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The effects of intercropping and plant densities on growth and yield of maize (*Zea mays* L.) and soybean (*Glycine max*) in the humid forest zone of Mount Cameroon

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A field experiment was conducted to evaluate the effects of intercropping and planting densities on the growth and yield of maize (*Zea mays*) and soybeans (*Glycine max*). A 1 ha plot located at the Institute of Agricultural Research for Development (IRAD), Ekona, South West Region of Cameroon was used. There were two blocks: block 1 which was fertilized with 60 kg/ha NPK (20:10:10) and top dressed with urea at 50 kg N and block 2 which was unfertilized. The experimental design was a randomized complete block design with three replications and a total of 15 treatments. Treatments were intercropped combinations of maize (53,320, 40,000 and 26,666 plants/ha) and soybeans (200,000, 160,000 and 100,000 plants/ha) and six sole-cropped treatments. Intercropping affected grain yields for both soybeans and maize; however, the effect on maize was not significant (P ≥ 0.05). Maize at 53,320 plants/ha intercropped with soybeans at 200,000 plants/ha produced the maximum mean number of pods (34.67), pod weight (13.09 g), number of grains (69.6) and grain weight (8.66 g) per pod. The productivity of the intercropping system indicated yield advantage of 25 to 80% in the unfertilized block and 33 to 96% in the fertilized block as depicted by the land equivalent ratio of 1.25 to 1.8 and 1.33 to 1.96, respectively. All the intercropped combinations had relative value total above unity (1.32 and 1.29) in both unfertilized and fertilized blocks, respectively, meaning a high profitability of this system as compared to monocropping. Maize at a population density of 53,320 plants/ha intercropped with soybean at a plant density of 200,000 plants/ha showed the highest profitability and overall, was the best intercropping combination in this study.

Key words: Intercropping, soybean, maize performance, yield.

INTRODUCTION

Food scarcity and security is one of the most important problems confronting the world today. On one hand, there is a growing demand for food quantity and quality; on the other hand, there are constraints on environmental protection issues and income certitudes for farmers within a global market. The challenge of agricultural research is to provide sustainable solutions to agricultural constraints to food production. As a result, farmers practice different cropping systems to increase productivity and sustainability in Africa. Intercropping, which is one of these systems is the growth of two or more crop species simultaneously in the same field during a growing season

(Carruthers et al., 2000; Onuh et al., 2011). It is also seen as a method of sustainable agriculture, where two or more crops are grown simultaneously during the same season, on the same area and are believed to utilize common limiting resources better than the species grown separately (Ghosh et al., 2006). It is a cropping system that has long been used in tropical areas because of its established advantages which include greater yield stability (Jensen, 1996), greater land-use efficiency (Zhang and Li, 2003), increased competitive ability towards weeds (Hauggaard-Nielsen et al., 2001), improvement of soil fertility (Shen and Chu, 2004; Dahmardeh et al., 2010), increase crop yield and quality (Dahmardeh et al., 2010), provision of security of returns and higher profitability due to higher combined returns per unit area of land (Javanmard et al., 2009). In the study off Javanmard et al. (2009), the dry matter yield for maize in intercrop with legumes ranged from 1044 to 1514 g/m^2, which were higher than 1002 g/m^2 obtained for maize as a sole crop.

Cereal-legume intercropping plays an important role in subsistence food production in both developed and developing countries, especially in situations of limited water resources and low fertility conditions, as it helps to maintain and improve soil fertility. The legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and used by other plants growing nearby. They can also transfer fixed N to intercropped cereals during their joint growing period and this N is an important resource for the cereals (Chen et al., 2010).

Important factors affecting competition between the intercrop components for water, sunlight, space and nutrients and hence input use efficiency, are crop density, relative proportion of component crops, spatial arrangement (Baumann et al., 2001) and time of intercropping. Plant density is an important crop management practice and is accorded a high priority (Sangoi et al., 2002). This was demonstrated in the study by Abuzar et al. (2011). They grew maize at six different plant population densities of 40,000, 60,000, 80,000, 100,000, 120,000 and 140,000 plants/ha. They observed a maximum number of grains per row (32.33) and grains per ear (4473) with the plant population of 40,000 plants/ha.

The maximum number of ears per plant (1.33), grain rows per ear (15.44), biomass yield (16890 kg/ha) and grain yield (2604 kg/ha) was observed with the plant population of 60,000 plants/ha. From this and other similar findings, it is evident that plant population density affects maize yield by influencing yield components such as number of ears per plant, number of kernels per ear and kernel mass.

Intercropping legumes with non-legume in Cameroon can be a principal means of intensifying crop production both spatially and temporally to improve crop yields for smallholder farmers. In the South West Region of Cameroon, growing soybean and maize by peasant farmers for home consumption and the market is common but documented information on the optimum plant population density of the recommended soybean and maize varieties is very scanty. Data on the profitability of soybean/maize intercropping systems in this region is lacking.

The objective of the present study was to determine the effect of intercropping and planting densities on the growth and yield of maize and soybean in the humid forest zone of Mount Cameroon area.

MATERIALS AND METHODS

Experimental site

The 1 ha plot was located at the Regional Research Center, IRAD, Ekona. Ekona Mbenge is situated in Fako division, in the South West Region of Cameroon. Its geographical coordinates are 4° 14′ 0″ North, 9° 20′ 4″ East. It has a humid tropical climate characterized by high temperatures and rainfall, with average annual rainfall of 2284 mm Hg (Etchu et al., 2012). This area has an altitude of about 400 m, a rich volcanic soil and a mean temperature of 24.4°C in the dry season while in the rainy season, it is 23.7°C. The rainy season runs from March to October and the dry season from November to March. The major activity in this region is agriculture which includes plants (major cash crops produced- coffee, cocoa and oil palm; major food crops- cocoyam, yam and plantains) and animal (poultry, small ruminants, non-conventional livestock such as grass cutter, quails and snails) (Etchu et al., 2012). This field experiment was carried out in 2016 cropping season.

Land preparation and experimental field layout

The vegetation was cleared with a cutlass, and the land was ploughed with a hoe and divided into 2 blocks separated by a 2 m path. Each block was further divided into 3 plots and each plot sub divided into 15 subplots. This gave a total of 45 subplots per block. The plots were separated from each other by a 1.5 m path and the subplots were separated by a 1 m path. Each block was 100 m x 23 m, each plot was 32 m x 23 m and each subplot was 6 m x 7 m. The experimental plots were laid out in a randomized complete block design (RCBD) with fifteen treatments and three replicates for each treatment (Figure 1). The detailed planting densities for the crops are shown in Table 1.

