

Experimental Research Paper

Determination of land productivity under maize-cowpea intercropping system in agro-ecological zone of mount Uluguru in Morogoro, Tanzania.

Beatrice Thomas Nyasasi and Eliakira Kisetu*

Department of Soil Science, Faculty of Agriculture, Sokoine University of Agriculture, P.O. Box 3008, Chuo-Kikuu, Morogoro. Tanzania.

Accepted 25th August, 2014

Abstract

The present study assessed the response of maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L. Walp) under sole and intercropping systems. It also determined potential of intercropping system with respect to the proportion of land used for cultivation and the area of land saved. Results indicated that the above-ground total biological yield in sole maize (31.8 t ha⁻¹) was insignificantly (p=0.055) larger than in maize (26.7 t ha⁻¹) intercropped with cowpea. The yield in sole maize (6.53 t ha⁻¹) was significantly (p=0.003) higher than in maize (6.47 t ha⁻¹) intercropped with cowpea. The mean number of pods per plant in sole cowpea (7.7) was significantly (p=0.039) higher than in cowpea (6.8) intercropped with maize. In addition, the mean number of seeds per pod in cowpea intercropped with maize (15.0) was significantly (p=0.009) lower than in sole cowpea (15.43). Furthermore, cowpea seed yield in sole cowpea (6.7 t ha⁻¹) was significantly (p=0.022) higher than in intercrop (6.25 t ha⁻¹). Further to that, the land equivalent coefficient between maize and cowpea was 0.92 and the competitive ratio between the two crops when intercropped was 1.07. The land saved when the two crops were intercropped was 47.9%.

Key words: maize yield, cowpea yield, land equivalent ratio, land saved.

INTRODUCTION

Maize is an important cereal crop and source of carbohydrate in human diet in the developing countries; it is used as animal feed worldwide and ranked the third most important cereal crop of the world (Dahmardeh et al., 2009). The potential maize production in Tanzania is

4 t ha⁻¹ but this quantity has not been attained because of different agronomic practices and low soil fertility levels (Kisetu and Mtakimwa, 2013). Cereal-legume intercropping has a pivotal role for increasing land use efficiency, land productivity of the cereal crop and atmospheric nitrogen (N) fixation (Banik and Sharma, 2009).

Intercropping is considered as the practical application of ecological principles such as diversity, crop interaction

*Corresponding-Author's: E-mail: keliakira@yahoo.com

and other natural regulation mechanisms. Nitrogen fixing legumes such as cowpea, pigeon pea, common bean, soybean, French bean, can be included to a greater extent in arable cropping systems via intercrops. Legumes contribute to maintaining the soil fertility via N fixation, which is increased in intercrops due to the more competitive character of the cereal for soil inorganic N (Adigbo et al., 2013). This leads to a complementary and more efficient use of N sources by the crops in the intercrop system.

Intercropping of grain legumes and cereals offers an opportunity to increase the input of fixed N into agroecosystems without compromising cereal N use, yield level and stability (Gomes *et al.*, 2007). Despite all its advantages, the agricultural intensification in terms of plant breeding, mechanization, fertilizer and pesticide use experienced by most farmers has led intercropping to disappear from many farming systems (Adigbo et al., 2013). According to Adigbo et al. (2013), intercropping is the agricultural practices of cultivating two or more crops in the same period of time and it offers farmers the opportunities to engage nature's principle of diversity on their farms.

Undie et al. (2012) reported that intercropping maize with soybean in one growing season had no significant effect on grain yield of maize but maize grain and soybean yields were reduced by 6% and 32%, respectively, compared to sole cropping. However, according to Undie et al. (2012), arrangement of maize and soybean significantly influenced yield components and yield. In addition, planting maize and soybean in 1:1, 2:2 or 1:2 arrangement depressed grain yield of maize by 38%, 35% and 14%, respectively, and soybean yield by 86%, 64% and 73%, respectively.

Previous studies (Ennin et al., 2002; Silwana et al., 2007; Ullah et al., 2007) indicated that 2 maize rows: 2 soybean rows or 1 maize row: 2 soybean rows increased grain yield than intercropping these crops in single alternate rows. Amasaib et al. (2011) reported that intercropping of maize and lablab bean along with application of doses of super phosphate in the levels of 50 and 75 kg P ha⁻¹ improved significantly the crude fiber, ash and ether extract content and dry matter digestibility with slight decrease in detergent fiber digestibility.

Banik and Sharma (2009) carried out an experiment on a baby corn–legume intercropping system in 2:1 and 2:2 series in the eastern plateau region of India over two consecutive rainy seasons (2003/2004) and found that total productivity in terms of baby corn yield equivalent (7063 kg ha⁻¹) was highest under the baby corn–groundnut intercropping system. The findings of similar authors (Banik and Sharma, 2009) suggested that intercropping baby corn and legumes increased productivity per unit area, improve land use efficiency, and increased atmospheric N fixing ability of the intercrops. Nitrogen from legume fixation is "free" N for use by the host plant or by associated or subsequent

crops (Adigbo et al., 2013). Gomes et al. (2007) reported that intercropping combined with competitive maize cultivars can reduce the use of herbicides to control weeds.

Agricultural systems that intercrop maize with a legume are able to reduce the amount of nutrients taken from the soil as compared to a maize monocrop (Carlson, 2008). Undie et al. (2012) confessed that late season maize and soybean may be planted in 2:2 or 1:2 arrangements to take advantage of optimum soybean seed yield and 65 – 100% of the maize grain yield in the humid South Southern Nigeria.

