of Okra (*Abelmoschus esculentus* L. Moench) and Maize (*Zea mays* L.) as Affected by Time of Planting Maize in Makurdi, Nigeria. *International Scholarly Research Network, 2(2): 38-44.*
Jackson M. 1964. Chemical Composition of soils. In: Bear F. (2ed). Chemistry of the soil, New York. 71-141 PP.
Kheroar S. and Patra C.B. 2013 Productivity of maize-legume intercropping systems under rainfed situated situation. *Afri. J. Agric. Res.,* 9(20): 1610-1617
Landon J.R. 1991. Booker tropical soil manual: A hand book for soil survey and agricultural land evaluation in the tropics and sub tropics. (ed). John W. and Sons I., New York, USA.
Legesse Hidoto, Gobeze Loha and Tenaw Workayehu, 2015. Effect of barley (*Hordeum vulgare* L.) / faba bean (*Vicia fabae* L.) intercropping on productivity and land use efficiency in highlands of Southern Ethiopia. Journal *of Biology, Agriculture and Healthcare; Vol.5, No.14*
Mahapatra S.c. 2011. Study of Grass-Legume Intercropping Systems in Terms of Competition Indices and Monetary Advantage Index under Acid Lateritic Soil of India. *American Journal of experimental agriculture.1 (1):1-6*
Mandal M.K., Banerjee M., Banerjee H., Alipatra A., Malik G.C. 2014. Productivity of maize (*Zea Mays*) based intercropping system during *Kharif* season under red and lateritic tract of west Bengal. The Bioscan, 9(1): 31-35.
Matusso J.M.M., Mugwe J.N., Mucheru-Muna M. 2014. Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub-Saharan Africa. *Res. J. Agric. Environ. Manage. 3(3): 162-174.*
McKee, G.W., 1964. A coefficient for computing leaf area in hybrid corn. *Agronomy Journal*, 56:240-241.

MOARD (Ministry of Agriculture and Rural Development). 2008. Animal and Plant Health Regulatory Directorate: Crop Varieties Register Addis Ababa, Ethiopia.Issue No.11

MOA (Ministry of Agriculture). 2011. Animal and Plant Health Regulatory Directorate: Crop Varieties Register Addis Ababa, Ethiopia.IssueNo.14

Morgado L.B., Willey R.W. 2003. Effect of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. *Sci. Agric., 38: 1257-1264.*

Muoneke C.O. and Mbah E.U. 2007. Productivity of cassava/okra intercropping systems as influenced by okra planting density. *African Journal of Agricultural Research*, 2 (5): 223-231.

Mutungamiri A., Mariga I.K. and Chivinge O.A., 2001. Effect of maize density, bean cultivar and bean spatial arrangement on intercrop Performance. *African Crop Science Journal, 9(3): 487-497*

Nnadi L.A. and Haque I. 1986. Forage legume - cereal systems: Improvement of soil-fertility and agricultural production with special reference to sub-Saharan Africa. *In*: Haque I., Jutzi S. and. Neate R.J.H. (eds). Potentials of forage legume in farming systems of Sub-Saharan Africa. ILCA, Addis Ababa, Ethiopia.

Nthabiseng R.T, Irvine M.K. and Moshibudi M.P. 2015. Response of a maize or dry bean intercrop to maize density and dry bean arrangement under rainfed conditions. *IJAAR, 6(6):18-29*

Ofori F. and Stern W.R. 1987. Cereal/legume intercropping systems. *Advances in Agronomy* 41: 41-90.

Olsen S. and Dean L. 1965. Phosphorus in: Methods of Soil Analysis. In: Black C., (ed). *American society of Agronomy.* Madison, Wis.USA. pp 1035-1048.

