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Effect of Population Density and Spatial Arrangements of Pigeon pea (*Cajanus cajan* L. Millsp) on Productivity of Maize-Pigeon pea Intercropping

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ABSTRACT

A field experiment was conducted to determine the effect of pigeon pea spatial arrangement and population density on the productivity of maize-pigeon pea intercropping. Treatments were consisted of two pigeon pea spatial arrangements and three population densities of pigeon pea using randomized complete block design with three replications. Spatial arrangement and population densities had significant influence on pigeon pea grain yield. Higher grain yield was obtained from the highest pigeon pea plant population density and 1:2 spatial arrangement (3.90 t/ha, 0.73 t/ha for maize and 3.74 t/ha, 0.75 t/ha for pigeon pea). Number of seeds/cob and biomass yield of maize were not significantly affected by pigeon pea spatial arrangement and population densities. The interaction effect of pigeon pea spatial arrangement and population density had a significant effect on maize biomass yield. The highest interaction effect on biomass yield was obtained from the lowest pigeon pea population density with 1:2 arrangements. Land use efficiency and monetary return was increased by increasing plant density and pigeon pea rows. Total LER of 1.16 and 1.24 was received from 1:2 and 250,000 plants ha^{-1}. Under pigeon pea spatial arrangement of 1:2 and population density of 125,000 and 250,000 plants ha^{-1} maize-pigeon pea intercropping was found to be advantageous. The highest monetary return was also obtained from these treatments of 1:2 and 250,000 plants ha^{-1}(28185 ETB ha^{-1} and 28106 ETB ha^{-1}). Intercropping maize-pigeon pea gave a gross monetary advantage of 75% and 21% of their respective sole crops of maize and pigeon pea.

***Keywords*:** Maize, Pigeon pea, spatial arrangement, population density, LER, monetary return

1. INTRODUCTION

Maize is one of the most important cereals cultivated in Ethiopia. It ranks second after teff in area coverage and first in total production. Out of the total grain crop areas, 79.34% (9,588,923.71 hectares) was under cereals. Of this maize covered 17% (about 2,054,723.69 hectares) and gave 6069413 tonnes of grain yields (CSA, 2012). Despite the large area under maize, the national average yield of maize is about 2.95 t/ha (CSA, 2012). This is by far below the world's average yield which is about 5.21t/ha (FAO, 2011). The low productivity of maize is attributed to many factors including poor agronomic practices (CIMMYT, 2004).

Pigeon pea (*Cajanus cajan* L., Figure 1) is grown by millions of resource-poor farmers on marginal land across the semi-arid regions of Asia and Africa. Pigeon pea is an edible legume that is capable of fixing atmospheric nitrogen in association with *Rhizobium* bacteria and provides farmers with valuable organic matter and micronutrients. Its grain is a good source of dietary protein for the family, and can be sold in the market for cash, while the dry stems make good fuel wood. It is also a major contributor to food security in areas facing the early effects of global climate change (CIMMYT, 2004). (In Sub-Saharan Africa, where fertilizer is expensive and often in short supply, the nitrogen supplied by pigeonpea is one of the few resources that farmers have for maintaining soil health and fertility. (http://exploreit.icrisat.org/page/pigeonpea/687). Pigeon pea plants have both physiological and morphological attributes that may reduce interspecific competition in mixed culture. The initial slow growth of pigeon pea relative to cereals minimizes competition in intercropping systems, making pigeon pea compatible with most cereal-based systems (Snapp *et al*, 2002).

Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources Tsubo *et al.*, (2005). Intercropping of cereal and legume crops helps maintain and improve soil fertility and plays an important role in subsistence food production in developing countries (Dahmardeh, *et al* 2010) because farmers cannot afford inorganic fertilizers. Cropping systems are used to maximize production and diversify crops from a parcel of land either in time or space than would be obtained by one crop. Intercropping is the growing of two or more crop species simultaneously on the same piece of land during the growing season (Palaniappan, 2000).

