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Influence of Pigeonpea (Cajanus Cajan (L.) Millsp.) Population Density, Spatial Rrangement and Cultivar on Performance and Yield in Intercrop of Maize (Zea Mays L.) – Pigeonpea At Kindo Koisha Woreda, Southern Ethiopia

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ABSTRACT
This research work was conducted to evaluate the effect of intercropping on the performance and productivity of maize (Zea mays L.) and pigeonpea (Cajanus cajan (L.) Millsp.) under semi-arid agro-ecology of Kindo Koisha, southern Ethiopia. A field experiment method was employed to study the effect. The experimental treatments consisted of a factorial combination of two pigeonpea cultivars (ICP 15027 and ICEAP 00071), two spatial arrangements (1 maize: 2 pigeonpea and 1 maize: 1 pigeonpea), and three population densities (125000, 187500 and 250000 plants ha^{-1}) of pigeonpea with sole pigeonpea density of 100%, 75% and 50%. Maize cultivar 'BH140' was planted simultaneously with pigeonpea using its normal recommended population density (25 cm x 80 cm= 50000 plants ha^{-1}). Randomized Complete Block Design with three replicates was used for the experiment. ***The results*** *indicated phenological stages, growth parameters, yield and yield components of maize were not significantly affected. However, pigeonpea cultivar, spatial arrangement and population density significantly affected grain yield of pigeonpea under intercropping. A significantly higher grain yield of intercropped pigeonpea was obtained from ICP 15027 pigeonpea cultivar (1.27 ton ha^{-1}) in 1:2 spatial arrangement (1.34 ton ha^{-1}) at 250000 plants ha^{-1} population density (1.30 ton ha^{-1}). Moreover, cropping system significantly affected grain yield of pigeonpea. The late emergence, slow growth nature at early stage and shorter morphological features of pigeonpea as compared with the associated main crop made it a poor competitor with maize. The strong competition from maize for growth resource and space consequently resulted in lower grain yield of pigeonpea. Interaction effect of intercropped pigeon pea cultivar by population density was also significant on grain yield of pigeonpea. A mean total land equivalent ratio (LER) of 1.49 was obtained from intercropping indicating that intercropping resulted in a more efficient land utilization by 49% over sole cropping of the associated crops. Similarly, gross monetary return was significantly affected by all the treatment factors and resulted in a mean of 4953 ETB (535.23 USD) ha^{-1}. Therefore, it is concluded that maize-pigeonpea intercropping is more advantageous than sole cropping of the component crops. Intercropping of pigeonpea with maize using ICP 15027 cultivar in 1:2 spatial arrangement at a population density of 250000 plants $ha^{-1}$is advisable since it resulted in higher total LER and greater gross monetary return.*
Key words: Cultivar, land equivalent ratio, maize, monetary return, pigeonpea, population density, spatial arrangement

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I. Introduction

Agricultural production is the main stay of Ethiopia's economy and the performance of the sector is directly correlated to overall national economic performance. The sector accounts for more than half of the GDP, 90 percent of the exports and 80 percent of employment (FDRE, 2005). At present, small-scale subsistence agriculture is the dominant form of production.

High population pressure and scarcity of arable land compelled farmers to grow two or more crops on the same pieces of land (Abera *et al.,* 2005). In southern Ethiopia, the population pressure is high (>400 people/km^2), with average land holding of less than 0.5 hectares (Tilahun *et al*., 2004). Use of multiple cropping systems in the southern region is thus attributed to high density of population.

Multiple cropping in a plot of land as practiced today will efficiently utilize the available land, and boost crop biomass and grain yield per unit area compared to sole cropping if optimum fertilizer is applied to reduce competition between the companion crops (Getahun and Tenaw, 1990). Farmers in the region practice intercropping systems with food crops though maize yield was reduced by up to 25% when intercropped with beans (Alemseged *et al.,* 1991). Besides, soil fertility decline is one of the major constraints for food production

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and insecurity in the region. Farmers found it expensive to replenish soil fertility due to increased price of inorganic fertilizers. Earlier attempts to integrate green manure legumes in maize production system were not successful due to very high opportunity costs of land and labor to grow legume cover crops at the expense of food crops (Fischler *et al*., 1999; Tilahun and Kirkby, 2004).

There are several socioeconomic (Ofori and Stern, 1987), and biological and ecological (Chemeda, 1996) advantages of intercropping relative to sole cropping for smallholders. The cereal/legume intercropping could benefit smallholders through generating sustainable income, minimizing risk of crop failure and providing a source of protein diet (Chemeda, 1997). Intercropping has an immense importance for small-scale resource poor farmers' experiencing food shortage (Abera *et al*., 2005). Maize is widely produced in Western, Central, Southern and Eastern regions of the country. During 2004/2005 production season, about 1.4 million hectares of land was covered by maize and the estimated production was about 23.9 million quintals. It is produced mainly for food, especially, in major maize producing regions mainly for low-income groups' food (MoARD, 2005). The total production of maize in southern region is 5071809 quintals (CACC, 2001).

Pigeonpea is an important pulse crop that performs well in semi-arid tropics where moisture availability is unreliable or inadequate (Reddy *et al.,* 1993). The crop can withstand low moisture condition and performs well in areas with less than 1000 mm of annual rainfall. Pigeonpea can improve soil fertility from the leaf fall and through nitrogen fixation and recycling of the nutrients (Mapfumes, 1993). Moreover, it controls soil erosion, used as fuel, fodder and is a potential cash crop (ICRISAT, 1998). The protein content of dry pigeonpea grain is about 24 percent (Singh, 1993), and like other pulses (beans, cowpea, mungbean, dolichos) it is mainly grown for food; to supplement the cereal based rural diets (Omanga, 1997).

II. Problem statement

Agriculture in Kindo Koisha district is the major source of income and it is a small-scale mixed farming (crop and livestock production) with relatively fewer livestock than elsewhere in Ethiopia (Farm Africa, 1992). The area is characterized by very high population density (about 450 persons km^{-2}), which results in a very small land holding, averaging about 0.24 hectares per household. Farmers cultivate a large number of cereal and root crops in multiple cropping systems such as intercropping and double cropping, taking the advantage of the bimodal pattern of rains (Eyasu, 2002).

The main crops growing in the area, in order of their importance are; maize, enset, teff, cotton, sweet potato, sorghum, taro, haricot beans, cassava and yam (Simon, 1992). The major cereal is maize, which is the co-staple crop with enset, and together they form the basic diet of the population (Eyasu, 2002).

Growing crop mixtures could make an important contribution in risk prone and variable environments by minimizing crop failure due to biotic and abiotic stresses (SAP, 1989). Because of small land holdings and decline in soil fertility, in Kindo Koisha woreda, intercropping especially cereals with legumes is practiced to increase production and productivity and ensure sustainability. Farmers in the area practice different cropping systems such as intercropping of maize with haricot beans, 'teff', cassava (during early growth stage), ginger, sweet potato, enset (during early growth stage) and taro, and even mixed cropping with sorghum.

Long duration pigeonpea is cultivated in the area for its multiple uses. However, use of short- and medium-duration pigeonpea, which have the ability to adapt the adverse growing conditions of dry land areas, is not yet practiced in the study area. Therefore, there is a need to look into the agronomic management of maize/pigeonpea intercropping, particularly in relation to population density, spatial arrangement and cultivars of intercropped pigeonpea.

III. Objectives of the Study

This research work was carried out with an overall objective of evaluating the effect of intercropping on the performance and productivity of maize (*Zea mays L.*) and pigeonpea (*Cajanus cajan (L.*) Millsp.) under semi-arid agro-ecology of Kindo Koisha. More specifically, the study had three specific objectives; (1) to determine the effect of different pigeonpea cultivars, population density and spatial arrangement on yield and yield components of the intercropped components, (2) to evaluate the compatibility of pigeonpea cultivars with maize, and (3) to assess the efficiency of intercropping as compared to sole cropping.

IV. Literature Review

4.1 The concept of intercropping and agronomic variables

Intercropping is defined as the growing of two or more crops together in the same field during a growing season to promote interaction between them. Available growth resources, such as light, water and nutrients are absorbed more and converted to crop biomass as a result of differences in competitive ability between intercrop components (Norman, 1979).