Soil analysis

Soil samples were collected prior to planting from different parts

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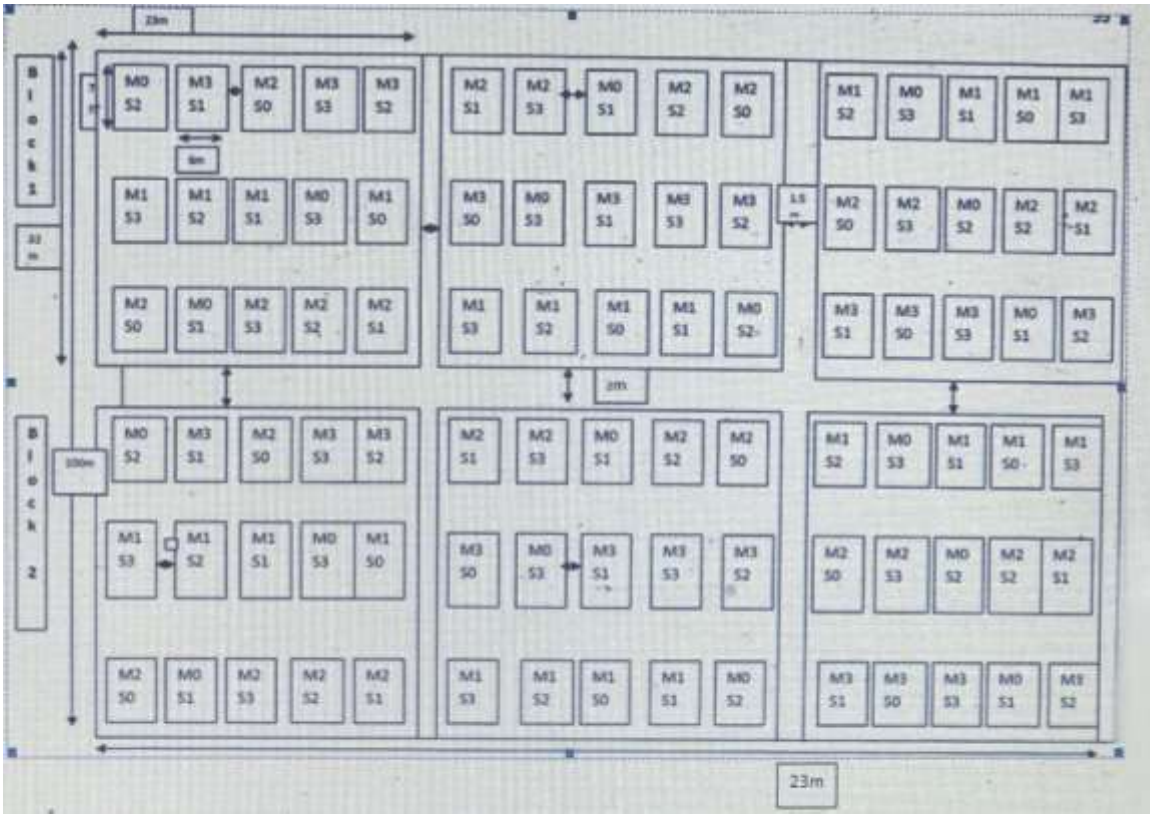

Figure 1. Experimental field layout.

Table 1. Planting densities for maize and soybeans.

Treatment no.	Plant Combinations (plants/ha)		Abbreviation
	Maize	Soybeans	
1	53,320	0	M1S0
2	53,320	200,000	M1S1
3	53,320	160,000	M1S2
4	53,320	100,000	M1S3
5	40,000	0	M2S0
6	40,000	200,000	M2S1
7	40,000	160,000	M2S2
8	40,000	100,000	M2S3
9	26,666	0	M3S0
10	26,666	200,000	M3S1
11	26,666	160,000	M3S2
12	26,666	100,000	M3S3
13	0	200,000	M0S1
14	0	160,000	M0S2
15	0	100,000	M0S3

from each of the replicated experimental plots. Samples were taken from 0 to 10, 10 to 20 and 20 to 30 cm depth using a soil auger. These soil samples were mixed for each of the replicated plots with uniformed soil layer. Chemical analysis was done in the Soil Laboratory, IRAD, Ekona. Organic C was determined by chromic acid digestion and spectrophotometric analysis (Heanes 1984). Total N was determined from wet acid digestion (Buondonno et al., 1995) by colorimetric analysis (Anderson and Graham, 1993).

Exchangeable Ca, Mg, K and Na were extracted using ammonium acetate at pH 7 (Chapman, 1965) and determined by atomic absorption spectrophotometry. Phosphorus was extracted by the Bray-1 procedure and analyzed using the molybdenum blue procedure (Murphy and Riley, 1965).

Plant varieties and densities

Plant varieties

The maize (CMS 8704 variety) obtained from IRAD, Ekona, which is yellow in colour, with a maturity period of (80-120 days) was used because of its high yield, adaptability to different climatic zones and its resistance to diseases. The soybean used was 'TGX 1448-2E' variety with medium maturity (90-120 days) which had been recommended for cultivation in the Rain forest Agro-ecology due to its high yield (Muoneke et al., 2007). The maize was sown at spacing of 75 x 25 cm, 50 x 50 cm and 75 x 50 cm and intercropped with the soybean simultaneously at 50 x 10 cm, 25 x 25 cm and 50 x 20 cm.

Planting densities

Three plant densities were used in this experiment. For maize, the low plant density contained 26,666 plants/ha, average plant density had 40,000 plants/ha, while optimum plant density consisted of 53,320 plants/ha. For soybean, low plant density was 100,000 plants/ha, average plant density was 160,000 plants/ha while optimum plant density was 200,000 plants/ha.

Weed control

Weed control was done manually. Two weeding were done at 3rd and 7th weeks after planting (WAP). A broad spectrum insecticide (Cypertex 10EC) was sprayed at 500 ml per 400 L of water per hectare using an 18 L knapsack sprayer. This was to control leaf hoppers and grasshoppers, which are the devastating leaf eating insects in soybean and maize.

Fertilizer application

Block 1 was fertilized while block 2 was not fertilized. NPK (20-10-10) was uniformly applied by side placement to both maize and soybean in block 1 (fertilized block), 4 weeks after planting at 60 kg N ha^{-1}, 60 kg P ha^{-1} and 60 kg K ha^{-1} and top-dressed with urea at 50 kg N ha^{-1}.

Harvesting

Maize and soybean were harvested at physiological maturity; brown leaf stage in soybean (Salado et al., 1993; Li et al., 2003) and black layer formation in maize (Jagtap and Abamu, 2003; Earl and Davis, 2003) 120 days after sowing. Proper sampling procedures were employed at the time of harvesting by picking the five tagged plant samples from the inner rows and thereby ensuring that no particular treatment was consistently favored or handicapped (Undie et al., 2012).