The main types of intercropping systems include strip, row, relay and mixed. However, spatial arrangements of crops is another form of intercropping when two or more crops are grown in separate rows or alternating rows on the same piece of land. In spatial arrangements, the crops involved compete for growth resources such as light, water, carbon dioxide and nutrients. Differences in the canopies of crops appear to provide more efficient light use by spatial arrangements than by sole cropping. Competition is one of the factors that can have a significant impact on yield of mixtures compared with pure stands (Caballero *et al*., 1995). Higher yields have been reported when competition between two species of the mixtures have lower competition than within the same species (Vandermer, 1990). Competition can also have a significant impact on the growth rate of the different species used in mixtures (Dhima *et al*., 2007).

Intercropping legumes with non-legume in Africa can be a principal means of intensifying crop production both spatially and temporally to improve crop yields for smallholder farmers (Legwaila *et al*., 2012).

Therefore the present study was initiated with the objective of evaluating the influence of pigeon pea spatial arrangement and population density on the component crops under maize/pigeon pea intercropping system.

Figure 1. *Cajanus cajan* L.

2. MATERIALS AND METHODS

2. 1. Experimental site description

The study was conducted at Hawassa University research and farm center located at 7°4'N latitude and 38°3' E longitude, with an altitude of 1760 masl. The average annual rainfall for the last 15 years is 1100 mm ranging from 674 to 1365 mm while, the average annual minimum and maximum temperatures are 12 °C and 27 °C respectively. The area has two rainy seasons, Belg (Feb-May) and Meher (Jun-Oct). However the main rainy season can extends from April to September interrupted by some dry spells in June and sometimes in May. Distribution of rainfall (Table 1) at tasseling, silking and grain filling stage was variable (August-November). The total amount of rainfall during the growing season from June to December was 12% higher than the long-term rain fall. The rainfall was also 34.7% greater than the long term during the grain filling stages of maize creating water logging situations during the growing season of September.

Table 1. Amount of rainfall during crop growing season and long term monthly mean rainfall

Months	**Rainfall (mm)**	
	Long term mean (1993-2007)	Growing season
June	111.8	118.2 (+6%)
July	122.6	120.5 (-1.7%)
August	128.4	123.5 (-3.8%)
September	118.8	160 (+34.7%)
October	80.6	66.1 (-18%)
November	32.8	97.1 (+196%)
December	22.9	5.8 (-74.7%)
Total	617.99	691.2 (12%)

Source: Southern zone National Meteorological Agency (2008)

2. 2. Experimental details

2. 2. 1. Experimental treatments

The treatments were three-population densities (P_1 = 250000, P_2 = 187500 and P_3 = 125000 plants ha^{-1}), and two spatial arrangements (one row of maize with one row of pigeon pea (1mz: 1pp) and one row of maize with two rows of pigeon pea (1mz: 2pp). Each spatial arrangement was combined with three population densities of pigeon pea using different intra-row spacing's (Table 2). Population densities of pigeon pea for both 1:2 and 1:1 arrangements were 250,000 plants ha^{-1}, 187,500 plants ha^{-1}, and 125,000 plants ha^{-1} to maintain 100%, 75% and 50% of the recommended population of sole pigeon pea (250,000 plants ha^{-1}), respectively. Sole crop of maize and pigean pea was used as a control treatments. Sole pigeon pea was planted using 40 cm by 10 cm (inter and intra row spacing, respectively) with a total population density of 250,000 plants ha^{-1}. Maize was planted using the recommended population density (25 cm x 80 cm = 50,000 plants ha^{-1}). The factorial experiment was laid out in randomized complete block design (RCBD) with three replicates.

2. 2. 2 Experimental procedures and management practices

Intercropped pigeon pea was planted between maize rows for the 1:1 row arrangement, which was 40 cm apart from maize rows on both sides. For the 1:2 row arrangements, two rows of pigeon pea were planted at a distance of 20 cm from both sides of maize rows with an intra-row spacing of 10, 13.5, and 20 cm (Table 2). In the 1:1 row arrangement, the intra row spacing's were 5, 6.5, and 10 cm to maintain the respective population densities of 100%, 75% and 50% of the recommended pigeon pea population.

Table 2. Level of spatial arrangement and population density.