Intercropping is a predominant cropping system in developing countries (Geiler *et al.*, 1991) and a complex and suitable system in agriculture for positive influence (Sullivan, 2003). It is a planned biodiversity and its diversification in turn contributes to conserve biodiversity.

In cereal/legume intercropping, cereal crops form relatively higher canopy structure than legume crops, and the roots of cereal crops grow to a greater depth than legume crops. This indicates that the component crops probably have differing spatial and temporal use of environmental resources such as radiation, water and nutrients (Willey, 1990).

Productivity of a cropping system comprising intercrops of two or more species depends upon the degree of complementarity between them. Enhancing productivity of maize and bean intercrops requires improving the interspecies complementarity or reducing competition effects (Rezende and Ramalho, 1994). This might be achieved through manipulation of plant arrangements, plant densities and planting compatible cultivars (Rao and Mittra, 1990). When two or more crops are grown together, each must have adequate space to maximize cooperation and minimize competition between them. To accomplish this, plant density, spatial arrangement, cultivars of the crops being grown, maturity dates and plant architecture need to be considered (Sullivan, 2003).

4.2. Factors affecting intercropping

4.2.1. Population density

Plant densities and relative proportions of component crops in intercropping are important in determining yields and production efficiency of cereal/legume intercrops (Willey and Reddy 1981). To optimize plant density, the seeding rate of each crop in the mixture should be adjusted below its full rate. If full rates of each crop were planted, neither would yield well because of intense overcrowding. By reducing the seeding rates of each, the crops have a chance to yield well within the mixture (Sullivan, 2003).

The population density of the component crops may vary depending on the type of cultivar used. A study by Rubaihayo *et al.* (2001) showed that in pigeonpea/finger millet intercrop, population density of 16.7 plants m^{-2} of ICPL 87091 and 8.3 plants m^{-2} of Pese 1 and 4.2 plants m^{-2} of KAT 60/8 produced significantly higher LER. Mariga *et al.* (2001) noted that changing maize plant density from 24000 to 37000 plants ha^{-1} increased maize yield from 28 to 39% but reduced bean yields from 11 to 18%. They also reported that maize yield was 19% less when intercropped with the natal Sugar cultivar than with Carioca cultivar.

Ofori and Stern (1987) proposed that the growth and yield of the legume component is reduced markedly when intercropped with high densities of the cereal component. In a maize/bean intercrop system, increasing maize density three-fold, from 18000 to 55000 plants ha^{-1}, reduced bean leaf area by 24% and seed yield by 70% (Gardiner and Craker, 1981). Yield of sorghum showed a generalized increase with increase in population density in sorghum/soybean intercrop (Akuda, 2004). He also added intercropping and population density did not influence sorghum head length in sorghum/soybean intercropping.

In velvet bean/maize intercropping, the highest maize grain yield and lowest grain loss were realized when velvet bean was planted either at a density of 40,000 plants per ha^{-1} and planted four weeks after maize, or at 20,000 plants per ha^{-1} and planted at least a week after maize (LRNP, 2003). When velvet bean was intercropped at the same time with maize, legume density had no significant effect on maize grain yield and yield loss in intercropping (LRNP, 2003). However, maize grain yield was significantly increased when velvet bean was planted two weeks after maize and at densities lower than 40,000 plants ha^{-1}. At velvet bean densities of 20,000 plants ha^{-1}, a two-week delay in legume planting led to a significant reduction in grain yield (LRNP, 2003). In maize/legumes (cowpea and lablab) intercropping, maize planting density had a significant effect on maize grain yield in that yield increased with increased plant population. However, the increase in grain yield was not proportional to the maize planting density and the best maize planting density was about 55,000 plants ha^{-1} (Alemseged *et al*., 1991).

4.2.2. Spatial arrangements

There are four basic spatial arrangements used in intercropping. Most practical systems are row, strip, mixed and relay intercropping (Sullivan, 2003). Spatial arrangement of component crops is one of the most important agronomic factors that determine whether an intercrop system is advantageous or not with regard to grain yield (Natarajan and Shumba, 1990). Row arrangements, in contrast to arrangements of component crops within rows, improve the amount of light transmitted to the lower legume. Such arrangements can enhance legume yields and efficiency in cereal/legume intercrop systems (Mohta and De, 1980).

According to Mergeai *et al.* (2001), paired rows of maize alternated with two rows of pigeonpea gave the highest land equivalent ratio (1.30) and the largest grain yield of maize. Study on spatial arrangement of finger millet/pigeonpea and sorghum/pigeonpea intercropping systems indicated that intercropping of pigeonpea with finger millet or sorghum in a 2:2 row arrangement gave higher total land equivalent ratio than the other row arrangements (Rubaihayo *et al*., 2001). The finding of Ebwongu *et al*. (2001) on three potato varieties intercropped with one maize variety in six spatial arrangements showed that potato yield differed significantly among the spatial arrangements with the highest yield in the sole crop followed closely by 2:1 and 2:2 potato: maize mixtures.

In maize/cowpea intercrop, Myaka (1995) reported that cowpea yields were 57% higher in 2:2 (maize: cowpea rows) compared with 1:1 (maize: cowpea rows). Asafu-Agyei *et al*. (1997) found that 2:2 (maize: cowpea rows) gave higher yields of maize and cowpea, larger land equivalent ratio and net benefit than the 1:1 arrangement (maize: cowpea rows). Obuo *et al*. (1998) investigated the effect of intra-row spacing on cowpea/sorghum intercrop and found that yields of both components were highest at 60 cm and 20 cm inter- and intra-row spacing, respectively. Mariga *et al.* (2001) reported that carioca planted in two rows between maize rows at maize density of 37,000 plants ha^{-1} is the ideal approach to dry land maize/carioca intercropping since it achieved high yields and facilitated weeding.

The result of row and mixed intercropping of sole pigeonpea and rice-black gram intercropping study showed effect of intercropping on grain yields of rice, black gram and pigeonpea (Mollah *et al.*, 2002). They found that row intercropping of pigeonpea at 6:1 and 10:1 row ratio and mixed intercropping at 6:1 ratio gave significantly higher rice equivalent yield than sole pigeonpea. Mollah *et al.* (2002) also stated that high gross return, gross margin and benefit-cost ratio was obtained from the more profitable system with 10:1 ratio arrangement, for pigeonpea and rice intercropping.

4.2.3 Varietal effect

Choice of appropriate and compatible crops and crop varieties is very essential in achieving better yield and yield stability in intercropping (Palaniappan, 1985). It is obvious that low yield per unit area could be attributed to low genetic yield potential of varieties. Therefore, cultivars performing better interms of total yield are required for improving grain yield per unit area (Khan and Maliku, 2001). Cultivars, which minimize intercrop competition and maximize complementary effects, are suitable for intercropping (Rao and Mittra, 1990). Productivity of intercropping can be enhanced through selection of bean cultivars suitable for intercropping as they have different growth habits and durations, which may result in different interactions with maize (Rao and Mittra, 1990). Maize cultivars with short internodes and broad leaves, shade beans relatively more than cultivars of a similar height with long internodes and narrow leaves. Tall cultivars generally give more shadding to understory crops (Davis and Garcia, 1983).

Study on the performance of six pigeonpea varieties intercropped with maize showed that the variety ICEAP 00040 outperformed all the other tested varieties (ICP 9145, ICEAP 00020, ICEAP 00053, ICEAP 00068, local variety) under farmers managed conditions (Høgh-Jensen *et al.*, 2007). Intercropping of cowpea cultivars with millet showed significant yield differences among cultivars for their seed and dry fodder yield but not significant effect on millet yields (Ntare and Bationo, 2005). Difference in bean cultivar significantly affected maize and bean grain yields in intercropping with maize (Mariga *et al.*, 2001). The results of extra short and traditional short duration pigeonpea cultivars in rotation with wheat gave empirical evidence that extra-short-duration pigeonpea genotypes could contribute to higher productivity of pigeonpea–wheat rotation system (Dahiya *et al.*, 2002). Some cowpea varieties that perform well under sole cropping tend to climb under intercropping and may not be adapted for intercropping (Ennin *et al.*, 1999). Full-season maize intercropped with short-duration cassava variety and early-maturing variety or full-season maize intercropped with medium-maturing cowpea resulted in high productivity of the intercrops with a LER values between 1.40 and 1.53 (Ennin *et al.*, 1999).