A study conducted by Song et al. (2007) investigated crop yield and various chemical and microbiological properties in rhizosphere of wheat, maize, and faba bean grown in the field solely and intercropped (wheat/faba bean, wheat/maize, and maize/faba bean) in the second and third year after establishment of the cropping systems. According to Song et al. (2007), intercropping increased crop yield, changed N and P availability, and affected the microbiological properties in rhizosphere of the crop species compared to sole cropping. Dahmardeh (2009) reported that the practice of cereals and legumes intercrop is old in tropical agriculture that dates back to ancient civilization. Different studies conducted by Li et al. (2003) and Mpairwe et al. (2002) reported that the main essence of intercropping is to maximize use of resources such as space, sun light and nutrients, as well as to improve crop quality and quantity.

The findings of relative crowding coefficient values from studies conducted by Ezumah and Ikeorgu (1993) on the nature of competition and the effects of various planting patterns on maize/cowpea intercrop yields indicated that maize dominated cowpea. According to Ezumah and Ikeorgu (1993), the magnitude of competition between maize and cowpea is related to season and nitrogen fertilizer because based on grain yields, maize and cowpea compete for N only when it was applied but tended to derive it from different sources in the absence of applied N. Sesay (2000) found that fertilizer application in a maize/cowpea intercrop system resulted in significantly higher yields than in the non-fertilized treatment for cowpea and maize, although sole cowpea did not respond to fertilizer application. A study conducted by Mkamillo (2004) revealed that intercropping maize and sesame maintained maize yields while producing an important cash crop to supplement smallholder income in southeast Tanzania. This interaction was also reported by Adu-Gyamfi et al. (2007) in maize/pigeon pea intercropping systems in semi-arid climates of Tanzania.

Undie et al. (2012) reported that the total farming system productivity is assessed by land equivalent ratio (LER) and the portion of land saved. Land equivalent ratio was first defined as the relative land area required as sole crops to produce the yields achieved in intercropping (Carlson, 2008). Land equivalent yield



Plate 1: Cropping systems: (a) Intercrop, (b) Sole cowpea, (c) Sole maize

values could also be thought of as relative yields. It combines the yields of two or more unlike crops into one index for comparison with sole culture of or among intercrop systems. Carlson (2008) reported that the LER is calculated by dividing the amount of the intercropped yield by the amount of the monocropped yield for each crop in the field. Many studies which assessed the importance of intercropping cereals and legumes have been conducted by Nguimgo et al. (2003), Odhiambo and Ariga (2001), Marer et al. (2007), Sesay (2000), Ijoyah et al. (2013), Tsubo et al. (2005).

Intercropping also results into proper land utilization for other production activities because of the land saved, diversification of diet, taking risks of losing one crop, and nutrients recycling in the soil. However, such information is limited for the intercropping systems of Tanzanian in its relied agro-ecological zones. Therefore, the specific objectives of this study were to assess the performance of maize and cowpea under sole and maize-cowpea intercrop systems and to determine land productivity potentials of maize/cowpea intercrop system.

MATERIALS AND METHODS

The Study Area

The study was conducted at the Sokoine University of Agriculture Farm, section of the Department of Soil Science. The field is located between latitude $6^{\circ} 85' S$ and longitude $37^{\circ} 64' E$ and at an elevation of 568 m above mean sea level and the slope of the area is 4%. Soil is generally infertile to support crop growth and development (Kisetu et al., 2013) and long rains for the 2014 season were above average (Kisetu et al., 2014).

Experimental Area, Design, Treatments and Planting

The trial area consisted of three treatments namely sole cowpea, sole maize and the intercrop of cowpea and maize, replicated three times in a randomized complete block design (RCBD). The field was ploughed, harrowed and divided into 3 blocks each with 9 subplots. Each block with sole maize, sole cowpea and maize-cowpea intercrop was $3 \text{ m} \times 22 \text{ m}$ (66 m^2). Maize seeds variety TMV-1 were sown at 30 cm within a row and 90 cm between rows; whereas the space between one maize row and cowpea row in either side of maize row was 30 cm. The plot gave 40 maize plants and 160 cowpea plants. In plots where sole maize was grown the sowing space was the same as for the maize-cowpea intercrop. The sole cowpea variety *Vuli 1* was sown at a spacing of $15 \text{ cm} \times 15 \text{ cm}$ which gave a plant population of 704 plants per plot (Plate 1). The methodology was a modification of the procedures of Dugje et al. (2009) and Ijoyah and Dzer (2012).

Routine Management of Crops in the Trial Field

Mixed fertilizer NPK 23-10-5 was applied to sole maize at the rate of 200 kg ha^{-1} while 6.3 g per hole of single superphosphate (SSP) that is 100 kg ha^{-1} equivalent to 25 kg P ha^{-1} was applied to sole cowpea. For the cowpea-maize intercrop there will be an application of 100 kg ha^{-1} of nutrient N and K exclusive of each other that is 4.7 g of urea per hole and 4.1 g of muriate of potash (KCl). In addition, the holes which will receive the latter nutrients that are N and K will also be applied with SSP at a rate of 0.2 g per hole equivalent to 8.6 kg P ha^{-1} as suggested by Ijoyah et al. (2013). Cowpea was harvested when the pods turned brown and seeds were at the hard-dough stage which indicated that moisture

content between 14 and 16% (Dugje et al., 2009). Maize was harvested when the signs of senescence appeared and at cob maturity (Ijoyah and Jimba, 2012).

DATA COLLECTION

Measurement of Plant Variables

The data collected from cowpea included number of pods per plot and per plant, pod length and diameter, number of seeds per pod, weight of seeds per plot and seed yield. On the other hand, the data collected from maize were maize plant height at 50% flowering/tasseling which was measured as the distance in from the soil surface to the collar of the top most leaf, total above-ground biomass and biological yield. Total above-ground biomass was determined by cutting whole maize plant with its cobs and weighed using a 50 kg x 200 g weighing balance. Other variables collected from maize were the weight of dehusked cob per plot; then the cobs were shelled manually and maize grains dried in a glasshouse. The total weight of all grains for each plot was weighed and corrected to maize yield (Plate 2).