Ossom EM, Rhykerd L 2007. Effect of corn (*Zea mays* L.) and grain legume associations on soil mineral nutrient concentration, soil temperature, crop yield, land equivalent ratio and gross income in Swaziland. *African Crop Science Proceedings, 8: 225-230.*

Page A., Miller R. and Keeney D. 1982. Method of soil analysis. Part 2 -Chemical and microbiological properties. 2nd ed. Olson R., Roscoe E., Dale E., Michael C., Breminer J. and Mulvaney C. Madison, Wisconsin, USA.

Peksen E. and Gulumser A. 2013. Intercropping Efficiency and Yields of Intercropped Maize (*Zea mays* L.) and Dwarf Bean (*Phaseolus vulgaris* L.) Affected by Planting Arrangements, Planting Rates and Relative Time of Sowing. *Int. J. Curr. Microbiol.App.Sci, 2(11): 290-299*

Radford, P.J. 1967. Growth analyses formula - their use and abuse. *Crop Science, 7:171-175.*

Rao L.J. and Mittra B.N. 1990. Evaluation of groundnut *(Arachis hypogea)* genotypes for intercropping with two types of pigeon pea *(Cajanus cajan). Journal of Agricultural Science* 115:337-342.

Reddy R.S. 2000. *Principles of Crop Production.* Kalyani Publishers, New Delhi-110002, India.

Rezaei-Ch. E., Nassab M., Dabbagh A., Shakiba R. M., Ghassemi- Golezani, K., Aharizad S., and. Shekari F. 2011. Intercropping of maize (*Zea mays L.*) and faba bean (*Vicia faba L.*) at different plant population densities. Department of Agronomy and Plant Breeding, Faculty of Agriculture, Tabriz University, Tabriz- Iran. Pp. 1791.

Sanginga N. & Woomer P. L. 2009. Integrated soil fertility management in Africa: Principles, Practices and Development Process. (Eds.). *Tropical Soil Biology and Fertility*. Institute of the International Centre for Tropical Agriculture. Nairobi.

Santalla M., Rodino A., Casquero P. and Ron A. 2001. Interaction of bush bean intercropped with field and Sweet maize. European Journal of Agriculture, 15:185-196

Selamawit Getachew 2007. Effect of plant population and nitrogen fertilizer on growth and yield of intercropped potato (*Solanum tuberosum L.*) and maize (*Zea mays* L.) crops. MSc Thesis, Alemaya University, Ethiopia.

Shahidullah M. and Hossain M.M. 1987. Influence of inter and intra row spacing of soybean on yield and its components. *Bangladesh J. Sci. and Ind. Res., 22:1-7.*

Silwana T.T.& Lucas, E. O. 2002. The effect of planting combinations and weeding on the growth and yield of component crops of maize/bean and maize/pumpkin intercrops. *Journal of Agricultural Science, 138:193-200.*

Sisay T. 2004. Effect of planting pattern and proportion of green gram *(Vigna radiate (L) wilczec*) on productivity of sorghum/ green gram intercropping system in Kewet wereda. Amhara Region. MSc. Thesis, Alemaya University. Pp. 33-45.

Szumigalski A.R., Van Acker R.C., 2006. Nitrogen yield and land use efficiency in annual sole crops and intercrops. *Agron. J., 98: 1030-1040.*

Tamado Tana 1994. Intercropping of groundnut (*Arachis hypogaea* L.) and sorghum (*Sorghum bicolar* L., Moench) with emphasis on spatial arrangements. M.Sc. Thesis, Alemaya University, Alemaya, Ethiopia. 94p.

Tamado Tana, Chemeda Fininsa & Worku W. 2007. Agronomic performance and productivity of common bean (*Phaseolus vulgaris* L.) genotypes in double intercropping with maize (*Zea mays* L.) in Eastern Ethiopia. *Asian journal of plant sciences, 6: 749-456*

Tamiru Hirpa 2014. Effect of intercrop row arrangement on maize and haricot bean productivity and the residual soil. *World Journal of Agricultural Sciences,* 2 (4): 069- 077

Tekalign Tadese 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Tilahun T. 2002. Effect of plant density and arrangement of component crops on productivity of maize/faba bean intercropping system. MSc Thesis, Alemaya University, Ethiopia.