4.3. Importance of intercropping

Intercropping has multiple importance to for not only the crop growers but also for natural resources. One of the most important reasons to grow two or more crops together is the increase in productivity per unit area of land (Sullivan, 2003; Tsubo et al., 2004). The study on the effect of maize/bean intercropping on yield of two early bean varieties with different growth habits showed significantly higher maize yield in relay intercrop whereas bean varieties produced higher grain yield in simultaneous intercropping (Negussie and Reddy, 1996). Similarly, Bhattis et al. (1995) reported that efficiency of soybean intercropped with maize and mungbean in alternate rows gave 15.2% higher income than sole maize.

The cereal/legume yield advantage in mixed intercropping had improved by 13% when bean was sown simultaneously with maize (Chemeda, 1996). Abera *et al*. (2005) reported that grain yield of component crops from intercrop were significantly higher than the monocultures at Bako. Abera *et al*. (2005) also added that grain yield of maize and climbing bean intercropped were 27 and 43% higher than the yield from their respective sole crops at Bako. Fusuo and Long (2004) obtained a significant yield increase of intercropped wheat in wheat/maize and wheat/soybean intercropping over sole wheat. Intercropping of maize with sweet potato influenced some growth parameters of potato but not of maize yield (Ebwongu *et al*., 2001).

Intercropping enhances soil moisture conservation and minimizes soil erosion through soil protection by increased vegetative cover during critical erosion periods compared to conventional cropping system (Willey, 1990). Growing legume and cereal species simultaneously in the same field can increase the use efficiencies of growth resources (Francis, 1986). Many studies confirmed the advantage of intercropping on water use in water limited environments (Tsubo *et al.* 2003; Jahansooz, 1999; Garrity, 1993).

Intercropping improves soil fertility and contributes to the prevention of N leaching. Inclusion of N_2 fixing crops in an intercrop leads to utilization of the renewable resources of atmospheric N_2, which increase the sustainability of agro-ecosystem (Anonymous, 2006). Pigeonpea is a good crop to improve soil fertility in both sole crop and intercropping since it forms nodules on its roots (CIMMYT, 2001). Total soil C and inorganic N content, nitrate and ammonium, were not affected by maize-pigeonpea intercropping as largely as the sole maize (Myaka *et al.,* 2006). They suggested that pigeonpea added up to 60 kg of N ha^{-1} to the system.

Intercropping of maize and pigeonpea increased total system yield compared to sole maize in terms of the total crop biomass, and soil N and P accumulation that in turn increased soil fertility (Myaka *et al.*, 2006). They also showed that pigeonpea increased the recirculation of dry matter, N and P in intercropping which may have a long-term effect on soil fertility. Vandermeer (1989) stated that greater nutrient uptake by intercropping has been shown for both macro and micronutrients. This has often been claimed as basic cause of intercropping advantages.

Intercropping systems have shown to be not only more efficient than sole cropping but also improves the overall ecology (Adelana, 1984). Intercropping is probably an essential part of future agriculture because it uses environmental and other resources more efficiently than does monocropping. Only such type of agriculture that maintains soil fertility can survive in the end. Monocropping that often allows erosion to process more quickly than soil can be formed, and which allows many other kinds of environmental damage has clearly a limited future (Donald, 1997).

4.4. Productivity of intercropping

A number of measures had been suggested for assessing the output of intercropping. Some of these are Land Equivalent Ratio (LER), Effective Land Equivalent Ratio (ELER), Staple Land Equivalent Ratio (SLER), Competitive Ratio (CR) and System Productivity Index (SPI). Among these, the measure that has received the widest adoption is the Land Equivalent Ratio (Petersen, 1994). LER is defined as the total land area required under sole cropping giving the yields obtained in the intercropping mixture (Saxena *et al.*, 1996). They explained that when LER equals to one, there is no advantage to intercropping in comparison with sole cropping.

Many studies revealed the advantage of intercropping over sole cropping. Intercropping of maize/climbing bean is advisable because the system achieved higher LER values (Tsubo *et al*., 2004). Maize intercropped with haricot bean gave yield advantage and land use efficiency of 99 and 73%, respectively as compared to sole maize (Negussie, 1995). Partial LER of maize and bean ranged between 0.94 to 1.19 and 0.30 to 0.90, respectively (Abera *et al*., 2005) from a maize/bean intercropping. They also reported that higher partial LER of maize indicated the superiority of maize over bean in intercropping. Chemeda (1997) reported that bean/maize intercropping relative yield advantage increased to a maximum of 18% and this improved overall total productivity. Similarly, Abera *et al*. (2005) showed that intercrops produced 32 to 98% more yield per unit area of land than the component monocultures. Ebwongu *et al*. (2001) showed that potato/maize intercropping had a significant LER of 1.58, indicating 58% yield advantage for intercropping whereas Mariga *et al*. (2001) found that a LER of greater than one for maize/haricot bean intercropping. Intercropping of maize with grain legumes gave partial LERs ranging from 0.8 to 1.7 (Musambasi *et al*., 2001). Moreover, Ahamed *et al*. (2000) reported that maize/mungbean intercropping had LER of higher than 1.0, and the highest LER (1.79) was observed in the low plant density plot.

V. Materials And Methods

5.1 Description of the study area

The study was conducted at Kindo Koisha Woreda, during the 2007 cropping season. Kindo Koisha Woreda is located in Wolaita administrative zone, Southern Nations Nationalities and Peoples Regional State, at 450 km from Addis Ababa in the southwest direction. The area lies at $6^0$56'N latitude and $37^0$39'E longitude at an elevation of 1300 meters above sea level.

The climate is characterized by an erratic rainfall, receiving a mean annual rainfall of 1105.1 mm per annum with bimodal pattern ('Meher' and 'Belg') where 'Belg' cropping season continues from February to June, and 'Meher' season from July to October. The area has an average maximum and minimum temperature of 30.7^0C and 19.2^0C, respectively (Simon, 1992).

The soil of the area is characterized as black cotton soil (swampy during wet seasons) and red soil with a texture of clay loam (Simon, 1992). The dominant arable soils are Eutric Nitisols, which are estimated to cover two-thirds of the area. Nitisols of the area belong to the major tropical soils, and show low soil fertility because of depletion through continuous cultivation, intense leaching and erosion (Weigel, 1986; Belay, 1992; Simon, 1992).

5.2 Experimental treatments, design and procedures

5.2.1 Experimental treatments

The treatment combination consisted of two cultivars, two spatial arrangements and three population densities of pigeonpea intercropped with maize cultivar 'BH140' (Table 1). The two pigeonpea cultivars were ICEAP 00071 and ICP 15027 which are in the pipeline to be released. Both cultivars are introduced from ICRISAT-Kenya and were tested at Melkassa (ICP 15027) and Werer (ICEAP 00071) Agricultural Research Centers. The varieties are early maturiting with 120 days growth duration. The two cultivars are indeterminate with semi-spreading growth habit.

Spatial arrangements were 1:2 (one row of maize with two rows of pigeonpea) and 1:1 (one row of maize with one row of pigeonpea). Each arrangement was combined with three population densities of pigeonpea using different inter and inta-row arrangements. Population density of pigeonpea for both 1:2 and 1:1 arrangement were 250000 plants ha^{-1}, 187500 plants ha^{-1}, and 125000 plants ha^{-1} to maintain 100%, 75% and 50% of sole pigeonpea population (250000 plants ha^{-1}), respectively. Maize was planted using its normal recommended population density (25 cm x 80 cm = 50000 plants per hectare). Sole crop of pigeonpea cultivars were planted using 40 cm by 10 cm row and plant spacing, respectively, with a total population density of 250000 plants ha^{-1}. Planting date for all treatments was 6th of May 2007.

The maize variety, BH 140 is best adapted to 1000-1800 meters above sea level with an annual rainfall of 1000-1200 mm. It matures in 140 days and the average height is about 225 cm. BH140 is best recommended for areas such as Pawe, Bako, Anger-Didesa valley and similar areas.