Plate 2: Different steps of data collection for maize grain yield

Assessment of the advantages of maize/cowpea intercropping system

The data on land equivalent ratio (LER), land equivalent coefficient (LEC), competitive ratio (CR) and percentage (%) land saved were determined as described by Ijoyah et al. (2013) and Workayehu (2014) using the formulae below:

$$LER = \frac{\text{intercropped yield of maize}}{\text{Sole yield of maize}} + \frac{\text{intercropped yield of cowpea}}{\text{Sole yield of cowpea}}$$

$$LEC = LER_m \times LER_c$$

Where LER_m is the partial LER of main crop (maize to this case) and LER_c is the partial LER of intercrop (maize-cowpea to this case).

Competitive ratio (CR) was calculated using the formula:

$$CR = \frac{LER_m}{LER_c} \times \frac{Lam}{Lac}$$

Where Lam and Lac are proportions area of intercropped maize and intercropped cowpea (2.0 m and 2.0 m) for all plots.

$$\text{Land saved (\%)} = 100 - \left(\frac{1}{LER} \times 100 \right)$$

Statistical Data Analysis

Growth and yield data generated from test crops were managed statistically by GenStat software using One Sample t-tests based on Two-Sided test of 95% Confidence Interval for mean.

RESULTS

Effect of Cropping Systems on Maize Performance

The results of the responses of maize under different cropping systems are presented in Table 1. In addition, the results of the statistical contribution of the effect of cropping systems on the performance of maize are presented in Table 2.

Maize Plant Height

Results indicated that maize plant height differed significantly ($p = 0.016$) between a maize plant grown under sole and that in intercropping systems and their differences ranged between 145.9 and 288.6 cm. Based on the results in Table 1, the maize plant (222.9 cm) obtained in sole maize was taller compared with that in the maize intercropped with cowpea (211.6 cm).

Above-ground Total Biomass and Biological Yield of Maize

Results indicated that there was no significant ($p=0.053$) variation between the total biomass obtained in the maize which were grown as sole and that obtained in the intercropping system. It was also observed that the total biomass of maize plants in a given plot ranged as small as -0.82 to 24.2 kg (Table 2). Based on the results in Table 1, the total biomass of maize recorded in the sole maize (12.7 kg) was larger than that in the maize-cowpea intercrop (10.7 kg) although the difference was

Table 1. The response variables of maize under sole and cowpea-intercrop systems

Cropping system	Plot	Plant height (cm)	Total biomass (kg/plot)	Biological yield (t ha ⁻¹)	Wt. dehusked cob (kg/plot)	Wt. seeds (kg/plot)	Yield (t ha ⁻¹)
Intercrop	1 st	222	13.4	33.5	5.4	2.9	7.4
Intercrop	2 nd	210.2	10.2	25.4	4.5	2.4	6.1
Intercrop	3 rd	202.7	8.5	21.2	4.5	2.4	5.9
	Mean	211.6	10.7	26.7	4.8	2.56	6.47
Sole	1 st	234.5	12	30.1	4.7	2.5	6.1
Sole	2 nd	219.8	14	35.1	4.7	2.6	6.6
Sole	3 rd	214.3	12	30.2	4.8	2.8	6.9
	Mean	222.9	12.7	31.8	4.7	2.63	6.53

Table 2: The statistical comparison of the means of each response variable of maize

Response variable	Size	Mean	Variance (σ^2)	Std. dev. (σ)	S. mean	95% CI for mean	Test "t" stat. (1 d.f.)	P-value
Plant height (cm)	2	217.2*	63.09	7.943	5.62	(145.9, 288.6)	38.68	0.016
Total biomass (kg/plot)	2	11.68	1.934	1.391	0.98	(-0.82, 24.2)	11.88	0.053
Biological yield (t ha ⁻¹)	2	29.25	13.01	3.606	2.55	(-3.16, 61.7)	11.47	0.055
Wt. dehusked cob (kg/plot)	2	4.77**	0.0022	0.047	0.033	(4.34, 5.2)	143	0.004
Wt. of seeds (kg/plot)	2	2.6**	0.0022	0.047	0.033	(2.18, 3.0)	78	0.008
Yield (t ha ⁻¹)	2	6.5**	0.0022	0.047	0.033	(6.08, 6.9)	195	0.003

Test of null hypothesis that mean of variable is equal to 0

statistically insignificant. Similar trend of results (Table 1) was observed in the biomass yield whereby the mean biological yield (31.8 t ha⁻¹) obtained in the sole maize was larger than in the intercropped maize (26.7 t ha⁻¹) but the difference was insignificant (Table 2). The range of biological yield was however, elevated in the cropping systems compared with that of total biomass which was from -3.16 to 61.7 t ha⁻¹ (Table 2).

Maize Yield

Results indicated that there was significant ($p= 0.003$) variation in the maize yield obtained in the sole and the maize yield obtained in the intercrop system. The difference in yields between the cropping systems ranged from 6.08 to 6.9 t ha⁻¹ (Table 2). Results in Table 1 show that the two cropping systems had very close yield but differed significantly whereby the yield (6.53 t ha⁻¹)

obtained in sole maize was higher than that obtained in the maize-cowpea intercrop (6.47 t ha⁻¹).

Effect of Cropping Systems on Cowpea Performance

Results of the responses of cowpea under different cropping systems are presented in Table 3. Results of the statistical contribution of the effect of cropping systems on the performance of cowpea are presented in Table 4.