Tolera Abera 2003. Effects nitrogen, phosphorus farmyard manure and population of climbing bean on the performance of maize (*Zea mays* L.)/ climbing bean (*Phaseolus vulgaris* L.) intercropping system in Alfisols of Bako. MSc Thesis, Alemaya University, Alemaya.1-75 pp.

Tolera Abera, Tamado Tana and Pant L.M. 2005. Grain yield and LER of maize-climbing bean intercropping as affected by inorganic, organic fertilizers and population density in Western Oromia, Ethiopia. *Asian Journal of plant science 4(5): 458-465.*

Tolessa Debele, Tesfa Bogale, Wakene Negassa, Tenaw Workayehu, Minale Liben, Tewodros Mesfin, Beirtukan Mekonen, and Waga Mazengia 2001. A review of fertilizer management research on maize in Ethiopia. In: *Enhancing the contribution of maize to food security in Ethiopia:* (eds. Mandefro Nigussie, Tanner D. and Afriyie S.) Proceedings of the second national maize workshop of Ethiopia. Addis Ababa, Ethiopia: CIMMYT and EARO. PP: 46-54.

Tsubo M., Mukhala E., Ogindo H.O. & Walker S. 2003. Productivity of maize-bean intercropping in a semi-arid region of South Africa. *Water SA, 29:381-388.*

Ullah A., Bhatti N.A., Gurmani Z.A. & Imran H. 2007. Studies on planting patterns of maize (*Zea mays* L.) facilitating legumes intercropping. *Journal of Agricultural Research*, 45, 113-118.

Undie U.L., Uwah D.F. & Attoe E.E. 2012. Effect of Intercropping and crop arrangement on yield and productivity of late season maize/soybean mixtures in the humid environment of Southern Nigeria. *J. Agric. Sci., 4(4): 37-50.*

Walkley A. and Black I.A. 1934. An examination of the Degtjareff method for determining soil organic method,, and a proposed modification of the chromic acid titration method. *soil Sci. 34: 29-38*

Willey R.W., Natarajan M., Reddy M.S., Rao M.R., Nambiar P.T.C., kanniayan J. & Bhatnagar V.S. 1983.Intercropping studies with annual crops. International crops Research Institute for the semi-arid tropics, India

Willey R.W. 1985. Evaluation and presentation of intercropping advantages. *Experimental Agriculture* 21:119-133.

Wortman C. 2006. Common bean (*Phaseolus vulgaris* L.). In: Brink, M. and Belay, G. (ed). Plant resources of tropical Africa 1. Cereals and pulses. PROTA Foundation, Blackhuys publishers, Leiden, Netherlands/CTA, Wagenigen, Netherlands. Pp. 146-151.

Wright A. 1981. The analysis of yield density relationship in binary mixtures using inverse Polynomials. *Journal of agricultural Science, 96:561-567.*

Yayeh Bitew 2014. Influence of small cereal intercropping and additive series of seed proportion on the yield and yield component of lupine *(Lupinus Spp.)* in North Western Ethiopia. *Agriculture, Forestry and Fisheries. 3(2):133-141*.

Yesuf M. 2003. Effects of planting arrangement and population densities of haricot bean on productivity of sorghum/haricot bean additive mixture. M.Sc. Thesis, Alemaya University.Pp.57.