Growth determination

Data collected for maize included plant height (cm), stem diameter (cm), leaf area (m^2), cob length (cm), cob diameter (cm), hundred seed weight per cob (g), number of grains per cob, cob yield (g) and grain yield (g). Data collected for soybeans included number of pods per plant, percentage sterile pods per plant, 100-grain weight, pod yield (g), seed yield (g), plant height (cm), leaf area (cm^2) and stem diameter (cm).

From the data, land equivalent ratio (LER) and relative value total (RVT) of yield of the maize and soybean were calculated. LER was taken as an accurate assessment of biological efficiency of competition under intercropping situation (Subbian et al., 2006). This is given as:

$$LER = Yab/Yaa + Yba / Ybb \quad (1)$$

Where, Yaa = yield of maize in monoculture; Ybb = yield of soybean in monoculture; Yab = yield of maize in intercrop with soybean; Yba = yield of soybean in intercrop with maize.
Relative value total (RVT) was estimated by the following equation (Vandermeer, 1992):

$$RVT = \frac{ap_1 + bp_2}{am_i} \quad (2)$$

Where, a is the price of the main crop, b is the price of the secondary crop, p_1 is the yield of main crop of intercropping, p_2 is the yield of the secondary crop of intercropping and m_i the yield of the pure cropping of the main species.

Data analysis

Data were analyzed using the SPSS statistical package version 21 at the 5% probability level. Prior to analysis, data were subjected to variance homogeneity tests and variables with significant variations ($P < 0.05$) were log10 transformed. Data expressed as percentage were added 0.5 and square-root transformed. Analysis of variance was used to determine if significant differences existed between treatment means (blocks and intercropping densities). Where significant, means were separated using least significant deference (LSD) and Duncan's new multiple range test (DMRT) (for treatment means greater than 5). Finally, the relationships existing between variables were determined through a Pearson correlation analysis.

RESULTS

Chemical analysis of soil sample

The pH of the soil was acidic, percentage organic carbon ranged from 3.04 to 3.67 and a C/N ratio from 3 to 33 (Table 2). The highest values for most parameters were observed at 10 to 20 cm soil depth (Table 2). However, the 0 to 10 cm depth had highest values for nitrogen and potassium.

Effect of intercropping and plant densities on maize growth and yield

Overall, intercropping and planting densities had effects on maize growth and yield in both the fertilized and unfertilized plots, but the effects were not significant ($P \geq 0.05$).

Table 2. Chemical properties of soil from the experimental site.

Chemical properties	Soil depth		
	0 - 10 cm	10 - 20 cm	20 - 30 cm
pH (H_2O)	5.39	5.17	5.47
Organic carbon (%)	3.04	3.67	3.33
Nitrogen (g/kg)	1.02	0.11	1.34
Phosphorus (mg/kg)	15	16	12
Potassium (cmol/kg)	1.09	0.86	0.69
Calcium (cmol/kg)	4.02	4.30	3.10
Magnesium (cmol/kg)	1.94	2.48	1.61
C/N	3	33	3
CEC (cmol/kg)	7.84	10.50	7.35

Table 3. Effect of intercropping and plant densities on maize growth parameters.

Treatment	Stem diameter (cm)		Plant height (cm)		Leaf area (cm^2)	
	Fertilized block	Unfertilized block	Fertilized block	Unfertilized block	Fertilized block	Unfertilized block
M1S0	4.65[a]	4.50[a]	284.80[a]	300.47[a]	935.66[a]	766.76[a]
M1S1	4.80[a]	4.77[a]	288.53[a]	288.73[a]	737.42[a]	790.82[a]
M1S2	5.15[a]	4.84[a]	292.67[a]	291.33[a]	758.31[a]	757.94[a]
M1S3	4.97[a]	4.57[a]	285.20[a]	287.27[a]	800.38[a]	758.36[a]
M2S0	4.71[a]	4.47[a]	277.47[a]	289.07[a]	747.36[a]	721.11[a]
M2S1	4.71[a]	4.64[a]	287.33[a]	271.67[a]	764.17[a]	759.62[a]
M2S2	4.86[a]	4.80[a]	279.53[a]	282.73[a]	1013.23[a]	807.99[a]
M2S3	5.17[a]	4.44[a]	291.73[a]	292.73[a]	779.78[a]	699.48[a]
M3S0	4.98[a]	4.78[a]	286.87[a]	303.60[a]	753.42[a]	833.95[a]
M3S1	5.20[a]	4.60[a]	292.60[a]	283.00[a]	775.16[a]	776.21[a]
M3S2	4.82[a]	4.47[a]	288.67[a]	286.93[a]	718.84[a]	730.94[a]
M3S3	5.02[a]	4.50[a]	285.07[a]	277.80[a]	740.99[a]	704.12[a]
±S.E.	0.07	0.06	3.17	3.04	0.08	0.08
Sig	0.8	0.93	1	0.79	0.48	0.19

Maize plant height

At the end of the experimental period in the unfertilized block, the best plant height (303.6 cm) was recorded when maize was cultivated solely at the low population density of 26,666 plants/ha (Table 3). However, intercropping maize at a density of 40,000 plants/ha with soybeans at a density of 160,000 plants/ha resulted in a plant height of 292.73 cm which was not significantly different (P ≥ 0.05) from the best height recorded. The least plant height was observed when maize at a population density of 40,000 plants/ha was intercropped with soybeans at a plant density of 200,000 plants/ha (Table 3).

In the fertilized plot, the plants were slightly shorter as compared to the observations in the unfertilized plots. Intercropping maize at population density of 53,320 plants/ha with soybeans at plant density of 160,000 plants/ha produced the best plant height of 292.67 cm, while the least plant height (277.47 cm) was observed when maize was planted solely at a population density of 40,000 plants/ha (Table 3).

Maize stem diameter

In the unfertilized block, best stem diameter (4.84 cm) was observed when maize at a population density of 53,320 plants/ha was intercropped with soybeans at a population density of 160,000 plants/ha. Reducing maize population density to 40,000 plants/ha and soybeans density to 100,000 plants/ha produced thinner plants with least diameter of 4.44 cm (Table 3).

In the fertilized plots, plants were sturdier as compared to those in the unfertilized plots. The highest stem diameter of 5.20 cm was obtained when maize at a population of 26,666 plants/ha was intercropped with soybean at a population of 160,000 plants/ha. The least stem diameter of 4.65 cm resulted when maize was grown solely at a population density of 53,320 plants/ha (Table 3).