Table 1: The treatment combinations of the field experiment

Treatment number	Treatment combination of pigeonpea		
	Cultivars	Arrangements	Population densities ha^{-1}
1	ICEAP00071	1:2	250,000 (100%)
2	ICEAP00071	1:2	187,500 (75%)
3	ICEAP00071	1:2	125,000 (50%)
4	ICEAP00071	1:1	250,000 (100%)
5	ICEAP00071	1:1	187,500 (75%)
6	ICEAP00071	1:1	125,000 (50%)
7	ICP15027	1:2	250,000 (100%)
8	ICP15027	1:2	187,500 (75%)
9	ICP15027	1:2	125,000 (50%)
10	ICP15027	1:1	250,000 (100%)
11	ICP15027	1:1	187,500 (75%)
12	ICP15027	1:1	125,000 (50%)
13	ICEAP00071 (sole pigeonpea)	0:1	250000
14	ICP1502 (sole pigeonpea)	0:1	250000
15	Sole maize (BH140	1:0	50000

5.2.2 Experimental design and procedures

The experiment was laid out in a factorial arrangement using Randomized Complete Block Design with three replicates. The plot size for all treatments was 3.0 m x 6.4 m. Intercropped pigeonpea was planted simultaneously with maize and mid-way between the maize rows for 1:1 arrangement, which was 40 cm apart from maize rows on both sides. For the 1:2 arrangements, two rows of pigeonpea were planted at a distance of 20 cm from both sides of maize rows. The intra-row spacings for intercropped pigeonpea in the 1:2 arrangements were 10 cm, 13.5 cm, and 20 cm to maintain 100%, 75% and 50% of normal pigeonpea population density, respectively. The intra-row spacings for intercropped pigeonpea in the 1:1 row arrangement were 5 cm, 6.5 cm, and 10 cm to maintain 100%, 75% and 50% of normal pigeonpea population density, respectively (Table 2).

Table 2: Level of cultivars, spatial arrangement and population density.

Factors	Levels	Spacing for pigeonpea			
		1: 2 arrangement		1: 1 arrangement	
		row	plant	row	plant
Cultivars	ICEAP 00071 ICPL 15027				
Spatial arrangement	1 maize: 2 pigeonpea (1:2) 1 maize: 1 pigeonpea (1:1)				
Population density	125,000 plants ha^{-1}	40 cm	20 cm	80 cm	10 cm
	187,500 plants ha^{-1}	40 cm	13.5 cm	80 cm	6.5 cm
	250,000 plants ha^{-1}	40 cm	10 cm	80 cm	5 cm

Fertilizer was applied to both sole and intercropped maize at the recommended rate of 64 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1}. Sole pigeonpea received 18 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} using DAP as source of fertilizer. Nitrogen application for both sole and intercrop maize plots was done in two splits: 18 kg N ha^{-1} at the time of planting in the form of diammonium phosphate and the remaining 46 kg N ha^{-1} were applied at knee height of maize using urea. The recommended fertilizer rate of 18 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} was applied during planting for sole pigeonpea. No additional fertilizer was applied for the intercropped pigeonpea.

5.3 Data collection and analysis

5.3.1 Crop phenology

For all phenological stages, recordings were made by counting number of days from planting to the time when 50% of the plant reached to the required phenological stage in each plot except days to maturity, which was recorded at 75% maturity. For both component crops date of emergence was recorded. Date of tasselling, silking and maturity were recorded for maize while date of flowering, pod setting and maturity were recorded for pigeonpea.

5.3.2 Growth parameters

Maize. Plant height was measured at maturity from five randomly selected plants. Leaf area was measured by using Portable Area Meter (Model-LI-3000A, Linuln, USA) when the plant reached 50% flowering by destructive sampling from all leaves of three sample plants which were distractively used to measure other parameters. Leaf area index was calculated by dividing leaf area to the ground area occupied by the sample plant.

Pigeonpea. Plant height was recorded during physiological maturity from five randomly selected sampled plants. Leaf area from five selected plants was measured during flowering by Portable Leaf Area Meter (Model-LI-3000A, Linuln, USA). Leaf area index was calculated by dividing the leaf area to the ground area occupied by the sample plant. Number of branches per plant was recorded from five randomly selected plants from each plot.

Nodule number and nodule fresh weight per plant were recorded during flowering from five randomly sampled plants which were distractively used to measure other parameters. Nodule fresh weight was measured using sensitive balance.

5.3.3. Yield and yield components

Maize. Grain yield was measured from two middle rows (3 x 1.60 cm = 4.8 m^2) and was adjusted to 12.5% moisture content. Ear number per plant was determined from five randomly selected plants from each plot. Number of rows per ear and number of seeds per row were determined from five randomly picked ears of each plot. Hundred seed weight was measured after oven drying of 100 randomly selected seeds to constant weight. Biomass yield was measured from the two middle rows when the plant reached harvest maturity. Harvest index was calculated as a ratio of the economic (seed) yield to the total biomass yield, as suggested by Egli (1988).

Pigeonpea. Grain yield was determined from the two middle rows and was adjusted to 12.5% moisture content. Number of pods per plant was taken from seven randomly selected plants of two middle rows in each plot. Number of pods per unit area was measured from 3 m^2 area selected randomly within a plot. Number of seeds per pod was recorded from 15 randomly selected pods from each plot. Hundred seed weight was measured after oven drying 100 randomly picked seeds to constant weight. Biomass yield was measured from the two middle rows when the plant reached harvest maturity. Harvest index was calculated as a ratio of the economic (seed) yield to the total biomass yield, as suggested by Egli (1988).

5.4 Soil sampling and analysis

Soil sample was taken from the surface layer of 0-30 cm depth from 31 different spots of the experimental field before planting. The sample was thoroughly mixed to make one composite sample representing the experimental field. At harvest, nine random samples were collected from the surface layer of each plot and a composite sample per plot was made. All samples were analyzed following the standard laboratory procedures (Sahlemedhin and Taye, 2000). Available P content of the soil was determined following Bray II method. The available K in the extract was measured by flame photometer. Total N contents and Organic carbon of the soil were determined following the wet digestion procedure of Kjeldahl and wet combustion method of Walkley and Black method, respectively. Ca and Mg contents were measured by using EDTA titration. Soil texture was analyzed by Bouyoucos hydrometer method. The cation exchange capacity of the soil was determined following the 1N ammonium acetate (pH 7) method. The pH of the soils was measured in water using pH meter with glass-calomel combination electrode.

5.5 Analysis of system Productivity

5.5.1 Land Equivalent Ratio

Biological efficiency of the intercropping system was evaluated using land equivalent ratio (LER) based on the method of Mead and Willey (1980). LER was calculated based on the average sole crop yield by using the formula:

$$LER = \sum_{C=1}^{n} \frac{Y_{lc}}{Y_{mc}} = \frac{Y_{im}}{Y_{sm}} + \frac{Y_{ipp}}{Y_{spp}}$$

Where, Y_{lc} = Yield of crop C in intercrop.
Y_{mc} = Average yield of crop C in sole crop (monocrop).
n = Number of crops used in intercrop

Y_{im} = Intercropped yield of maize
Y_{sm} = Sole cropped yield of maize
Y_{ipp} = Intercropped yield of pigeonpea
Y_{spp} = Sole cropped yield of pigeonpea

For the partial LER intercrop of maize and pigeonpea it would be:

$$PLER_{im} = \frac{\text{Yield of intercrop maize}}{\text{Yield of sole maize}}$$

$$PLER_{ipp} = \frac{\text{Yield of intercrop pigeonpea}}{\text{Yield of sole pigeonpea}}$$

$$TLER = PLER_{im} + PLER_{ipp}$$

Where, $PLER_{im}$ = partial land equivalent ratio for maize
$PLER_{ipp}$ = partial land equivalent ratio for pigeonpea.
TLER = total land equivalent ratio.

5.5.2 Economic Return

The monetary advantage (MA) was calculated based on gross return as suggested by Willy (1979).

$$MA = (\text{values of combined intercrop yields}) \times \left[\frac{LER-1}{LER}\right]$$

5.6 Statistical analysis

The Analysis of Variance of data obtained from both crops was conducted using general linear model of the statistical analysis system software version 8.5 (SAS Institute, 2000) and means were compared using LSD at a probability level of 0.05.