Row arrangement	Plant spacing (Pigeon pea) Distance from maize rows	Pigeon pea intra row spacing(cm)		
		50%	75%	100%
Single alternate (1:1)	40 cm	10	6.5	5
Double alternate (1:2)	20 cm	20	13.5	10

Maize variety "Melkassa-2", and Pigeon pea variety ICP-9444 was used as a test crop. Chemical fertilizer was applied for both sole and intercropped maize using the recommended rate (64:46 kg N: P_2O_5 ha^{-1}). DAP was applied at the rate of 100 kg ha^{-1} (18 kg N and 46 kg P_2O_5 ha^{-1}), at planting. Then Urea at the rate of 100 kg ha^{-1} (46 kg N ha^{-1}) was applied as top dressing in two splits one-third at 20 DAE (days after maize emergence), and two third just before the tasseling of maize.

2. 3. Data collection and analysis

2. 3. 1 Yield and yield components

Maize number of ears $plant^{-1}$ and seeds ear^{-1} were determined from five randomly selected plants from each plot. While pigeon pea pods $plant^{-1}$, seeds pod^{-1} and pod length were recorded from 20 randomly selected plants of each plot. Grain yield was taken from the central rows and the moisture content was taken using electronic moisture tester after which the final grain yield was adjusted to 12.5%. Hundred seed weight was determined by counting a sample of seeds from each plot and weighed using sensitive balance. Biomass yield of both maize and pigeon pea was determined by taking 250 g plant sample from each plot and chopped and oven dried at 70 °C for 48 hours.

2. 3. 2 System Productivity

Land Equivalent Ratio (LER)

The benefit of intercropping is most frequently quantified by LER which is defined as the relative land area in pure stands that is required to produce the yields of all products from the mixture (Vandemeer, 1989). Intercropping efficiency was evaluated by using land equivalent ratio.

$$LER = Yim/Ysm + Yipp/Yspp$$

where: Yim and Yipp are yields of intercropped maize and pigeon pea, and
Ysm and Yspp are yields of sole maize and pigeon pea, respectively.

Monetary return (MR)

Monetary return evaluate the advantages of intercropping against sole cropping and these values were calculated based on gross returns as suggested by Willy (1979)

MA = (values of maize yield + values of pigeon pea yield) X [LER-1]/ LER

2. 3. 3. Statistical analysis

The data were subjected to analysis of variance (ANOVA) for factorial arrangement in randomized complete block design using SAS program (SAS, 2000). Means were compared using LSD at 0.05 and 0.01 probability level of significance.

3. RESULT AND DISCUSSION

3. 1. Effect on Maize

Grain yield: Spatial arrangement and pigeon pea population density had no significant influence on maize grain yield (Table 3). The maximum grain yield (3.74 t/ha) was produced by 1:2 spatial arrangement of wider spacing, whereas the minimum (3.68 t/ha) from the 1:1 pigeon pea spatial arrangement. Though it's non-significant the highest maize grain yield (3.9 t/ha) was obtained from the highest pigeon pea population density. Whereas the finding of Tamiru (2014) indicated that total grain yield of maize decreases as haricot bean population increase. Comparing with the sole grain yield maize was not significantly different from the intercropped in maize- pigeon pea intercrop. Thwala and Ossom (2004) also reported that there was no significant difference in grain yield of maize, whether it is cultivated as a sole crop or intercropped with sugar bean or ground nut.

Number of seeds cob^{-1}: Pigeon pea spatial arrangements and population density has resulted a non significant effect on maize number of seeds per cob (ear). Where relatively large number of seeds cob^{-1} were obtained from single alternate arrangement. In contrast Akbar (1998) reported that number of grains per cob was significantly influenced by different planting patterns. Cropping system also did not brought any significant difference on the number of seeds per cob (ear). However, intercropped maize was slightly greater as compared to sole cropped maize. Number of seeds per cob of 427 and 415 was obtained from intercropped and sole cropped maize respectively.