APPENDICES

Appendix Table

Appendix 1. Analysis of variance for phenological and growth parameters of maize as affected by spatial arrangement, population densities and cropping system under intercropping with haricot bean at Wondo Genet during 2015 cropping season

Mean square

Source of variation	DF	Days to 50% Tasseling	Days to 50% Silking	Days to 50% Maturity	Plant height (cm)	Ear length (cm)	Leaf area index
Replication	2	5.17*	8.167*	4.50^{ns}	243.32*	0.67^{ns}	1.78**
PD	3	2.56^{ns}	2.94^{ns}	2.56^{ns}	23.39^{ns}	2.41^{ns}	0.11^{ns}
SA	1	0.67^{ns}	0.167^{ns}	2.67^{ns}	45.93^{ns}	0.11^{ns}	0.25^{ns}
SA *PD	3	1.67^{ns}	2.056^{ns}	4.11^{ns}	100.76^{ns}	0.99^{ns}	0.09^{ns}
Error	14	0.98	2.02	2.88	44.72	0.85	0.18
CV		1.40	1.86	1.23	3.19	4.11	13.82
Cropping systems							
Replication	2	1.322^{ns}	0.385^{ns}	5.281^{ns}	70.17**	0.80^{ns}	0.3764*
CS	1	6.00*	10.010*	3.37^{ns}	278.93**	0.04^{ns}	0.1536^{ns}
Error	2	0.6562	1.6354	2.281	0.748	0.40	0.15
CV		1.13	1.65	1.09	3.27	2.84	12.43

*, **, *** and ns significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; DF= degree of Freedom; SA=spatial arrangement; PD=Population density; CS=Cropping system

Appendix 2. Analysis of variance for yield and yield components of maize as affected by spatial arrangement, population densities and cropping system under intercropping with haricot bean at Wondo Genet during 2015 cropping season

Mean square

Source of variation	DF	100-kernel weight(g)	Grain yield (ton ha^{-1})	AGB (ton ha^{-1})	Harvest index
Replication	2	0.13^{ns}	0.5345^{ns}	2.97^{ns}	0.0002^{ns}
PD	3	4.06*	0.3654^{ns}	2.75^{ns}	0.0001^{ns}
SA	1	0.51^{ns}	0.1568^{ns}	17.95^{ns}	0.002^{ns}
SA * PD	3	4.53*	0.3911^{ns}	7.00^{ns}	0.003*
Error	14	1.21	0.1509	4.24	0.0007
CV (%)		4.04	5.50	9.67	8.28
Cropping systems					
Replication	2	1.92^{ns}	0.047^{ns}	1.3898^{ns}	0.00012^{ns}
CS	1	5.90*	0.976*	12.2122*	0.00015^{ns}
Error	2	1.70	0.039	0.4708	0.00035
CV (%)		5.33	6.30	10.04	7.64

*, **, *** and ns significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; DF= degree of Freedom; SA=spatial arrangement; PD=Population density; CS=Cropping system

Appendix 3. Analysis of variance for Phenological and growth parameters of haricot bean under maize-haricot bean intercropping affected by spatial arrangement, population densities and cropping system of haricot bean at Wondo Genet during 2015 cropping season

Mean square					
Source of variation	DF	Days to 50% flowering	Days to 50% maturity	Plant height (cm)	Leaf area index
Replication	2	2.79^{ns}	5.79**	5.28^{ns}	0.82^{ns}
PD	3	33.48***	1.15^{ns}	35.28**	18.80***
SA	1	12.04*	0.37^{ns}	52.81**	0.28^{ns}
SA * PD	3	3.15^{ns}	2.37*	40.66**	0.66^{ns}
Error	14	2.17	0.60	5.42	0.34
CV (%)		3.64	0.97	4.06	14.19
		Cropping systems			
Replication	2	4.81^{ns}	2.68^{ns}	0.342^{ns}	0.388^{ns}
CS	1	1.14^{ns}	0.58^{ns}	45.87*	28.21**
Error	2	1.88	0.38	0.695	0.033
CV (%)		3.35	0.77	3.81	8.03

*, **, *** and ns significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; DF= degree of Freedom; SA=spatial arrangement; PD=Population density; CS=Cropping system