Maize leaf area

In the unfertilized plot, maize planted solely at a population of 26,666 plants/ha produced the largest leaves, with diameter of 833.95 cm^2. Intercropping maize at a population of 40,000 plants/ha with soybeans at a population of 160,000 plants/ha led to the production of plants with slightly smaller leaves (807.99 cm^2). Growing maize at plant population of 26,666 plants/ha and soybeans at a population density of 100,000 plants/ha led to plants with the least leaf area of 704.12 cm^2 (Table 3).
In the fertilized plots, intercropping maize at a population density of 40,000 plants/ha with soybeans at a population of 160,000 plants/ha led to the production of plants with a maximum leaf area of 1013.23 cm^2. The minimum leaf area of 718.84 cm^2 was observed when maize was grown at a population density of 26,666 plants/ha intercropped with soybeans at a density of 160,000 plants/ha (Table 3).

Maize cob dry weight

In the unfertilized plots, the highest cob dry weight of 163.08 g was obtained when maize at a population density of 40,000 plants/ha was intercropped with soybeans at a population of 200,000 plants/ha. The least cob dry weight of 145.73 g was observed in maize planted solely at a population density of 40,000 plants/ha (Table 4).

Fertilization led to the production of heavier cobs. The highest cob dry weight of 180.53 g was obtained when maize at a population of 26,666 plants/ha was intercropped with soybean at a population of 200,000 plants/ha. The least cob dry weight (149.29 g) was observed when maize at a population of 40,000 plants/ha was intercropped with soybeans at a population of 100,000 plants/ha (Table 4).

Maize number of grains per cob

In the unfertilized plots, maize at a density of 40,000 plants/ha with soybeans at a density of 200,000 plants/ha produced the highest number of grains per cob (448.87), while the least number of grains per cob (382.60) was observed when maize was planted solely at a population density of 40,000 plants/ha (Table 4).
In the fertilized plots, the numbers of grains were slightly higher as compared to the observations in the unfertilized plots. Intercropping maize at a density of 26,666 plants/ha with soybeans at a density of 160,000 plants/ha produced the best number of grains per cob (454.23). The least number of grains (383.51) was observed when maize was planted solely at a population density of 40,000 plants/ha (Table 4).

Maize grain weight

In the unfertilized plots, the best grain weights (119.40 g) was observed when maize at a population density of 40,000 plants/ha was intercropped with soybeans at a population density of 200,000 plants/ha. The least grain weight resulted from maize planted solely at a population of 40,000 plants/ha (Table 4).

In the fertilized plots, plants produced slightly higher grain weight as compared to the results from the unfertilized plots. The best grain weight (127.13 g) was recorded when maize was cultivated at a population density of 26,666 plants/ha with soybeans at a density of 200,000 plants/ha, while the least grain weight (112.73 g) was observed when maize at a population of 40,000 plants/ha was intercropped with soybeans at a population of 100,000 plants/ha (Table 4).

Effect of intercropping and plant densities on soybean growth and yield parameters

Generally, cropping density had significant ($P = 0.01$) effects on some growth and yield parameters at harvest time in both fertilized and unfertilized blocks. It was generally noticed that the crops performed better as monocrops when compared with all the other intercropping treatments and for all parameters measured, except for plant height (Figures 2 to 6).

Soybeans plant height

At the end of the experimental period, in the unfertilized plots, the best plant height (73.13 cm) was recorded when soybeans at a population of 200,000 plants/ha was intercropped with maize at a population density of 26,666 plants/ha. The least plant height (41.47 cm) was recorded when soybeans was cultivated solely at a population of 200,000 plants/ha (Figure 2).

In the fertilized plots, the plants were slightly shorter as compared to the observations in the unfertilized plots. The best plant height (68.23 cm) was observed when soybeans at a population density of 160,000 plants/ha was intercropped with maize at a population of 40,000 plants/ha. The least (49.79 cm) was recorded when soybeans was cultivated solely at a population of 160,000 plants/ha (Figure 2).

Table 4. Effect of intercropping and plant densities on maize yield parameters.

Treatment	Unfertilized block			Fertilized block		
	Cob dry weight (g)	Number of grains per cob	Cob grain weight (g)	Cob dry weight (g)	Number of grains per cob	Cob grain weight (g)
M1S0	158.87[a]	438.60[a]	117.29[a]	159.93[a]	413.09[a]	116.65[a]
M1S1	150.31[a]	402.93[a]	110.37[a]	157.20[a]	400.58[a]	116.70[a]
M1S2	162.65[a]	422.67[a]	115.75[a]	160.07[a]	425.78[a]	124.12[a]
M1S3	154.25[a]	396.20[a]	111.87[a]	154.79[a]	395.90[a]	117.83[a]
M2S0	145.73[a]	382.60[a]	105.09[a]	154.53[a]	383.51[a]	114.11[a]
M2S1	163.08[a]	448.87[a]	119.40[a]	149.29[a]	431.02[a]	121.36[a]
M2S2	150.24[a]	401.00[a]	108.54[a]	152.21[a]	398.50[a]	113.95[a]
M2S3	159.37[a]	446.60[a]	115.85[a]	150.87[a]	394.31[a]	112.73[a]
M3S0	160.65[a]	398.67[a]	119.27[a]	154.00[a]	438.23[a]	116.14[a]
M3S1	161.97[a]	444.07[a]	117.01[a]	180.53[a]	407.11[a]	127.13[a]
M3S2	147.44[a]	394.33[a]	108.63[a]	153.57[a]	454.23[a]	120.17[a]
M3S3	149.95[a]	397.20[a]	107.01[a]	158.13[a]	397.83[a]	113.03[a]
S.E.	2.6	7.12	1.93	2.65	6.59	1.45
Sig	0.94	0.53	0.91	0.72	0.63	0.67

Soybeans number of pods per plant

In the unfertilized plots, the highest number of pods (49.87) was observed when soybeans were planted solely at a population of 200,000 plants/ha. However, intercropping maize at a population of 53,320 plants/ha with soybeans at a population of 200,000 plants/ha resulted in 34.67 number of pods, which was significantly (P = 0.01) different from the highest number of pods recorded. The least number of pods (11.33) was observed when maize at a population density of 40,000 plants/ha was intercropped with soybeans at a density of 100,000 plants/ha (Figure 3).

In the fertilized plots, the number of pods was higher as compared to the observations in the unfertilized plots. Planting soybeans solely at a population of 100,000 plants/ha produced the highest number of pods (56.4). However, intercropping maize at a population of 53,320 plants/ha with soybeans at a population of 200,000 plants/ha resulted in a significant (P = 0.01) decrease in number of pods (42.93). The least number of pods (17.73) was observed when soybeans at a population of 160,000 plants/ha was intercropped with maize at a population density of 53,320 plants/ha (Figure 3).