Biomass yield: The effect of spatial arrangement and pigeon pea population density had no significant effect on maize total biomass (Table 3). The total biomass obtained from 1:2 pigeon pea spatial arrangements was higher than it's respective. The finding of Abreham (2008) also indicates pigeon pea spatial arrangements and population densities had no significant effect on maize biomass. Also Tamiru (2014) stated that raising the population density of beans plant from 1:2 to 1:3 reduced the biomass production of maize by about 12.6%.

Table 3. Yield and yield components of maize as influenced by pigeon pea spatial arrangement and population density.

Treatments	Seeds cob^{-1}	Grain yield (t ha^{-1})	Biomass yield (t ha^{-1})
Spatial Arrangement			
1mz:1pp	431	3.68	5.33
1mz:2pp	423	3.74	5.45
LSD (5%)	NS	NS	NS
Population Density			
125000	429	3.54	5.43
187500	429	3.69	5.36
250000	423	3.90	5.38
LSD (5%)	NS	NS	NS
Cropping system			
Sole	415	4.25	6.34
Intercrop	427	3.83	5.39
LSD (5%)	NS	NS	NS
CV (%)	8.10	14.59	6.43

NS- Non significant, 1mz:1pp – One maize intercropped with one pigeon pea and 1mz: 2pp-one maize intercropped with two pigeon pea.

Interaction effect of pigeon pea spatial arrangement and population density had significantly influenced maize biomass yield (Figure 2). The highest biomass yield was obtained when 1:2 pigeon pea spatial arrangements intercropped with the lowest 125,000 plants ha^{-1}, and the lowest biomass is received when 1:1 spatial arrangement is intercropped with the lowest 125,000 plants ha^{-1} of pigeon pea population density.

As the figure indicates at the population density of 187,500 plants ha^{-1} both spatial arrangements resulted in almost similar biomass yield. Population density of 250,000 plants ha^{-1} when intercropped with the 1:1 pigeon pea spatial arrangement gave highest biomass yield compared to the 1:2 spatial arrangement.

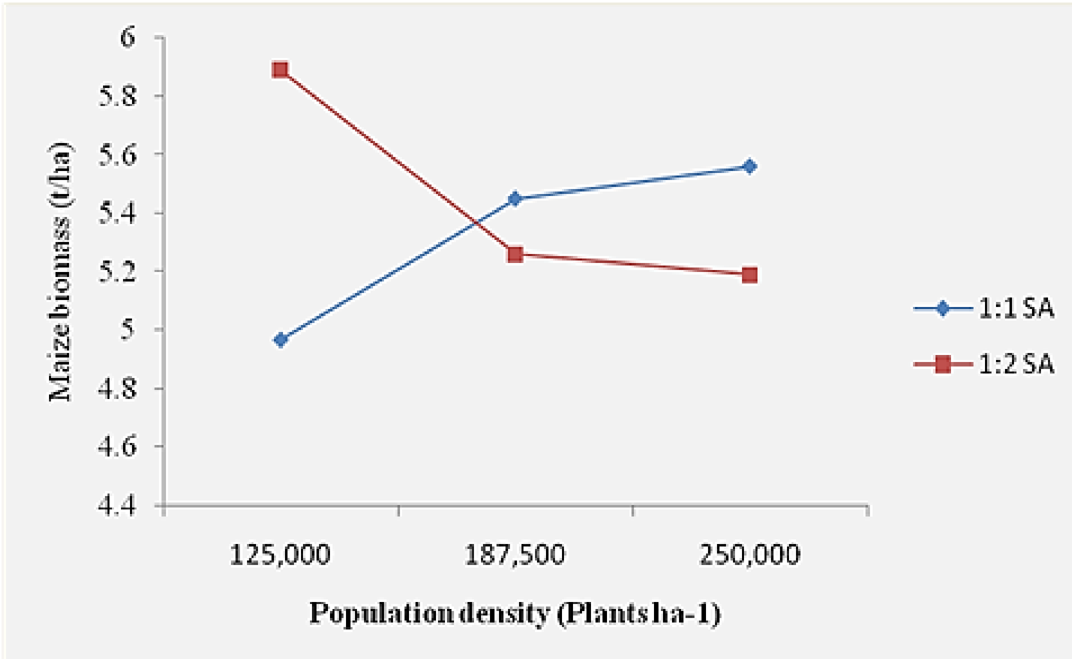

Figure 2. Interaction effect of pigeon pea spatial arrangement and population density on maize biomass.