VI. Findings And Conclusion

The results of maize-pigeonpea intercropping in this study indicated phenological stages, growth parameters, yield and yield components of intercropped maize were not significantly affected due to cultivar type, spatial arrangement and population density of the associated pigeonpea. Cropping system also did not significantly affect phenological stages, growth parameters, yield and yield components of maize. The interaction effect of either cultivar type, spatial arrangement or population density (two-way or three-way interaction) were found non-significant for all of the observed parameters of intercropped maize. The early emergence, relatively fast establishment at early growth stages and morphological characteristics of maize made it more competitive for growth resources. These conditions led the maize crop to be unaffected in its development and performance during its growth in association with pigeonpea (Appendix I).

On the other hand, days to flowering, days to pod setting, number of branches plant^{-1}, number of nodules plant^{-1} and nodule fresh weight plant^{-1} were significantly affected by cultivar type (**Appendix II).** Grain yield, number of pods per unit area, number of pods plant^{-1}, number of seeds pod^{-1}, hundreds seed weight and harvest index were also significantly different between the intercropped pigeonpea cultivars. The cultivar ICP 15027 produced higher yield (1.27 ton ha^{-1}) than that of ICEAP 0007, showing a 23% increment. This was attributed to the higher number of pods per unit area and number of pods per plant.

Spatial arrangement and population density of the intercropped pigeonpea significantly affected days to flowering, days to pod setting, number of branches plant^{-1}, leaf area plant^{-1}, leaf area index, number of nodules plant^{-1} and nodule fresh weight plant^{-1}. Spatial arrangement also significantly affected grain yield, number of pods plant^{-1}, number of seeds pod^{-1} and biomass yield of intercropped pigeonpea. The 1:2 spatial arrangement resulted in higher yield (1.34 ton ha^{-1}) than that of 1:1 spatial arrangement.

Grain yield, number of pods per unit area, number of pods plant^{-1}, number of seeds pod^{-1} and hundred seed weight of pigeonpea were significantly affected by differences in population density of intercropped pigeonpea (Appendix III). The highest grain yield was obtained from a population density of 250000 plants ha^{-1} (1.30 ton ha^{-1}). This was attributed to higher number of pods per unit area.

Cropping system significantly influenced all the phenological stages and growth parameters except plant height of pigeonpea (**Appendix IV).** It also significantly influenced yield and yield components except number of seeds pod^{-1} and hundreds seed weight. The higher grain yield (2.24 ton ha^{-1}) was obtained from sole cropped pigeonpea as compared to the intercropped one which yielded 1.10 ton ha^{-1}. The late emergence, slow growth at early growth phase and plant structure of pigeonpea as compared to the associated maize made it to be stressfully affected by maize. The aggressive use of growth resources and space by maize plant affected the growth and development of pigeonpea and consequently resulted in lower grain yield.

The interaction effect of spatial arrangement by population density had significant effect on leaf area index, number of nodules plant^{-1}, nodule fresh weight plant^{-1}, number of branches plant^{-1}, number of pods per unit area, number of pods plant^{-1}, hundreds seed weight and harvest index (**Appendix V).** Similarly, the interaction effect of cultivar by population density was significant on number of branches plant^{-1}, grain yield per hectare and harvest index. Significant interaction effect was also observed between cultivar and cropping system on number of nodules plant^{-1}, nodule fresh weight plant^{-1} and grain yield per hectare. However, only some of these interactions showed an effect which is meaningful and remarkably different from the main effect.

Results of land equivalent ratio (LER) and gross monetary return indicated that growing maize in association with pigeonpea is more advantageous than growing them separately (**Appendix VI)**. Partial LER of maize was not significantly affected by variation in cultivar type, spatial arrangement and population density of the intercropped pigeonpea. The mean partial LER of maize (0.98) indicated that maize was unaffected by intercropping with pigeonpea due to non-stressful influence of pigeonpea on it. However, partial LER of pigeonpea was significantly affected by cultivar type, spatial arrangement and population density of pigeonpea. Mean partial LER of pigeonpea (0.52) showed a 48% grain yield reduction of pigeonpea in intercropping with maize. It also indicated that pigeonpea was highly influenced by maize in intercropping.

Total LER was significantly affected by cultivar type, spatial arrangement and population density. The highest total LER recorded from each of the three factors was for cultivar ICP 15027 (1.58), for the 1:2 spatial arrangement (1.58) and for the 250000 plants ha^{-1} population density (1.57). Mean total LER was found to be 1.49, which indicated the more efficient land utilization by 49% under intercropping compared to sole cropping.

Gross monetary return was significantly affected by cultivar type, spatial arrangement and population density of pigeonpea in intercropping with maize. Mean gross monetary return of 4953 ETB ha^{-1} was obtained from intercropping. Higher gross monetary returns were obtained from ICP 15027 (5713 ETB ha^{-1}), 1:2 spatial arrangement (5693 ETB ha^{-1}) and 250000 plants ha^{-1} population density (5625 ETB ha^{-1}).

Statistical correlation between major variables

Pearson's correlation coefficient analysis (**Appendix VII**) revealed that, intercropped pigeonpea grain yield was strongly and positively correlated with biomass yield (r=0.78**), number of pods plant^{-1} (r=0.58***), number of nodules plant^{-1} (r=0.51**) and nodule fresh weight plant^{-1} (r=0.45**). It was also positively correlated with plant height (r=0.38*), number of seeds pod^{-1} (r=0.36*), hundreds seed weight (r= 0.35*), and leaf area plant^{-1} (r=0.36*). Similar result was found by Setegn *et al.* (2006) who reported that bean seed yield significantly correlated with the number of seeds per pod. Biomass yield was strongly and positively correlated with number of pods plant^{-1} (r=0.51**), plant height (r=0.55**) and leaf area plant^{-1} (r=0.45**). Harvest index was positively correlated with nodule fresh weight plant^{-1} (r=0.47**) and number of nodules plant^{-1} (r=0.47**). Number of pods per unit area was positively correlated with number of pods plant^{-1} (r= 0.35*), number of branches plant^{-1} (r=0.44**) and nodule number plant^{-1} (r=0.33*). Number of pods plant^{-1} was positively correlated with number of branches plant^{-1} (r=0.37*), number of nodules plant^{-1} (r=0.40*) and leaf area plant^{-1} (r=0.42*).

Conclusion

Based on the above findings, intercropping of cereals with legumes especially maize with pigeonpea could be considered as an alternative by small farmers for increasing productivity from their limited land holding. Because of the higher grain yield, total LER and gross monetary return, intercropping of pigeonpea using cultivar ICP 15027 with 1:2 spatial arrangement at a population density of 250000 plants ha^{-1} with maize is advisable. Under circumstances where there is shortage of seed and for ease of agronomic management, it is also possible to use the cultivar ICP 15027 with 1:2 spatial arrangement using a population density of 187500 plants ha^{-1}. However, due to year to year variability in rainfall amount and distribution it is important to run the experiment further for at least one more season to come up with final recommendation regarding cultivar type, spatial arrangement and population density.

References

[1]. Abera Tolera, Tamado Tana and L.M. Pant. 2005. Grain yield and land equivalent ratio of maize-climbing bean intercropping as affected by inorganic, organic fertilizers and population density in western Oromia, Ethiopia. Asian Journal of Plant Sciences 4(5): 458-465.

[2]. Adelana, B.O. 1984. Evaluation of maize-tomato mixed cropping in southwestern Nigeria. Indian Journal of Agricultural Science 24 (7): 564-569.

[3]. Ahamed, F., O. Hirota, Y. Yamada, T. Haraguchi, M. Matusumoto and T. Mochizuki. 2000. Studies on yield, land equivalent ratio and crop performance rate in maize-mungbean intercropping. Journal of Agriculture 45(1): 39-40.

[4]. Akuda, E.M. 2004. Intercropping and population density effects on yield component, seed quality and photosynthesis of sorghum and soybean. The Journal of Food Technology in Africa 6(3): 96-100.