Pod Length and Pod Diameter

Results indicated significant ($p= 0.02$) variation between pod length obtained in the cowpea grown in sole and that from cowpea-maize intercrop. Table 4 shows that pod length between the two cropping systems ranged from 10.97 to 20.29 cm and in sole system the diameter recorded (16 cm) was larger than in the intercrop system

Table 3: The response variables of cowpea under sole and maize-intercrop systems

Cropping system	Plot	Pod length (cm)	Pod diameter (cm)	Pods/plot	Pods/plant	Seeds/pod	Wt seeds (kg/plot)	Yield (t ha ⁻¹)
Intercrop	1 st	15	0.3	56.7	8.7	16.3	3	7.5
Intercrop	2 nd	15.1	0.7	28	5.3	18	2	5
Intercrop	3 rd	15.7	0.9	27.3	6.3	10.7	2	5
	Mean	15.3	0.6	37.3	6.8	15.0	2.3	6.25
Sole	1 st	14.1	0.6	252	6	14.7	1	2.5
Sole	2 nd	16.6	0.8	202.3	8	17.2	4	10
Sole	3 rd	17.3	0.8	182	8	14.4	3	7.5
	Mean	16	0.73	212.1	7.7	15.43	2.7	6.7

Table 4: The statistical comparison of the means of each response variable of cowpea

Response variable	Size	Mean	Variance (σ^2)	Std. dev. (σ)	S. mean	95% CI for mean	Test "t" stat. (1 d.f.)	P-value
Pod length (cm)	2	15.63*	0.27	0.52	0.37	(10.97, 20.29)	42.64	0.02
Pod diameter (cm)	2	0.68*	0.01	0.07	0.05	(0.05, 1.32)	13.67	0.05
Pods/plot	2	124.7	15272	123.6	87.4	(-985.9, 1235)	1.43	0.39
Pods/plant	2	7.3*	0.41	0.64	0.45	(1.530, 12.97)	16.11	0.039
Seeds/pod	2	15.2**	0.93	0.304	0.215	(12.48, 17.95)	70.77	0.009
Wt seeds (kg/plot)	2	2.5	0.08	0.28	0.2	(-0.04201, 5.042)	12.50	0.051
Yield (t ha ⁻¹)	2	6.5*	0.1013	0.3182	0.225	(3.615, 9.335)	28.78	0.022

Test of null hypothesis that mean of variable is equal to 0

(15.3 cm) (Table 3). There was also significant ($p=0.05$) variation between the pod diameter obtained from the cowpea in sole system and that obtained in the intercrop. The pod diameter obtained in the sole cowpea (0.73 cm) was larger than that recorded in the intercrop (0.6 cm) (Table 3). On the other hand, the range of the pod diameter between the two cropping systems was 0.05 to 1.32 cm (Table 4).

Number of pods per plot and number of pods per plant

There was no significant ($p=0.39$) variation in the average number of pods per plot but that of pods per plant differed significantly ($p=0.039$) obtained in cowpea planted in the sole and those obtained from the intercropping system. Results indicated that the number of pods per plot ranged

from as small as -985.9 to the highest 1235 and the number of pods per plant ranged from 1.530 to 12.97 (Table 4). The number of pods per plot in sole cowpea (212.2) was larger than that in the intercrop system (33.7). The larger mean number of pods per plant (7.7) was obtained in the sole crop and the lower in the intercrop system (6.8) (Table 3).

Number of seeds per pod

Results showed that there was very significant ($p=0.009$) variation between the number of seeds per pod obtained from cowpea in sole and in the intercrop systems ranging from 12.48 to 17.95 (Table 4). Results presented in Table 3 show that the average number of seeds per pod in the intercrop system was relatively smaller (15) than that of sole system (15.4).

Table 5: The statistical comparison of the means of each response variable of cowpea

Cropping system	Yield (t ha ⁻¹)	Partial Land Equivalent Ratios		Land Equivalent Ratio (LER)	Land Equivalent Coefficient (LEC)	Competitive Ratio (CR)	Land saved (%)
		Maize (LERm)	Cowpea (LERc)				
Maize intercrop	6.47	0.99 (51.6%)					
Maize sole	6.53			1.92	0.92	1.07	47.9
Cowpea intercrop	6.25	0.93 (48.4%)					
Cowpea sole	6.7						

$$\text{Partial Land Equivalent Ratio (\%)} = \frac{PLER}{LER} \times 100$$

Cowpea yield

The variation in weights of seeds per plot of cowpea in sole and in intercrop systems were insignificant ($p=0.051$). However, the yield of cowpea in terms of seeds was significantly ($p=0.022$) different between sole and intercrop systems (Table 4). The total average weight of seeds in a given plot ranged from low as between -0.042 to 5.042 kg/plot and the yield of cowpea ranged from 3.615 to 9.335 t ha⁻¹ (Table 4). The weight of cowpea seeds obtained from sole system (2.7 kg/plot) was larger than that obtained in the intercrop system (2.3 kg/plot) (Table 3). In addition, the yield followed the same trend as that of the weight of seeds per plot and the yield obtained in sole cowpea (6.7 t ha⁻¹) was larger than that obtained in the intercrop system (6.25 t ha⁻¹).

Effects of maize/cowpea intercrop system on land productivity potential.

The results of the effect of intercropping system on land productivity potential are presented in Table 5. Results indicated that the partial land equivalent ratios (LERs) of maize and cowpea were 0.99 and 0.93, respectively and the combined LER of the cropping systems was 1.92. The partial land equivalent ratios of maize (LERm) and cowpea (LERc) were 51.6% and 48.4%, respectively obtained as fractions of the total LER of 1.92.