3. 2. Effect on Pigeon pea

Yield: Spatial arrangements and population densities has resulted a significant difference on yield of pigeon pea (Table 4). The 1:1 spatial arrangement of pigeon pea gave (0.47t/ha) yield and it's by 37.3% lower than 1:2 spatial arrangement. Highest number of seeds per pod that were obtained from the 1:2 spatial arrangements contributed for the higher number of seed yield in the 1:2 spatial arrangement. It was due to its efficiency in using the available resources such as light, water and soil nutrient. The result is supported by Hirpa, (2006) in sorghum/pigeon pea inter cropping pigeon pea grain yield was higher in 1:2 spatial arrangements. Increasing pigeon pea population density from 125,000 to 250,000 plants ha^{-1} resulted a significant yield increment from 0.56t/ha to 0.73t/ha. Similar results were reported by Geremew, (2006) and Tollossa, (1996) indicating that grain yield was highest for 100% and the least for 50% population density in sorghum/cowpea and maize/haricot bean intercropping. Cropping system also significantly affected yield of pigeon pea. The sole pigeon pea had significantly higher grain yield compared to the intercropped. Intercropped pigeon pea had a yield reduction of 74% compared to sole cropping.

Pod per plant: The effect of pigeon pea spatial arrangement and population density had no significant influence on number of pods per plant. The lowest number of pods per plant was resulted from the highest (250,000 plants ha^{-1}) pigeon pea population density. This was due to stiff competition for growth resources in high-density plantings. In line with this Muoneke and Mbah, (2007) indicated number of pods per plant decreased as the okra plant population increased. Even though, cropping system did not result a significant variation sole cropping pigeon pea had resulted relatively higher number of pods per plant.

Table 4. Yield and yield components of pigeon pea as influenced by pigeon pea spatial arrangement and population density

Treatments Spatial Arrangement	**Pod plant^{-1}**	**Seeds pod^{-1}**	**Hundred seed weight (gm)**	**Grain yield (t/ha)**	**Biomass yield (t/ha)**
1mz:1pp	88.04	3.44	9.89[b]	0.47[b]	4.71
1mz:2pp	77.04	3.55	10.22[a]	0.75[a]	3.82
LSD (5%)	NS	NS	0.27	0.13	NS
Population Density					
125000	88.98	3.58	10.18	0.56[b]	3.88
187500	70.23	3.53	9.98	0.53[b]	3.79
250000	88.42	3.38	10.01	0.73[a]	5.12
LSD (5%)	NS	NS	NS	0.16	NS
Cropping system					
Sole	90.87	3.67	9.17	2.34[a]	13.09[a]
Intercrop	82.54	3.49	10.17	0.61[b]	4.26[b]
LSD (5%)	NS	NS	NS	1.05	5.84
CV (%)	41.26	4.75	3.81	20.22	19.15

NS- Non significant, 1mz:1pp – One maize intercropped with one pigeon pea and 1mz:2pp - One maize intercropped with two pigeon pea.

Number of seeds per pod: In (Table 4) spatial arrangements and population density of pigeon pea was not significantly affected the number of seeds per pod. Even though pigeon pea spatial arrangements and population densities did not affect the number of seeds per pod, a 1:1 arranged pigeon pea gives lowest number of seeds per pod than that of 1:2 arrangements. In contrast Abreham, (2008) resulted higher number of seeds per pod from 1:1 arranged plots. Besides this higher number of seeds per pod was obtained from the lowest (125,000 plants ha^{-1}) pigeon pea population density. Similarly, in pigeon pea-sorghum intercropping, Hirpa (2006) obtained plant density and planting pattern had no significant effect on pigeon pea seeds per pod. The highest number of seeds per pod under intercrop has no significant difference with that of the sole pigeon pea. Geremew (2006) also found a non-significant difference on the number of seeds per pod between sole cropped cowpea intercropped with sorghum.