[5]. Alemseged, Y.B., G.W. King, V.L. Coppock, and J.C Tothill. 1991. Maize-legume intercropping in a semi-arid area of Sidamo region, Ethiopia. I-Maize response. East African Agricultural and Forestry Journal 56:77-84.

[6]. Anonymous. 2006. Intercrop for increased productivity, weed control, improved product quality and prevention of N-losses in European organic farming systems. Conference proceedings on joint organic congress, Odessa, Denmark.

[7]. Asafu-Agyei, J.N., K. Ahenkora, B. Banful, and S. Ennin-Kwabiah. 1997. Sustaining food production in Ghana: the role of cereal–legume-based cropping systems Ouagadougou, Burkina Faso. Pages 409–416.

[8]. Bhattis, M.S., A.D. Rashid and M.S. Izbal. 1995. Efficiency of soybean intercropped with corn and mungbean. Journal of Agricultural Research 33(1): 7-14.

[9]. CACC (Central Agricultural Census Commission). 2001. Ethiopian Agricultural Sample Enumeration. Statistical report on area and production of crops. Results for SNNPR. Part II-B. Addis Ababa.

[10]. Chemeda Fininsa. 1997. Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/Maize intercrop. African Crop Science Journal 5 (1): 15-22.

[11]. CIMMYT (Center for International Maize and Wheat Research). 2001. A publication of the soil fertility network for maize-based cropping system in countries of southern America. Field crops research 25:133-144.

[12]. Dahiya, S.S., Y.S. Chauhan, C. Johansen, R. S. Waldia, H. S. Sekhon and J. K. Nandal. 2002. Extra-short-duration pigeonpea for diversifying wheat-based cropping systems in the sub-tropics. Cambridge Journals 38(1):102-107.

[13]. Davis , J.H.C. and S. Garcia. 1983. Competitive ability and growth habit of indeterminate beans and maize for intercropping. Field Crops Research 6:59-75.

[14]. Donald Qinnis. 1997. Intercropping and the scientific basis of traditional approach. Intermediate technology publications 1997. V-4.

[15]. Ebwongu, M., E. Adipala, S. Kyamenywa, Ck. Sekabombe and A. S. Bhagsan. 2001. Influence of spatial arrangements in maize/solanum potato intercrop in interference of potato aphids and leaf hoppers in Uganda. Africa crop science Journal 9(1):83-96.

[16]. Egli, D.B. 1988. Seed biology and the yield of grain crops. CAB International. Willingford. U.K. Pp 134-139.

[17]. Ennin, S., A. Asafu-Agyei, and H.K. Dapaah. 1999. Intercropping maize with cassava or cowpea in Ghana. Ghana Journal of Agricultural Science 32(2): 129-136.

[18]. Eyasu Elias. 2002. Farmers' perceptions of soil fertility change and management. SOS Sahel, Institute for Sustainable Development. Addis Ababa.

[19]. Farm Africa. 1992. Reports of diagnostic survey in Hanze and Fagena-matta peasant associations in Kindo Koysha. SOS Sahel, Farm Africa and Ministry of Agriculture. Environmental protection and development program.

[20]. FDRE (Federal Democratic Republic of Ethiopia), Ministry of water resources. 2005. Genale-Dawa river basin development master plan study project. Phase I report. Part II. Addis Ababa, Ethiopia.

[21]. Fischler, M., C.S. Wortmann and B. Feil, 1999. Crotalaria as a green manure in maize-bean cropping systems in Uganda. Field Crops Research 61:97-107.

[22]. Francis, C.A. 1986. Multiple cropping systems. MacMillan. New York. 383 p.

[23]. Fusuo, Z. and L. Long. 2004. Using competitive and facultative interactions in intercropping systems enhances crop productivity and nutrient-use efficiency. Netherlands Plant and Soil Journal 248:305-312.

[24]. Gardiner, T.R. and L.E. Craker. 1981. Bean growth and light interception in a bean/maize intercrop. Field Crops Research 4:313-320.

[25]. Geiler, K.E., J. Ormesher and F. M. Awa.1991. Nitrogen transfer from phaseolus bean to intercropped maize measured using 15-N enrichment and 15-N isotope dilution methods. Journal of Soil Biology and Biochemistry 23: 239-246.
[26]. Getahun Degu and Tenaw Workayehu. 1990. Initial result of informal survey: Areka area mixed farming zone, Wolaita District, Sidamo. Working paper no.15, Institute of Agricultural Research, Addis Ababa, Ethiopia.
[27]. Høgh-Jensen, H., F.A. Myaka, W.D. Sakala, D. Kamalongo, A. Ngwira, J.M. Vesterager, R. Odgaard, and J.J. Adu-Gyamfi. 2007. Yields and qualities of pigeonpea varieties grown under smallholder farmers' conditions in Eastern and Southern Africa. African Journal of Agricultural Research 2(6): 88-100.
[28]. ICRISAT(International Crop Research Institute for Semi-Arid Tropics). 1998. Improvement of pigeonpea in Eastern and Southern Africa. Project completion report. Nairobi, Kenya. P 48.
[29]. Jahansooz, M.R. 1999. Wheat-chickpea yield performance, competition and resource use in intercropping under rain fed conditions of South Australia, PhD Thesis. University of Adelaide, Australia.
[30]. Khan, A. and M.A. Maliku. 2001. Determining biological yield potential of different mungbean cultivars. Journal of Biological Science 1(7): 575-576.
[31]. LRNP (Legume Research Network Project). 2003. Newsletter. Kenya agricultural research institute. Nairobi, Issue No. 10.
[32]. Mapfumes, P. 1993. Pigeonpea in Zimbabwe: A new crop with potential in soil fertility research for maize based farming systems in Malawi and Zimbabwe.
[33]. Mariga, I.K., A. Mutungamiri and O. A. Chivinge. 2001. Effect of maize density, bean cultivar and bean spatial arrangement on intercrop performance. African Crop Science Journal 9(3): 487-498.
[34]. Mergeai, G., S.N. Silim and J.P. Baudoin. 2001. Improved management practices to increase productivity of cereal/pigeonpea intercropping system in East Africa. In: Silim, S.N., Mergeai, G., and Kimani, P.M. (eds). Status and potential of pigeonpea in Eastern and Southern Africa. Proceedings of a regional workshop. Nairobi, Kenya. PP73-83.
[35]. MoARD (Ministry of Agriculture and Rural Development). 2005. Crop variety register. Crop development department. Issue no.8. Addis Ababa, Ethiopia.
[36]. Mohta, N.K. and R. De. 1980. Intercropping maize and sorghum with soybean. Journal of Agricultural Science 95:117-122.
[37]. Mollah, M.I., U. Nur-e-Elahi, A. Khatun and M. M. Alam. 2002. Increasing productivity of upland ecosystem through row and mixed intercropping of pigeonpea with rice-black gram crop sequence. Journal of Agronomy 1(1): 34-37.
[38]. Musambasi, D., O.A. Chivinge and I.K. Mariga. 2001. Intercropping maize with grain legumes for striga control in Zimbabwe. African Crop Science Journal 10:2-8.
[39]. Myaka, F. M., W.D. Sakala, J.J. Adu-Gyamfi, D. Kamalongo, A. Ngwira, R. Odgaard, N. E. Nielsen and H. Høgh-Jensen. 2006. Yields and accumulations of N and P in farmer-managed intercrops of maize-pigeonpea in semi-arid Africa. Plant and Soil Science Journal 28(5):11-17.
[40]. Myaka, F.A. 1995. Effect of time of planting and planting pattern of different cowpea cultivars on yield of intercropped cowpea and maize in tropical sub-humid environment. Tropical Science 35:274–279.
[41]. Natarajan, M. and E.M. Shumba. 1990. Intercropping research in Zimbabwe: Current status and outlook for the future. In: Waddington, S.R., A.F.E. Palmer and O.T. Edje (Ed.). Research methods for cereal/legume intercropping. Proceedings of workshop on research methods for cereal/legume intercropping in Eastern and Southern Africa., CIMMYT, Harare, Zimbabwe. pp:190-193.
[42]. Negussie Tesfamikael and M.S. Raddy. 1996. Performance of maize/bean intercropping systems under low and medium rainfall situations: Insect pest incidence. Addis Ababa, Ethiopia.
[43]. Negussie Tesfamichael. 1995. Cropping system research status and future trends in Rift Valley: II. Weed insects and diseases. In: Habtu, A. (Ed.). Proceeding of 25th Anniversary of Nazareth Agricultural Research Center, 20-23 September 1995. Nazareth, Ethiopia, pp: 98-105.
[44]. Norman, M.J. 1979. Annual cropping system in the tropics: An introduction. University of Florida Press. USA.
[45]. Ntare, B.R. and A. Bationo. 2005. Effects of phosphorus on yield of cowpea cultivars intercropped with pearl millet. Springer Netherlands 32: 2.
[46]. Ofori, F. and W.R. Stern. 1987. Cereal and legume intercropping systems. Advances in Agronomy 41:41-90.
[47]. Omanga, P. 1997. KARI, Pulses Priority Setting Paper- used as a guide during priority setting workshop held in Machakos, August, 1998.
[48]. Palaniappan, S.P. 1985. Cropping system in tropics: Principles and management. Willey Easterner Limited, New Delhi, Pp. 37-38.
[49]. Petersen, G.R. 1994. Agricultural field experiments design and analysis. Oregon state University, Oregon.
[50]. Rao, L.J. and B.N. Mittra. 1990. Evaluation of groundnut genotypes for intercropping with two types of pigeon pea. Journal of Agricultural Science 115:337-342.
[51]. Reddy, M.V., T.N. Rajn, S.B. Sharma, Y.L. Nene and D. McDonald. 1993. Abstract of Handbook of pigeonpea diseases.
[52]. Rezende, G.D. and S.P. Ramalho. 1994. Competitive ability of maize and common bean cultivars intercropped in different environments. Journal of Agricultural Science 123:185-190.
[53]. Rubaihayo P.R., L. Owere and D.S.O. Osiru. 2001. Cereal-pigeonpea intercropping systems: the Ugandan Experience. Sabrao Journal 7(2):183-187.
[54]. Sahlemedhin Sertsu and Taye Bekele. 2000. Procedures for soil and plant analysis. National soil research center, EARO, Technical Paper No.74, Addis Ababa, Ethiopia.
[55]. SAP (Sustainable Agriculture Program). 1989. Crop variety mixtures in marginal environments. Gatekeeper Series No. SA19. Sustainable Agriculture Programme.
[56]. SAS Institute. 2000. SAS User's Guide, Statistics version 8.2 ed. SAS Institute, Cary, NC, USA.
[57]. Saxena, K.B., N. Parajasingham, H.D. Fonseka and H.P. Ariyarante. 1996. Effect of plant population on yield and yield components in main and ratoon crops of pigeonpea in SirLanka. International Chickpea and pigeonpea Newsletter. ICRISAT publication. India.
[58]. Setegn Gebeyehu, Belay Simane and R. Kirkby. 2006. Genotype × cropping system interaction in climbing beans grown as sole crop and in association with maize. European Journals of Agronomy 24(4):396-403.
[59]. Simon Adebo. 1992. Report of diagnostic survey of Fajena Mata peasant association in Kindo Koysha Awraja. SOS Sahel, Farm Africa and Ministry of Agriculture, Environmental Protection and Development. North Omo Region, Ethiopia.
[60]. Singh, F. 1993. Nutritive value and uses of pigeonpea and groundnut. Human resource development program, skill development series No.14 ICRISAT.
[61]. Sullivan, P. 2003. Intercropping principles and production practice NCAT 1997-2006 NCAT African specialist. Cole loeffle HTMC production. IP 135, Slot 8.
[62]. Tilahun Amede and R. Kirkby. 2004. Guidelines for integration of legume cover crops into the farming systems of East African Highlands. Pp 43-64. In: Bationo, A. (ed.). Managing nutrient cycles to sustain soil fertility in Sub-Saharan Africa. Academic science publishers. 608p.