Soybeans pod weight

In the unfertilized plots, soybeans planted solely at a population of 200,000 plants/ha produced the heaviest (20.93 g) pods. Intercropping soybeans at a population of 200,000 plants/ha with maize at a population of 53,320 plants/ha led to the production of plants with lighter pods (13.09 g). Growing soybeans at 100,000 plants/ha intercropped with maize at a population of 40,000 plants/ha produced plants with the least pod weight of 3.84 g (Figure 4).

In the fertilized plots, pods were heavier as compared to those in the unfertilized plots. The heaviest pods (22.94 g) were produced when soybeans were planted solely at a population of 100,000 plants/ha, while the least pod weight (6.29 g) was recorded when soybeans at a population density of 160,000 plants/ha was intercropped with maize at a population density of 53,320 plants/ha (Figure 4).

Soybean number of grains

In the unfertilized plots, the best and highest number of grains (97.27) was observed when soybeans were planted solely at a population density of 200,000 plants/ha. However, intercropping soybeans at a population of 200,000 plants/ha with maize at a population of 53,320

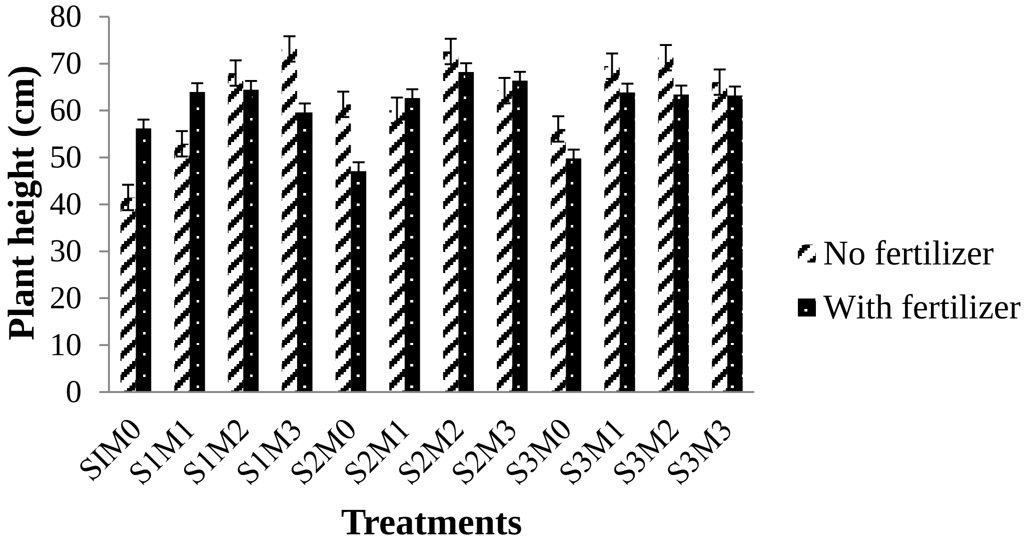

Figure 2. Effects of intercropping and plant densities on soybean plant height at harvest. Vertical bars represent standard error of mean.

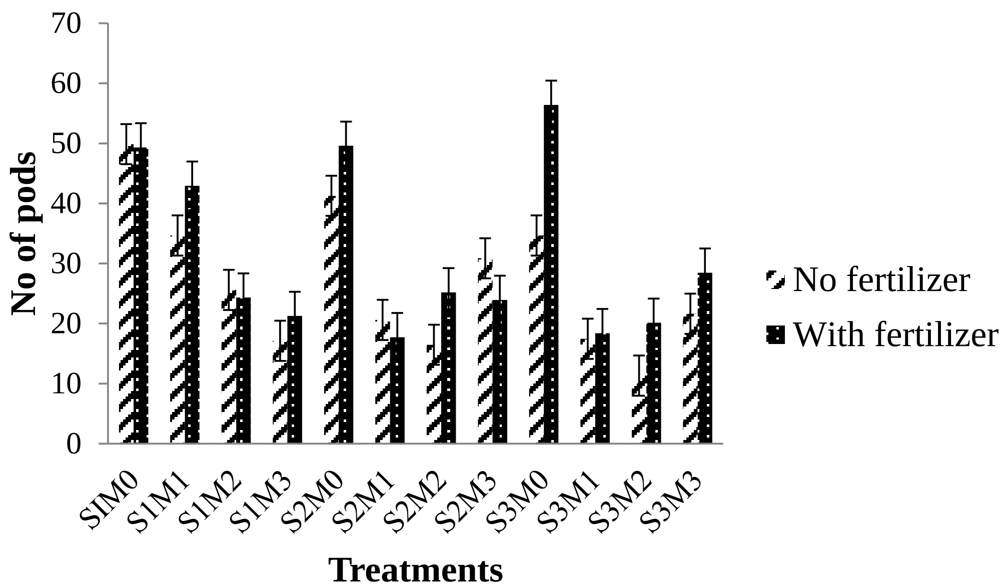

Figure 3. Effect of intercropping and plant densities on soybeans number of pods at harvest. Vertical bars represent standard error of mean.

plants/ha caused a significant decrease in grain number to 69.6. The least (23.6) was recorded in maize at a population of 40,000 plants/ha intercropped with soybeans at a population of 100,000 plants/ha (Figure 5).

In the fertilized plots, plants produced higher number of grains as compared to the unfertilized plots. The highest number of grains (109.93) was obtained when soybeans was cultivated solely at a population density of 100,000 plants/ha. Intercropping maize at a population of 53,320 plants/ha with soybeans at a population of 200,000 plants/ha produced a grain number of 97.2. The least grain number (35.47) was recorded when maize at a population of 53,320 plants/ha was intercropped with soybeans at a population of 160,000 plants/ha (Figure 5).