Hundred Seed weight: Spatial arrangements during this study gave a significant difference on hundred seed weight. The result indicated that the highest seed weight of pigeon pea (10.22 g) was obtained from 1:2 spatial arrangements. Hundred seed weight of pigeon pea was not significantly influenced by the population density. Among the different plant populations the highest seed weight was recorded from the lowest 125,000 plants ha^{-1} and the lowest seed weight was obtained from the highest population density though it's not statistically significant. 125,000 plants ha^{-1} of pigeon pea were by 1.7% greater than it's respective. The result is supported by Walelign (2006) who found a non significant variation among different plant densities.

(Figure 3) indicated that interaction effect of pigeon pea spatial arrangement and population density significantly affected the hundred seed weight of pigeon pea. It shows that hundred seed weight of pigeon pea increased for both the lowest (125,000) and highest (250,000) population density in combination with 1:2 spatial arrangements. Lowest seed weight was obtained in the 1:2 spatial arrangements with 187,500 plants ha^{-1}. 1:1 pigeon pea spatial arrangement when intercropped with 187,500 plants ha^{-1} gives the highest seed weight. For both 125,000 and 250,000 plants ha^{-1} hundred seed weight of pigeon pea decreased with 1:1 spatial arrangements.

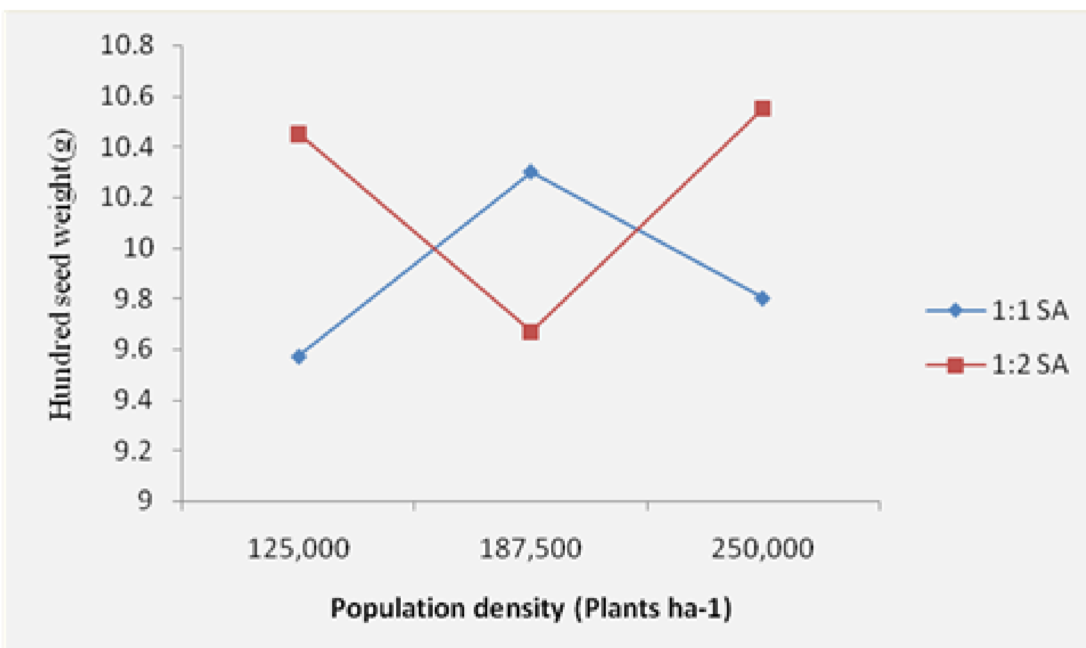

Figure 3. Interaction effect of pigeonpea population density and spatial arrangement on hundred seed weight of intercropped pigeonpea

Biomass yield: Spatial arrangements and population density had no significant influence on biomass yield of pigeon pea. A 1:1 spatial arrangement of pigeon pea had resulted the highest (4.71 t/ha) biomass yield as compared to the 1:2 spatial arrangement. Increasing pigeon pea population from 125,000 to 250,000 plants/ha did not significantly increase the biomass yield of pigeon pea. In contrast the finding of Walelign (2006) indicates when population density increase total biomass was increase linearly. The increment of biomass with rising of population density is due to the increasing number of plants per unit areas.