[63]. Tilahun Amede, A. Stroud and J. Aune. 2004. Advancing human nutrition without degrading land resources through modeling cropping systems in the Ethiopian highlands. Food and Nutrition Bulletin 25(4):344-353.
[64]. Tsubo, M., E. Mukhala, H. Ogindo and S. Walker. 2003. Productivity of maize/bean intercropping in semi arid region of South Africa. African Crop Science Journal 29(4):272-278.
[65]. Tsubo M., H. Ogindo and S. Walker. 2004. Yield evaluation of maize-bean intercropping in a semi-arid regions of South Africa. Journal of African Crop Science 12(4): 351-358.
[66]. Vandermeer, J.H. 1989. The ecology of intercropping. Cambridge Univ. press. New York.
[67]. Weigel, G. 1986. The Soils of Gununo area (Kindo Koisha). Soil conservation research project. Research report 8, University of Berne, p. 89.
[68]. Willey, R.W. 1990. Resource use in intercropping system. Agricultural water management. 17:215-231.
[69]. Willey, R.W and M.S. Reddy. 1981. A field technique for separating above and below ground interaction for intercropping of experiment with pearl millet/groundnut. Experimental Agriculture. 17: 257-264.

APPENDICES

Appendix I: Maize phenological stages as influenced by difference in cultivars, spatial arrangement and population density of intercropped pigeonpea at Kindo Koisha, in 2007.
NS = Not significant

Treatments	Days to		
	tasselling	Silking	maturity
Cultivars			
ICEAP 00071	65.02	70.00	126.07
ICP 15027	64.97	70.03	126.00
$LSD_{5\%}$	NS	NS	NS
Spatial Arrangement			
1 : 1	65.00	70.00	126.04
1 : 2	64.99	70.02	126.03
$LSD_{5\%}$	NS	NS	NS
Population Density			
125000	64.95	69.96	126.00
187500	64.92	69.98	126.02
250000	65.12	70.10	126.09
$LSD_{5\%}$	NS	NS	NS
CV (%)	0.52	0.44	0.78
Cropping system			
Sole crop	64.30	69.60	126.00
Intercrop	64.99	70.01	126.04
$LSD_{5\%}$	NS	NS	NS
CV (%)	0.69	0.62	0.81

Appendix II: Plant height, leaf area per plant, leaf area index, ear height, ear length, number of internodes per plant and stand count of maize as influenced by difference in cultivars, spatial arrangement and population density of intercropped pigeonpea at Kindo Koisha, in 2007.

Treatments	Plant height (cm)	Leaf area per plant (m^2)	Leaf area index	Ear height (cm)	Ear length (cm)	Internodes per plant	Stand count (%)
Cultivars							
ICEAP 00071	216.83	0.69	3.44	113.11	20.79	14.22	95.83
ICP 15027	220.78	0.66	3.29	115.89	20.93	14.32	95.39
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
Spatial Arrangement							
1 : 1	217.50	0.68	3.41	114.44	21.14	14.19	95.67
1 : 2	220.11	0.66	3.32	114.56	20.58	14.35	95.56
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
Population Density							
125000	222.17	0.70	3.49	116.17	19.99	14.44	95.83
187500	223.00	0.66	3.30	116.58	21.61	14.00	95.25
250000	211.25	0.66	3.30	110.75	20.98	14.36	95.75
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	7.05	8.91	8.91	11.26	12.42	3.84	0.81
Cropping system							
Sole	210.00	0.65	3.24	115.00	20.87	13.78	96.00
Intercrop	218.81	0.67	3.36	114.50	20.86	14.27	95.61
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	3.28	6.69	6.69	10.74	15.12	4.11	0.16

NS = Not significant

Appendix III: Gain yield, biomass yield, harvest index, number of ears per plant, number of rows per ear, number of seeds per row and hundreds seed weight of maize as influenced by difference in cultivars, spatial arrangement and population density of intercropped pigeonpea at Kindo Koisha, in 2007.