Soybean grain weight

In the unfertilized plots, soybeans planted solely at a plant density of 200,000 plants/ha produced the heaviest

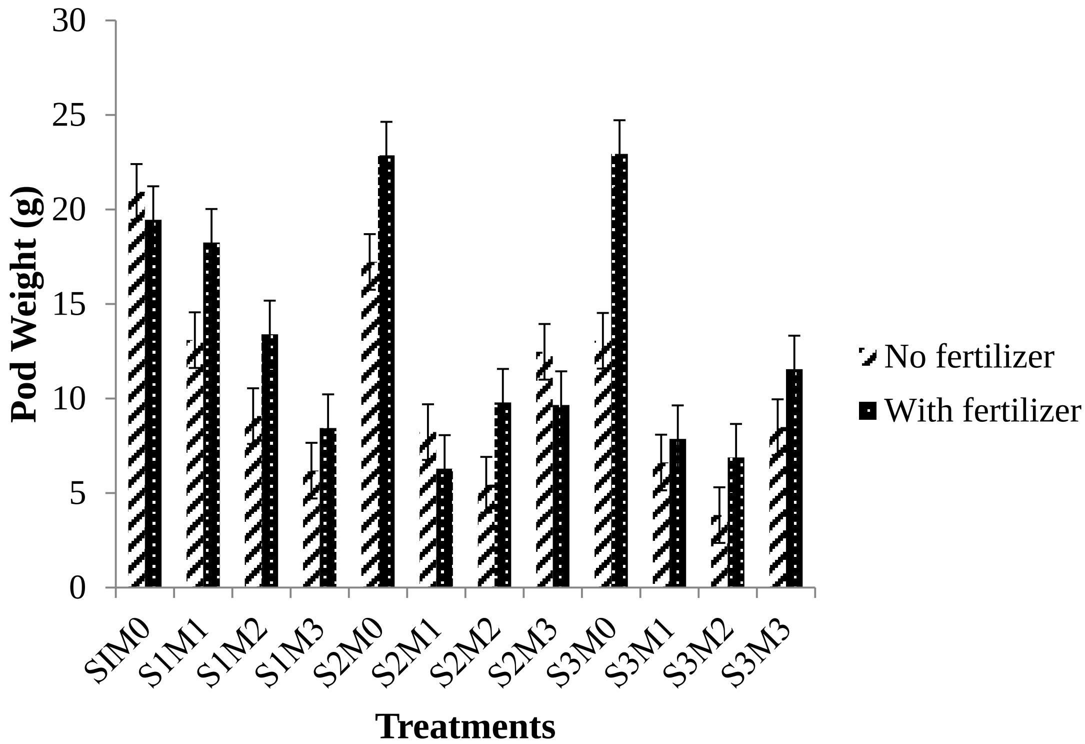

Figure 4. Effect of intercropping and plant densities on soybean pod weight at harvest. Vertical bars represent standard error of mean.

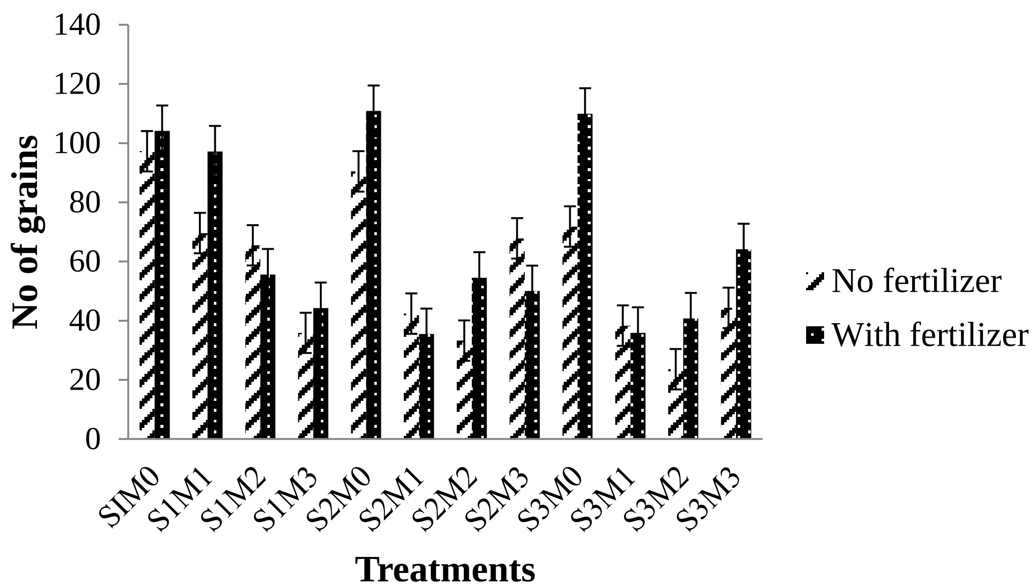

Figure 5. Effect of intercropping and plant densities on soybeans grain number at harvest. Vertical bars represent standard error of mean.

(13.69 g) grains. Intercropping maize at a population of 53,320 plants/ha with soybeans at a density of 200,000 plants/ha led to the production of plants with slightly lighter (8.66 g) grains. Growing maize at a population of 53,320 plants/ha and soybeans at a density of 160,000 plants/ha led to plants with the least (3.87 g) grain weight

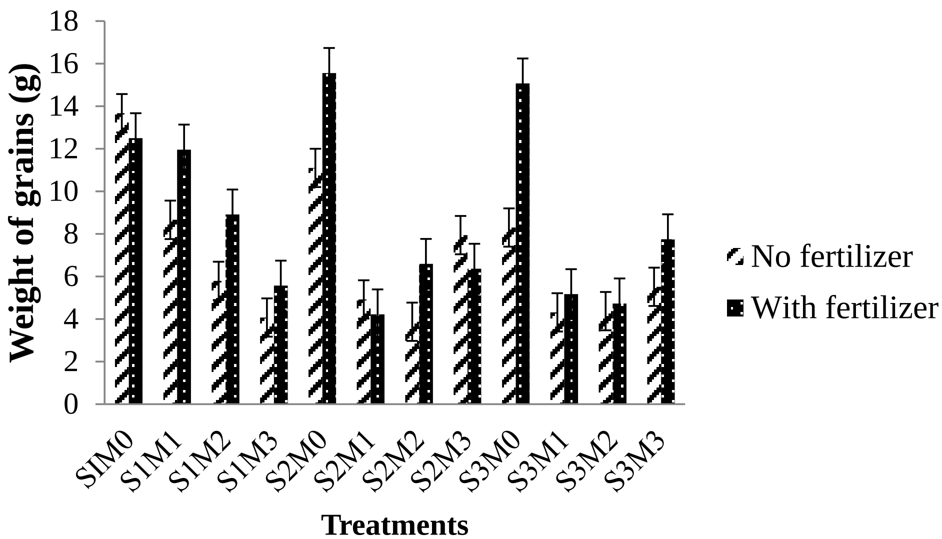

Figure 6. Effect of intercropping and plant densities on soybean grain weights at harvest. Vertical bars represent standard error of mean.

Table 5. Land equivalent ratio and relative value total of the intercropped treatments.