The LEC between the main crop that is maize and that of the intercrop that is cowpea was 0.92 and the CR between the two crops when intercropped was 1.07. Furthermore, the portion of land saved when the two crops were intercropped was 47.9%.

DISCUSSION

Performance of Maize Crop

The height of maize plant was relatively smaller in intercrop than that in sole maize. The difference was

however insignificant although it indicates the impact of competition between the two crops for the available resources in the field including space, nutrients, light, water and soil exploration. In a similar study, Alhaji (2008) found that intercropping of different varieties of cowpea with maize was significant in affecting the plant height, leaf area and leaf area indices of maize. The findings of the present study concur with those of Lemlem (2013) who found insignificant differences in plant height for sole maize (220.55 cm) and maize-cowpea (169.22 cm) intercropping. However, the same author found significant differences in maize plant heights for maize grown as sole and in maize-lablab intercrop, which could be attributed to the nature of the legume plants which was intercropped with maize. A study conducted by Silwana and Lucas (2002) found that sole maize plant was taller than maize which was intercropped with beans. Lemlem (2013) also found that intercropping maize with cowpea reduced maize plant height as determined by environmental factors and competition between the two crops. Furthermore, Hussan et al. (2003) reported that maize plant height was reduced by the use of different legumes in an intercropping system.

Above-ground total biomass and biological yield of maize varied depending on the cropping system but these attributes were low in the intercrop as opposed to the sole maize system. The difference observed in biological yield between the two cropping systems could be explained by the competition pressure between plants differing in species and discrepancies in nutrients' utilization. It is obvious that cowpea is a light feeder crop compared with maize but its rooting ability explores an advantage to benefit from underground nutrients and stored soil moisture in horizons where maize roots might not reach. This increases reliance of maize plant to the subsequent nutrients and moisture thereafter being exhaustively utilized by the cowpea plant.

This also retards the ability of the dependent maize plant to capture its growth potentials in the same land of intercrop with cowpea in the same growing season. Morgado and Willey (2003) reported that dry matter yield accumulation in an individual maize plant decreased with increase in bean plant population when grown under intercrop. According to Prasad and Brook (2005), with increasing maize density, the accumulation of dry matter and leaf area index also increased thereby decreasing transmission of light to the intercropped legume.

The yield obtained in the sole maize was numerically close to that in the intercrop but the former was statistically larger than in the latter. The close yield similarity obtained in the two cropping systems would suggest that maize yield might be increased in the following season as a subsequent crop in the same field because of residual nutrients which would have been enhanced and set free for plant uptake during the previous season. Giller et al. (1991) reported that the evidence of substantial benefits of N-transfer from grain legumes to the associated cereal crops is limited. According to Ledgard and Giller (1995), the benefits of an intercrop system between a legume and cereal crop are more likely to occur to subsequent crops as the main transfer path-way is due to root and nodule senescence and fallen leaves.

Performance of cowpea crop

The length and diameter of the pods, number of pods per plot and per plant, and seeds per pod in the sole cowpea outperformed those in the cowpea-maize intercrop. Lemlem (2013) reported that intercropping affect pod length and cowpea in monocrop had the longest pod length but this was significantly reduced under intercropping. The sole cowpea produced many pods per plot (212.1) and this was about 6 times the number of pods obtained in the intercropped cowpea (37.1). The number of pods per plant also followed the same trend but the difference was not significant. These findings suggest that the number of pods obtained per plot was attributed to the number of cowpea plants which were many in the sole plot compared with that in the intercrop. In addition, there was flower abortion in the intercrop which reduced the final number of pods obtained in a plot. In disparity to this argument, the insignificant difference observed in the number of pods obtained per plant regardless of the cropping system was specifically determined by the cowpea plant which was the same variety that is *Vuli 1*. A research done by Iderawumi and Friday (2013) also showed that sole cowpea plants produced significantly higher number of harvested pods per plant than those which were intercropped with maize. Alhaji (2008) found that the number of pods, pod weight and seed yield was significantly reduced when cowpea was intercropped with maize.

The cowpea in the sole produced relatively many seeds compared with those obtained in the cowpea intercrop.

This study found that many pods formed by cowpea plants in intercrop were not filled with viably reliable seeds and this was attributed to the early death of seeds at a tender stage prior to attain maturity. A research done by Lemlem (2013) revealed that intercropping had significant effect on the number of seeds per pod as compare to those planted in sole. The small number of seeds per pod in the intercrop obtained in the present study was ultimately explained by the small yield compared with the yield in the sole cowpea. Khan et al. (2012) and Shahbazi and Sarajuoghi (2012) indicated that different intercropping treatments of mungbean with maize significantly affected the number of seeds per pod. Mukungu (2002) reported that nutrients requirements by cowpea and maize differ and this causes competition among the plants and thus reduced yield of the cowpea. This was attributed to the reduction in the incidence of the light which reduced the rate of photosynthesis and thus reduced growth and yield. According to Alhaji (2008), maize leaves form canopy and barricades light from reaching the cowpea leaves and this reduced the ability of cowpea to make more food for the formation of flowers and pods. Addo-Quaye et al. (2011) reported that the growth and yield of bean was reduced when intercropped with maize. When maize plants are were at high density they caused reduction in the growth and development attributes of cowpea due to the effects of canopy and as a result grain yield of cowpea was low compared with sole crops when cowpea is was intercropped with maize. This observation was attributed to the inter-specific competition and depressive effect of maize crop on the counter legume crop.