3. 3. Productivity of maize-pigeon pea intercropping

Land equivalent Ratio (LER): The effect of 1:2 pigeon pea spatial arrangement gave higher LER (1.16) than 1:1, indicating that 1:2 pigeon pea spatial arrangement with maize gives more productivity (Table 5). Increasing pigeon pea population from 125,000 to 250,000 plants ha^{-1} increased total LER from 10 to 12%. However, a plant population of 187,500 plants ha^{-1} was not significantly different from its lower (125,000 plants ha^{-1}). Muoneke and Asiegbu (1997) indicated that productivity of the mixtures showed that the highest yield advantage (35%) of growing okra and maize together was obtained from 28000 okra plants ha^{-1}. Ossom and Rhykerd (2007) also resulted a total LER ranged from the lowest 1.19 to highest 1.59 for intercropped sweet potato with a groundnut plant density of 33,333 plants ha^{-1} and 66,667 plants ha^{-1} respectively. Under all pigeon pea spatial arrangements of 1:2 and population density of 125,000 and 250,000 plants ha^{-1} maize-pigeon pea intercropping was found to be advantageous; that means total LER was greater than one, 1:1 spatial arrangement and 187,500 plants ha^{-1} had resulted a LER of 1.

Monetary advantage: The effect of spatial arrangements and population density had resulted non significant variation on gross monetary return in maize and pigeon pea. A spatial arrangement of 1:2 resulted in relatively higher gross monetary advantage (28,185 ETB ha^{-1}) than the 1:1 spatial arrangement. It resulted an additional gross monetary return of 7,632 ETB ha^{-1}. The result of Abreham, (2008) also indicated higher gross monetary return obtained from 1:2 pigeon pea spatial arrangements. The effect of population density on gross monetary return is different when population density increases from 125,000 to 250,000 plants ha^{-1} the gross monetary also increases with additional gross monetary return of 6,729ETB ha^{-1}. Muoneke and Asiegbu, (1997) obtains the highest monetary return in maize-okra intercropping was from the highest okra planting density. The overall mean gross monetary advantage of 24,368 ETB ha^{-1} was obtained from intercropping system. Intercropping maize-pigeon pea gave a gross monetary advantage of 75% and 21% of their respective sole crops of maize and pigeon pea respectively.

Table 5. LER and GMR as influenced by spatial arrangements and population densities of pigeon pea in maize/pigeon pea intercropping.

Treatments	**Grain yield (tha^{-1})**		**Total LER**	**Monetary return ($ETB\ ha^{-1}$)**
Spatial Arrangement	Maize	Pigeon pea		
1mz:1pp	3.68^b	0.47^b	1.00^b	20553^a
1mz:2pp	3.74^a	0.75^a	1.16^a	28185^a
LSD (5%)	0.31	0.13	0.19	9413

Population density				
125000	3.54[a]	0.56[b]	1.10[a]	21377[a]
187500	3.69[a]	0.53[b]	1.00[a]	23623[a]
250000	3.90[a]	0.73[a]	1.12[a]	28106[a]
LSD (5%)	0.38	0.16	0.24	11529
CV (%)	12.02	31.39	27.16	55.88
Sole Crop	4.25	2.34		
Mean			1.06	24368.5

NS- Non significant, 1mz:1pp = One maize intercropped with one pigeon pea, 1mz:2pp = One maize intercropped with two pigeon pea

4. CONCLUSION

This maize-pigeon pea intercropping was carried out to evaluate the performance and productivity of intercropping and to identify the compatible pigeon pea spatial arrangement and plant population densities while intercropped with maize. The findings have significant implications in improving future crop management practices for grain production through effective row arrangements and population densities. Therefore farmers in this area can improve the yields of the crop by increasing the plant population of pigeon pea to 250,000 plants ha^{-1} together with double alternate row arrangements for the extra benefits associated with this system.

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