Treatment	RYM_{NF}	RYM_F	RYS_{NF}	RYS_F	LER_{NF}	LER_F	RVT_{NF}	RVT_F
M1S1	0.94	1.00	0.63	0.95	1.57	1.96	1.15	1.29
M1S2	0.99	1.06	0.42	0.66	1.41	1.72	1.13	1.26
M1S3	0.95	1.01	0.29	0.45	1.25	1.46	1.05	1.15
M2S1	1.14	1.06	0.44	0.27	1.57	1.33	1.27	1.17
M2S2	1.03	0.99	0.35	0.42	1.38	1.41	1.14	1.16
M2S3	1.10	0.99	0.72	0.41	1.8	1.39	1.32	1.12
M3S1	0.98	1.09	0.52	0.34	1.49	1.43	1.08	1.22
M3S2	0.91	1.03	0.53	0.31	1.44	1.34	1.02	1.15
M3S3	0.89	0.97	0.66	0.51	1.55	1.48	1.03	1.16

M1, M2 and M3: 53320, 40000, and 26666 maize plants per hectare; S1, S2 and S3: 200000, 160000, and 100000 soybean plants per hectare, respectively. Relative yields for maize non-fertilized (RYM_{NF}) and fertilized (RYM_F), Relative yields for soybean non-fertilized (RYS_{NF}), and fertilized (RYS_F), Land equivalent ratio for non-fertilized (LER_{NF}) and fertilized (LER_F), and Relative value total, non-fertilized (RVT_{NF}) and fertilized (RVT_F) for grain yields of maize and soybean at different cropping densities.

(Figure 6).

In the fertilized plots, the grains were heavier as compared to the observations in the unfertilized plots. The best grain weight (15.56 g) was recorded when soybean was planted solely at a density of 160,000 plants/ha, while the least (4.22 g) was observed when maize at a density of 53,320 plants/ha was intercropped with soybeans at 160,000 plants/ha (Figure 6).

Assessment of mixed cropping

Land equivalent ratio (LER)

Results showed that LER values were greater than 1 in all the intercropping combinations of maize and soybean, signifying yield advantage and greater crop complementarities in this intercropping system (Table 5).

In the unfertilized block, intercropping maize at a population of 40,000 plants/ha with soybeans at a population of 100,000 plants/ha recorded the highest LER value of 1.8, thus indicating the combination with the best yield advantage. The least LER value of 1.25 was obtained when maize at a population of 53,320 plants/ha was intercropped with soybeans at a plant density of 100,000 plants/ha.

In the fertilized block, intercropping maize at a population density of 53,320 plants/ha with soybeans at a density of 200,000 plants/ha recorded the highest LER value of 1.96. This was the planting density with the best yield advantage. The least LER value of 1.33 was seen when maize at a population of 40,000 plants/ha was intercropped with soybeans at a population of 200,000 plants/ha.

Relative value total (RVT)

The RVT of all treatments were greater than one (RVT>1) (Table 5). The RVT ranged from 1.02 to about 1.32 in both blocks indicating economic advantage in this cropping system. In the unfertilized block, the highest RVT of 1.32 was obtained when maize at 40,000 plants/ha was intercropped with soybeans at 100,000 plants/ha, while the least (1.02) was recorded when maize at 26,666 plants/ha was intercropped with soybeans at 160,000 plants/ha.

In the fertilized block, the highest RVT of 1.29 was obtained when maize at 53,320 plants/ha was intercropped with soybeans at 200,000 plants/ha, whilst the least (1.12) was observed when maize at 40,000 plants/ha was intercropped with soybeans at 100,000 plants/ha.

It is worth noting here that the same plant density combinations (maize at 40,000 plants/ha intercropped with soybeans at 100.000 plants/ha) that produced the highest RVT in the unfertilized block is the same one that produced the least RVT in the fertilized block.

Correlation between growth and yield parameters

Maize

Correlation results showed some significant (P = 0.01) differences in the relationship between the growth and yield parameters. In the unfertilized block, it was noticed that stem diameter was strongly and positively correlated (R = 0.05) to the yield components. Plants with larger stem diameter produced heavier cobs (fresh and dry weight). Plants with longer cob lengths had more grains and a resultant higher grain weight. Plant height also correlated positively (R = 0.01) with the yield components in that, taller plants produced heavier cob weights (fresh and dry), longer cob length, more grains and higher grain weight. There was a correlation in leaf area whereby the longer the leaf area, the heavier the cob weight (fresh and dry), the longer the cob length and the more the cob grains, irrespective of the treatments.

In the fertilized block, stem diameter was seen to be positively correlated (R = 0.05) with yield components in that, the higher the stem diameter, the heavier the cob weight (fresh and dry), the longer the cob length, the more the grain number and the higher the grain weight. Plant height also correlated positively (R = 0.01) with the yield components in that taller plants produced heavier cob weights (fresh and dry), longer cob lengths, more grains and higher grain weights. A significantly (P = 0.01) negative correlation was seen in leaf area where by the shorter the leaf area, the heavier the cob weights (fresh and dry), the longer the cob lengths and the more the cob grains, irrespective of the treatments. Generally, stem diameter and plant height were the two growth parameters that correlated (R = 0.05) most with the yield components in both blocks.

Soybeans

Results generally showed highly significant correlations (R = 0.05) between growth parameters (number of leaves, plant height, length and width of leaves) and yield parameters (% sterile pods, number of pods, weight of pods, number of grains and weight of grains) irrespective of treatments.

In the unfertilized block, the number of leaves showed highly significant and strong positive correlations (R = 0.05) with yield parameters in that, the higher the number of leaves, the more the number of pods, the higher the pod weights, the more the grain number and the higher the grain weights. Correlation between plant height and these parameters were generally weak and negative in that, the higher the plant height, the lower the number of pods, weight of pods, number of grains and grain weights. Leaf lengths showed significant (P = 0.01) and strong positive correlations (R = 0.05) in that, the longer the length of the leaf, the higher the number of pods, weight of pods, number of grains and weight of grains.

In the fertilized block, the number of leaves showed significant (P = 0.01) and strong positive correlations (R = 0.05) with reproductive parameters in that, the higher the number of leaves, the more the number of pods, the higher the pod weights, the more the grain number and the higher the grain weights. Correlation between plant height and these parameters were highly significantly (P = 0.01) negative in that, the higher the plant height, the lower the number of pods, weight of pods, number of grains and grain weights. Leaf lengths recorded no significant (P = 0.05) correlation with weight of pods and weight of grains but negative correlation in the case of number of pods and number of grains.

DISCUSSION

This study has shown that yield and yield components of the intercropped components varied significantly with planting density of the maize - legume component. The performance of the associated legume appeared to have been affected by the growth of maize and its associated micro-climatic changes. This is reflected in the significant differences among treatments in terms of grain yield.