Land productivity potential for maize/cowpea intercrop system

The productivity of intercropping maize with cowpea in the present study was assessed using LER and related attributes described in previous sections. According to Workayehu (2014), when $LER < 1$ there is obvious disadvantage of the intercropping and the available resources are used more efficiently by the sole crop than may be used by the intercrop. In addition, Mariotti et al. (2006) and Kitonyo et al. (2013) stressed that when $LER = 1$ there is no advantage or disadvantage of the intercropping in respect to sole crop but when $LER > 1$, an intercropping warrants an advantage in terms of the improved use of available resources for plant growth and development.

The findings of the present study indicate high percent of partial land equivalent ratios of maize and cowpea but maize (51.6%) outperformed the cowpea (48.4%). These findings are similar to those of Workayehu (2014) who found that partial land equivalent ratios of maize and bean in intercrop were 28.6% and 15.8%, respectively. In addition, the LER (1.92) of the present study is greater than 1 which shows an advantage of intercropping maize with cowpea compared with growing each crop

separately. The findings of the study conducted by Ijoyah et al. (2013) which involved intercropping soybean and maize gave land equivalent ratio greater than one, indicating high productivity per unit area achieved by growing the two crops together. The results of LER obtained in the present study gave 47.9% of land saved as intercropping potential, which could be used for other land productivity related activities.

The land equivalent coefficient (LEC) obtained in the present study of 0.92 shows an advantage of the intercropping system over the sole cropping system. The competitive ratio (CR) obtained between the two cropping systems (1.07) indicates that cowpea is more competitive than the maize crop when these crops are grown together. This could be attributed to the growth habit of the cowpea variety *Vuli 1* which is bushy and climbing to an extent that most maize plant parts were obscured from sunlight. This is a very important concern during photosynthesis and microbial activation in the soil and ultimately contributes to the formation of metabolites in plants. Iderawumi et al. (2012) conducted a study which determined the effect of different planting pattern on total dry matter production and maize forage quality in maize and intercropped as whole-crop forage. The findings of their study showed that intercropping systems had a significant effect on forage dry weight, and dry matter yield was increased by intercropping as compared with maize and cowpea sole crops. This observation was related with high consumption of environmental resources, such as photosynthetically active radiation and soil moisture by the intercropped crops.

In a similar study, Egbe (2010) found that the competitive ratio of soybean in sorghum intercrop increased (0.76 - 1.15) with increasing density of the soybean indicating higher competitiveness at higher densities than the sorghum component. The same author also found that the competitive ratio of sorghum had the opposite response (1.23 - 0.76). This suggests that cereal crops are less competitive than legumes when the two crop species are grown in intercrop systems. The findings of this study are in line with other previously conducted similar studies. Ijoyah et al. (2013) found LER values greater than one in two growing seasons which suggested that high productivity per unit area was achieved by growing the two crops together. The LER values greater than one indicating positive impact of increased yield of the main crop in the intercropping systems. For instance, according to Ijoyah and Usman (2013) and Ijoyah et al. (2012), LER of 1.25 can be interpreted as 25% greater yield for intercropping or as a 25% greater area requirement for the sole cropping system. Ijoyah and Anyam (2013) found that planting density of okra into soybean gave the highest LER values of 1.69 and 1.71 and LEC values of 0.71 and 0.73 in two different growing seasons. In the same study using the LER values, they found that 40.8% and 41.5% of lands were saved in two growing seasons. Ijoyah et al. (2013)

found that 28.6% and 22.5% of lands were saved in two separate growing seasons of intercrops suggesting that these saved lands could be used for other production activities. They also found that LEC values which exceeded 0.25 indicating yield advantage of the intercropping system. Ijoyah and Jimba (2012) found that 45.7% and 44.4% of land was saved respectively, in 2009 and 2010 when maize was intercropped with okra. Ijoyah et al. (2012) found that 60.2% and 59.5% of lands were saved respectively, in 2010 and 2011, when cassava, maize and egusi melon intercropping in a three crop system.

According to Matusso et al. (2014), one of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping. Muoneke et al. (2007) found yield advantage of intercropping system of 2-63% with LER of 1.02-1.63 showing efficient utilization of land resource. Of the most researches which involved different intercropping systems, none of them reported LER values less than one and this is evidenced in the studies conducted by Raji (2007), Addo-Quaye et al. (2011), Allen and Obura (1983), Samba et al. (2007) and Osman et al. (2011). A review conducted by Matusso et al. (2014) found that intercropping of cereal and legumes is widespread among smallholder farmers due to the ability of the legume to cope with soil erosion and with declining levels of soil fertility. There is an in-pull for the smallholder farmers to continue with intercropping systems because of flexibility, profit maximization, risk minimization against total crop failure, soil conservation and improvement of soil fertility status, weed suppression and balanced human and livestock diet. In addition, Matusso et al. (2014) reviewed that several scientists have been working with cereal-legume intercropping systems in sub-Saharan Africa and proved its combined success compared to the sole cropping systems. Tsubo and Walker (2003) reported that intercropping technique is common for smallholder farmers worldwide but Ranbir et al. (2001) stretched that intercropping maize with legume crops including soybean, cowpea, French beans and common beans was superior to sole maize crops. Gathumbi et al. (2003) suggested that mixing of leguminous plants with cereal crops helps to enhance subsoil nitrogen retrieval for the growing crops.

CONCLUSION

The practice of intercropping maize with cowpea saves substantial land which would be used for other productivity activities. Despite the fact that intercropping the two crops saved about 50% of the land, there were yield differences between the two crops. This argument needs to be investigated under a different study which considers plant population among many other factors. Moreover, similar or studies which follow the same approach should be conducted using different maize and cowpea varieties to ascertain the validity of the findings of

this study before are recommended for adoption by farmers.