Treatments	Number ears plant^{-1}	Number of rows ear^{-1}	Number of seeds row^{-1}	Hundreds seed weight	Grain yield (ton ha^{-1})	Biomass yield (ton ha^{-1})	Harvest Index
Cultivars							
ICEAP 00071	1.01	13.96	30.73	32.97	4.75	16.61	0.29
ICP 15027	1.02	13.78	31.07	34.23	4.87	16.81	0.29
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
Spatial Arrangement							
1 : 1	1.01	13.71	30.84	33.95	4.81	16.97	0.29
1 : 2	1.02	14.02	30.96	33.25	4.82	16.44	0.29
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
Population Density							
125000	1.00	13.90	30.30	34.78	4.80	17.41	0.30
187500	1.02	13.97	31.13	32.77	4.81	16.22	0.30
250000	1.03	13.73	31.27	33.25	4.85	16.49	0.28
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.68	6.44	11.87	8.11	8.32	10.22	10.57
Cropping system							
Sole crop	1.00	14.27	32.80	34.70	4.93	17.31	0.28
Intercrop	1.02	13.87	30.90	33.60	4.81	16.71	0.29
$LSD_{5\%}$	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.45	2.78	9.10	6.12	4.32	10.18	3.35

NS = Not significant

Appendix IV: Phenological stages of pigeonpea as influenced by cultivar, spatial arrangement and population density of pigeonpea under intercropping with maize at Kindo Koisha, in 2007.

Treatments	Days to		
	Flowering	pod setting	maturity
Cultivars			
ICEAP 00071	91.65b	99.13b	182.56
ICP 15027	87.60a	94.84a	181.78
$LSD_{5\%}$	1.54	1.63	NS
Spatial Arrangement			
1 : 1	91.65a	99.13a	181.78
1 : 2	87.60b	94.84b	182.56
$LSD_{5\%}$	1.54	1.63	NS
Population Density			
125000	90.98a	98.42a	183.33
187500	90.98a	98.42a	182.75
250000	86.93b	94.13b	180.42
$LSD_{5\%}$	1.88	2.00	NS
CV (%)	2.52	2.46	5.68
Cropping system			
Sole crop	81.10	88.12	153.00
Intercrop	89.63	96.99	182.17
$LSD_{5\%}$	2.14	2.02	3.07
CV (%)	2.92	3.21	1.37

Values followed by the same letter(s) within column were not significantly different at $p<0.05$.
NS = Not significant

Appendix V: Growth parameters of pigeonpea as influenced by cultivars, spatial arrangement and population density of pigeonpea under intercropping system with maize at Kindo Koisha, in 2007.

Treatments	Plant height (cm)	Number of branches plant^{-1}	Leaf area plant^{-1} (dm^2)	Leaf area index	Nodules plant^{-1}	Nodule fresh weight plant^{-1} (g)
Cultivars						
ICEAP 00071	173.56	12.95a	9.79	1.81	2.64a	0.90a
ICP 15027	174.50	17.32b	9.85	1.85	5.04b	1.64b
$LSD_{5\%}$	NS	1.64	NS	NS	1.15	0.51
Spatial Arrangement						
1 : 1	169.11	14.25a	8.50a	1.54a	3.29a	1.01a
1 : 2	178.94	16.02b	11.13b	2.10b	4.40b	1.53b
$LSD_{5\%}$	NS	1.64	1.37	0.32	1.05	0.51
Population Density						
125000	177.00	19.10a	10.68	1.38c	3.15b	0.85b
187500	172.00	13.72b	9.63	1.81b	3.10b	0.80b
250000	173.08	12.59b	9.14	2.29a	5.28a	2.16a
$LSD_{5\%}$	NS	2.00	NS	0.39	1.40	0.62
CV (%)	9.51	15.85	20.16	25.33	43.73	58.89
Cropping System						
Sole	187.17	28.24a	25.22a	4.38a	16.20a	3.92a
Intercrop	174.03	15.14b	9.82b	1.99b	3.84b	1.27b
$LSD_{5\%}$	NS	5.24	2.82	1.52	1.61	0.35
CV (%)	9.65	18.13	11.39	8.96	12.05	10.17

Values followed by the same letter(s) within a column are not significantly different at $p < 0.05$. NS = Not significant.

Appendix VI:Partial land equivalent ratios of maize and pigeonpea, total land equivalent ratio and gross monetary return as influenced by cultivar type, spatial arrangements and population densities of pigeonpea in maize/pigeonpea intercropping at Kindo Koisha, in 2007.

Treatments	Partial LER		Total LER	Monetary return (ETB ha^{-1})
	Maize	pigeonpea		
Cultivars				
ICEAP 00071	0.96	0.44	1.40	4193.3b
ICP 15027	0.99	0.59	1.58	5712.6a
$LSD_{5\%}$	NS	0.06	0.08	774.92
Spatial Arrangement				
1 : 1	0.97	0.43	1.41	4213.4b
1 : 2	0.98	0.60	1.58	5692.5a
$LSD_{5\%}$	NS	0.06	0.08	774.92
Population Density				
125000	0.97	0.46b	1.42b	4348.7b
187500	0.97	0.51ab	1.49ab	4884.7ab
250000	0.98	0.58a	1.57a	5625.4a
$LSD_{5\%}$	NS	0.07	0.10	949.08
CV (%)	8.30	15.92	7.88	23.01374
Mean	0.98	0.52	1.49	4952.95

Values followed by the same letter(s) within a column are not significantly different at $p < .05$. NS = Not significant

Values (price) of maize and pigeonpea were 250.00 and 275.00 ETB ha^{-1}, respectively during analysis (January, 2008).

Appendix VII:Correlation among crop parameters of pigeonpea as affected by pigeonpea cultivar, spatial arrangement and population density in intercropping with maize at Kindo Koisha, in 2007.

	GY	M	HI	PDM	PDP	SDP	BR	HT	NDF	NDN	HSW	LA	DF	DPS	DM
GY	1	0.78***	0.33	0.27	0.58***	0.36*	-0.11	0.38*	0.45**	0.51**	0.35*	0.36*	0.24	0.24	-0.01
BIM		1	-0.29	- 0.01	0.51**	-0.12	-0.16	0.55***	0.13	0.19	0.11	0.45**	-0.26	-0.26	-0.13
HI			1	0.31	0.12	0.23	0.08	-0.28	0.47**	0.47**	0.22	-0.06	0.22	0.22	0.17
PDM				1	0.35*	-0.31	0.44**	0.02	0.19	0.33*	-0.24	0.01	-0.17	-0.17	-0.08
PDP					1	-0.23	0.37*	0.32	0.26	0.40*	-0.05	0.42*	0.19	0.19	-0.05
SDP						1	-0.19	-0.15	0.26	0.21	0.24	0.00	0.37*	0.37*	-0.05
BR							1	0.16	-0.19	0.01	-0.09	0.00	0.12	0.12	-0.01
HT								1	0.16	0.10	0.23	0.48**	-0.11	-0.11	0.01
NDF									1	0.26	0.31	0.22	0.35*	0.35*	-0.01
NDN										1	-0.21	0.19	0.37*	0.37*	-0.23
HSW											1	0.09	0.65***	0.65***	0.12
LA												1	-0.28	-0.28	0.06
DF													1	1.00***	0.15
DPS														1	0.15
DM															1

*, ** and *** indicate significant at 0.05, 0.01 and 0.001 probability levels, respectively.
GY= Grain yield (ton ha^{-1}), BIM= Biomass yield (ton ha^{-1}), PDM= Number of pods m^{-2}, PDP= Number of pods $plant^{-1}$, SDP= Number of seeds pod^{-1}, BR= Number of branches $plant^{-1}$, HT= Plant height at maturity (cm), NDF= Nodules fresh weight $plant^{-1}$ (g), NDN= Number of nodules $plant^{-1}$, HSW= Hundreds seed weight (g), LA= Leaf area $plant^{-1}$ (dm^2), DF= Days to flowering, DPS= Days to pod setting and DM= Days to physiological maturity.

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PREVIOUS PUBLICATIONS

1. Factors affecting private investment in Ethiopia's industry sector: the case of sugar factories in Scientific and Academic Publishing (SAP), 2020; 8(1): 11-22, ISSN: 2168-457X e-ISSN: 2168-4588 (Published: November 2020)
2. Complete Leadership Theory: Updating Situational Leadership Theory to the Complete Status and Proposing a New Theory in The American Journal of Humanities and Social Sciences Research (THE AJHSSR), Volume-05, Issue-05, pp-01-10. E-ISSN: 2581-8868. Crossref DOI: https://doi.org/10.56805/ajhssr (Published: September 2022)

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