Appendix 4. Analysis of variance for yield and yield components of haricot bean under maize-haricot bean intercropping as affected by spatial arrangement, population densities and cropping system of haricot bean at Wondo Genet during 2015 cropping season

Mean square						
Source of variation	DF	Pods per plant	Seeds per pod	1000-seed weight(g)	Grain yield (ton/ha)	AGB (ton/ha)
Replication	2	43.167*	0.025^{ns}	3174.32**	0.008^{ns}	1.16^{ns}
PD	3	1.09^{ns}	0.066^{ns}	494.86^{ns}	0.866***	95.26***
SA	1	2.16^{ns}	0.035^{ns}	2.64^{ns}	0.158**	48.20***
SA * PD	3	12.83^{ns}	0.011^{ns}	848.86^{ns}	0.190***	50.32***
Error	14	10.17	0.027	351.162	0.015	1.93
CV		19.25	2.98	6.81	7.74	15.61
				Cropping systems		
Replication	2	31.6162^{ns}	0.0008^{ns}	992.649^{ns}	0.0067^{ns}	0.991^{ns}
CS	1	268.002*	0.064^{ns}	2522.730*	1.6120**	250.91**
Error	2	6.433	0.006	409.98	0.0017	0.822
CV		10.91	1.43	4.56	4.18	11.45

*, **, *** and ns significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; DF= degree of Freedom; SA=spatial arrangement; PD=Population density; CS=Cropping system

Appendix 5. Analysis of variance for productivity of intercropping of maize as affected by spatial arrangement and population densities of haricot bean at Wondo Genet during 2015 cropping season

Mean square					
Source of variation	DF	Partial LER of maize	Partial LER of haricot bean	Total LER	MAI
Replication	2	0.009*	0.0014^{ns}	0.0045^{ns}	10300566.0^{ns}
PD	3	0.006^{ns}	0.127***	0.189***	125872326.4***
SA	1	0.003^{ns}	0.022**	0.010^{ns}	2485061.9^{ns}
SA * PD	3	0.0064^{ns}	0.027***	0.011^{ns}	3000669.7^{ns}
Error	14	0.002	0.0024	0.005	5038037.9
CV (%)		5.48	8.15	4.95	13.27

*, **, *** and ns significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; DF= degree of Freedom; SA=spatial arrangement; PD=Population density;

Appendix 6. Analysis of variance for pH, total N, Avai P, CEC and OC of the soil at different spatial arrangement, population densities of haricot bean and cropping system of maize under sole and intercropped treatments at Wondo Genet, during 2015 cropping season

Mean square						
Source of variation	DF	pH	Total N	Avai P	CEC	OC
Replication	2	0.0105^{ns}	0.0011^{ns}	0.3726^{ns}	5.405^{ns}	0.0245^{ns}
PD	3	0.0038^{ns}	0.0049^{ns}	2.9031*	0.9962^{ns}	0.2713^{ns}
SA	1	0.00082^{ns}	0.0030^{ns}	3.4201^{ns}	5.5584^{ns}	0.4108^{ns}
PD * SA	3	0.0258^{ns}	0.0043^{ns}	1.0398^{ns}	1.4617^{ns}	0.1241^{ns}
Error	14	0.0093	0.0038	1.3817	2.8511	0.1301
CV (%)		1.42	33.56	36.42	4.59	15.41
			Cropping systems			
Replication	2	0.00065^{ns}	0.0033^{ns}	0.221^{ns}	4.50^{ns}	0.011^{ns}
CS	1	0.0066^{ns}	0.013*	0.126^{ns}	0.096^{ns}	0.640^{ns}
Error	2	0.0012	0.0043	0.468	4.349	0.02
CV (%)		1.37	27.26	30.71	4.68	5.31

*, **, *** and ns significant at P≤0.05, p≤0.01 and p≤0.001 probability levels respectively; ns= not significant; DF= degree of Freedom; PD=Population density; SA=spatial arrangement; CS=Cropping system