REFERENCES

- Addo-Quaye AA, Darkwa AA, Ocloo GK (2011). Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement. *J. Agric. Biol. Sci.* 6(9): 50-57.
- Adigbo SO, Iyasere E, Fabunmi TO, Olowe VIO, Adejuyigbe CO (2013). Effect of spatial arrangement on the performance of cowpea/maize intercrop in derived Savannah of Nigeria. *Am. J. Exp. Agric.* 3(4): pp. 12.
- Adu-Gyamfi JJ, Myaka FA, Sakala WD, Odgaard R, Vesterager JM, Høgh-Jensen H (2007). Biological nitrogen fixation and nitrogen and phosphorus budgets in farmer-managed intercrops of maize-pigeon pea in Semi-arid Southern and Eastern Africa. *Plant and Soil*, 295(1-2): 127-136.
- Alhaji IH (2008). Yield performance of some cowpea varieties under sole and intercropping with maize at Bauchi, Nigeria. *Afr. Res. Rev.* 2(3): 278-291.
- Allen JR, Obura RK (1983). Yield of corn and soybean in intercropping soybeans. *Agron. J.* 75: 1005-1009.
- Amasaib EO, Balgees A, Elmnan A, Mahala AG, Elseed AMAF (2011). Nutritive value of maize (*Zea mays*) and doleous (*Lablab purpureus*) as affected by phosphorous fertilization and intercropping. *Online J. Animal and Feed Res.* 2(6): 488 – 492.
- Banik P, Sharma RC (2009). Yield and resource utilization efficiency in baby corn-legume intercropping system in the eastern plateau of India. *J. Sust. Agric.* 33: 379 - 385.
- Carlson JD (2008). Intercropping with Maize in Sub-arid Regions. Community Planning & Analysis. Technical Brief. April 16, 2008. p. 2 – 5. Retrieved on 02/12/2013. Available online: <http://forest.mtu.edu/pcf/forestry/resources/studentprojects/Maize%20Intercropping%20in%20East%20Africa.pdf>
- Dahmardeh M, Ghanbari A, Syasar B, Ramroudi M (2009). Effect of intercropping maize (*Zea mays* L.) with cow pea (*Vigna unguiculata* L.) on green forage yield and quality evaluation. *Asian J. Plant Sci.* 8: 235-239. DOI: [10.3923/ajps.2009.235.239](https://doi.org/10.3923/ajps.2009.235.239)
- Dugje IY, Omoigui LO, Ekelem F, Bandyopadhyay R, Kumar PL, Kamara AY (2009). Farmers guide to soybean production in Northern Nigeria, pp. 16.
- Egbe OM (2010). Effects of plant density of intercropped soybean with tall sorghum on competitive ability of soybean and economic yield at Otobi, Benue State, Nigeria. *J. Cereals Oilseeds*, 1(1):1–10.
- Ennin SA, Clegg MO, Francis CA (2002). Resource utilization in soybean/maize intercrops. *Afr. Crop Sci. J.* 10(73): 251–261.
- Ezumah HC, Ikeorgu JEG (1993). Population and planting pattern effects on intercropped maize and cowpea. *J. Agron. Crop Sci.* 170(3): 187–194.
- Gathumbi, S.M., Cadisch, G., Buresh, J.R. and Giller, K.E. (2003). Subsoil nitrogen capture in mixed legume stands as assessed by deep ¹⁵N placement. *Soil Sci. Soc. Am. J.* 67:573–582.
- Giller KE, Ormisher J, Awah FM (1991). Nitrogen transfer from *Phaseolus* bean to intercropped maize measured using ¹⁵N-enrichment and ¹⁵N-isotope dilution methods. *Soil Biol. Biochem.* 23:339-346.
- Gomes JKO, Silva PSL, Silva KMB, Filho RFF, Santos VG (2007). Effects of weed control through cowpea intercropping on maize morphology and yield. *Planta Daninha*, 25(3): 433-441.
- Hussain N, Shamsi IH, Khan S, Akbar H, Wajid AS (2003). Effect of legume intercrops and nitrogen levels on the yield performance of maize. *Asian J. Plant Sci.* 2(2):242-246.
- Iderawumi AM, Friday CE (2013). Effects of geometric row arrangement on growth and yield of cowpea in a maize-cowpea intercrop. *Indian J. Innov. Dev.* 2:816-820.
- Iderawumi AM, Olusola OS, Friday CE (2012). Effect of different planting pattern on total dry matter production and maize forage quality in maize (*Zea mays*) and cowpea (*Vigna sinensis*) intercropped as whole-crop forage. *J. Agric. Vet. Sci. (IOSR-JAVS)*, 1(4): 42-46.
- Ijoyah MO, Adagba EO, Iorlamen T (2012). Productivity of okra-maize intercropping system as influenced by varying maize plant densities in Makurdi, Nigeria. *Int. J. Current Res.* 4(4): 059-063.
- Ijoyah MO, Anyam HH (2013). Evaluation of okra-soybean based cropping system as influenced by sowing densities of okra in a southern Guinea Savannah location, Nigeria. *Int. J. Current Sci.* 6(E): 147-152.
- Ijoyah MO, Bwala RI, Iheadindue CA (2012). Response of cassava, maize and egusi melon in a three crop intercropping system at Makurdi, Nigeria. *Int. J. Dev. Sust.* 1(2): 135-144.
- Ijoyah MO, Dzer DM (2012). Yield performance of okra (*Abelmoschus esculentus* L. Moench) and Maize (*Zea mays* L.) as affected by time of planting maize in Makurdi, Nigeria. *Int. Scholarly Res. Network (ISRN Agron.)*, Vol. 2012, Article ID 485810, 7 pages, doi: 10.5402/2012/485810.
- Ijoyah MO, Jimba J (2012). Evaluation of yield and yield components of maize (*Zea mays* L.) and okra (*Abelmoschus esculentus* L. Moench) intercropping system at Makurdi, Nigeria. *J. Biod. Environ. Sci.* 2(2): 38-44.
- Ijoyah MO, Ogar AO, Ojo GOS (2013). Soybean-maize intercropping on yield and system productivity in Makurdi, Central Nigeria. *Scientific J. Crop Sci.* 2(4): 49-55.
- Ijoyah MO, Usman UA (2013). Okra: a potential intercrop for farmers in Nigeria. *J. Global Biosci.* 2(6): 222-235.
- Khan AM, Naveed K, Ali K, Ahmad B, Jan S (2012). Impact of mungbean-maize intercropping on growth and yield of mungbean. *Pak. J. Weed Sci. Res.* 18(2): 191-200.
- Kisetu E, Mtakimwa ZS (2013). Incorporating pigeon pea compost with Minjingu fertilizer brands to determine their effects on maize production in Morogoro, Tanzania. *World J. Agric. Sci.* 1(9): 294 – 298.
- Kisetu E, Nyasasi BT, Nyika M (2014). Effect of cropping systems on infestation and severity of field insect pests of cowpea in Morogoro, Tanzania. *Modern Res. J. Agric.* 1(1):1-9.
- Kisetu E, Silayo SA, Tsere GS (2013). Use of predictive screening parameters in selected common bean genotypes to assess their salt tolerance ability using NaCl concentration. *Adv. J. Agric. Res.* 1(4): 51 – 60.
- Kitonyo OM, Chemining'wa GN, Muthomi JW (2013). Productivity of farmer-preferred maize varieties intercropped with beans in semi-arid Kenya. *Int. J. Agron. Agric. Res.* 3(1):6-16.
- Ledgard SJM, Giller KE (1995). Atmospheric N₂-fixation as alternative nitrogen source. In: Nitrogen Fertilization and the Environment. Bacon P (editor). Marcel Dekker, New York, pp. 443–486.
- Lemlem A (2013). The effect of intercropping maize with cowpea and lablab on crop yield. Relief society of Tigray (REST). *Herald J. Agric. Food Sci. Res.* 2(5): 156–170.
- Li L, Zhang FS, Li XL, Christie P, Sun JH, Yang SC, Tang C (2003). Interspecific facilitation of nutrient uptake by intercropped maize and faba bean. *Nutr. Cycling Agro-ecosys.* 65: 61-71.
- Marer SB, Lingaraju BS, Shashidhara GB (2007). Productivity and economics of maize and pigeon pea intercropping under rainfed condition in northern transitional zone of Karnataka. *Karnataka J. Agric. Sci.* 20: 1-3.
- Mariotti M, Masoni A, Ercoli L, Arduini I (2006). Forage potential of winter cereal/legume intercrops in organic farming. *Italian J. Agron.* 3:403-412.
- Matusso JMM, Mugwe JN, Mucheru-Muna M (2014). Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub-Saharan Africa. *Res. J. Agric. Environ. Manage.* 3(3): 162-174.
- Mkamilo GS (2004). Maize-sesame intercropping in Southeast Tanzania: Farmers' Practices and Perceptions, and Intercrop Performance. PhD Thesis, Wageningen University, Netherlands.
- Morgado LB, Willey RW (2003). Effects of plant population and nitrogen fertilizer on yield and efficiency of maize-bean intercropping. *Brazilian Agric. Res.* 38(11):1257-1264.
- Mpairwe DR, Sabiiti EN, Ummuna NN, Tegegne A, Osuji P (2002). Effect of intercropping cereal crops with forage legumes and source of nutrients on cereal grain yield and fodder dry matter yields. *Afr. Crop Sci. J.* 10: 81-97.
- Mukungu M (2002). Effects of cowpea planting date and row arrangement on crop growth and yield in maize (*Zea mays*) and