From the results, the yields of maize in the sole crops were similar (difference were not significant ($P \geq 0.05$)) to those in the intercrops. There were neither yield gains nor yield decline. The results of this study agreed with the findings of other researchers (Undie et al., 2012; Muoneke et al., 2007; Mudita et al., 2008), which showed that maize grain yield was not significantly affected by intercropping and planting densities. It had been demonstrated in another study (Mutungamiri et al., 2001) that intercropping had no negative impact if maize population is not reduced below 37000 plants/ha. In intercrops usually, the cereal has a competitive advantage since they are taller and therefore benefits from maximum PAR reaching the foliage, hence they may not experience yield declines (Muoneke et al., 2007). Other researchers reported that the grain yield of maize in maize/soybeans mixture was reduced as compared to its sole crop yields (Ennin et al., 2002; Silwana and Lucas, 2002; Mashingaidze, 2004).

The fact that there was no yield increase in maize as a result of intercropping with soybeans indicated that it was unlikely that soybean can provide a nitrogen advantage to associated crops within an intercropping system in the same season. There is little evidence on direct transfer of significant amounts of nitrogen between roots of legumes and cereals in mixture (Geiler, 2001). The nitrogen advantage would benefit the proceeding crop after harvesting the legume (Mpepereki and Geiler, 1998). There was no reduction in maize yield due to intercropping which is probably because of lack of competition between the maize and soybean. The crops extracted nutrients from different zones in the soil profile since they had different rooting depths, so competition for nutrients could have been minimal or non-existent. The plant densities were not high enough to result in competition between the maize and soybean (Mutungamiri et al., 2001). The main effect of maize planting density showed that maize grain yield per unit area increased as maize planting density increased (53,330 plants/ha), probably due to more maize cobs, as maize plant population increased. A similar study (Olufajo, 1992) had shown that in maize/soybean intercrops, increasing maize plant density increased maize yield significantly.

Grain yield components were relatively higher for soybeans in the monocrops as compared to the intercrops probably due to a higher degree of interspecific competition and depressive effect of maize, a C_4 species on soybeans, a C_3 crop. Crops with C_4 photosynthetic pathways such as maize have been known to be dominant when intercropped with C_3 crops like soybeans (Hiebsch et al., 1995). The higher seed yield of sole over intercropped soybeans had been reported by other workers (Olufajo, 1992; Muneer et al., 2004). Also, reduction in the intercropped soybean could be as a result of the shading effect imposed by the taller maize plants. It had been reported that shading by the taller plants in mixture could reduce the photosynthetic rate of the lower growing plants and thereby reduce their yields (Olufajo, 1992; O'Callaghan et al., 1994). The intensity and quality of solar radiation intercepted by the canopy are important determinants of yield components, hence yield of soybean (Jomol et al., 2002). From the results of this study, it was observed that plant in the intercropped treatments were taller than those in the monocropped treatments. Soybean plants were taller with the lowest maize density (26,666 plants/ha) than other planting densities, probably because of their struggle for light. This result is contrary to others, where soybean was reported to be taller with the highest maize density (53,330 plants/ha) (Muoneke et al., 2007) and plant height in intercropped treatments were adversely affected due to competition with main crop for light and plant height was recorded as maximum in soybean planted alone rather than in mixture (Muneer et al., 2004).

Yield advantage

Land equivalent ratio

Previous studies have shown that, the non-legume crop is considered a suppressing crop in legume/non-legume associations like sorghum/pigeon pea (Tobita et al., 1994), groundnut/cereal fodders (Ghosh, 2004) and berseem (*Trifolium alexandrinum* L.)/barley (Ross et al., 2005). This was shown to be true in soybean/maize intercropping in the present study as indicated by the yield and yield components.

The LER gives an accurate assessment of the biological efficiency of the intercropping situation. The trade-off between increasing the yield of suppressing species and decreasing that of the suppressed species has three possible outcomes for intercropping systems, that is, yield advantage (LER > 1), yield disadvantage (LER < 1) and the intermediate result (LER = 1) (Vandermeer, 1992). The results of the present experiment showed mean LER values of above one in all the different combinations. The values above unity in most systems indicated complementarity in resource utilization by the component crops (Muoneke et al., 2007). LER greater than one had been attributed primarily to the increase in nitrogen absorption (Ghanbari, 2000).

The total land equivalent ratio was between 1.25 and 1.8 for the unfertilized block and 1.33 and 1.96 for the fertilized block. The yield advantages due to intercropping when compared with sole cropping of both maize and soybean were 25 to 80 and 33 to 96% in the unfertilized and fertilized blocks, respectively. This implies that 25 to 80 and 33 to 96% more land should be used in sole cropping in order to obtain the same yield of intercropping. It is therefore an indication of the superiority of the intercrops over pure stands in terms of the use of environmental resources during plant growth and development (Dhima et al., 2006). This also agreed with work which reported that sorghum-soybean intercropping system gave higher yield (38 to 124%) than other cropping systems (Sharma et al., 1994).

The total LER of the mixtures were contributed more by the maize component as depicted by the higher partial LER of maize in all the intercropping systems, probably because maize being a C4 crop suppressed the soybean crop. The mean LER values increased with an increased in maize planting density of 53,330 plants/ha. This is in agreement with reports in which LER increased at closer spacing (higher plant population), provided that the pure and intercropped plots were given the same level of management (Muoneke et al., 2007).

Relative value total (RVT)

The relative value total (RVT) of 32 and 29% shows that intercropping of maize and soybean can increase net income (NI) by 32 and 29%. This confirms that this type of cropping system has the advantage of generating more benefits. Therefore, intercropping of maize and soybean with high production stability can considerably increase economical revenues and the profitability of the farmlands. Higher monetary return had been reported for intercropping maize-soybean than the sole crops (Muoneke et al., 2007). Intercropping of maize-groundnut produced higher LER and monetary advantage (>1) than sole crops (Ghosh, 2004). The implication of this is that farmers in the study area would earn higher income growing maize/soybean than cropping them separately.

Conclusions

Finally, it can be concluded that intercropping and plant densities have an effect on the growth and yield of maize and soybean in the humid forest zone of Mt Cameroon area. The effect was not significant for maize. Overall, the yield components for soybeans decreased with a decrease in plant densities. The yield components for soybean grown as an intercrop with maize were significantly lower than those obtained when soybean was grown as a sole crop. Nonetheless, the combination of 53,320 plants/ha of maize and 200,000 plants/ha of soybeans showed the highest profitability and land use efficiency and could be introduced as best intercropping system.

The trading perspectives of the yields observed with intercropping could be improved if different tilling and cultivation methods are evaluated, the appropriate ones are identified and suitable genotypes of the intercrops are used. An intensification of training in agricultural techniques in secondary and vocational education as well as for the small holder farmers would also be of help. The implementation of government policies and regulations meant to control agricultural production and to secure farmers income will go a long way to improve crop production in intercropping. This is because increase in production will permit the farmers to supply local and international markets, thus increasing their income.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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