- cowpea (*Vigna unguiculata* L. (Walp)) intercrop. M.Sc. Thesis. The University of Zambia. pp. 71. Retrieved on 19/07/2014. Available online: http://dspace.unza.zm:8080/jspui/bitstream/123456789/193/1/mukungu_0001.PDF
- Muoneke CO, Ogwuche MAO, Kalu BA (2007). Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savannah agro-ecosystem. *Afr. J. Agric. Res.* 2(12):667-677.
- Nguimgo KAB, Balasubramanian V, Kaho F, Zonskeng P (2003). Maize-legume rotation and association for intensive maize production in the humid forest zone of Cameroun. In: *Maize Revolution in West and Central Africa* (Badu-Akraku B, Fakorede M, Ouedraogo M, Carsky RJ, Menkir A) (editors). Proc. Regional Maize Workshop. International Institute for Tropical Agriculture, Cotonou, Benin Republic. 14-18 May, 2001.
- Odhiambo GD, Ariga ES (2001). Effect of intercropping maize and beans on striga incidence and grain yield. Proc. Eastern/Southern Afr. Regional Maize Conf. 7: 183-186.
- Osman AN, Ræbild A, Christiansen JL, Bayala J (2011). Performance of Cowpea (*Vigna unguiculata*) and pearl millet (*Pennisetum glaucum*) intercropped under *Parkia biglobosa* in an agroforestry system in Burkina Faso. *Afr. J. Agric. Res.* 6(4): 882-891.
- Prasad RB, Brook RM (2005). Effect of varying maize densities on intercropped maize and soybean in Nepal. *Exp. Agric.* 41:365-382.
- Raji JA (2007). Intercropping soybean and maize in a derived savanna ecology. *Afr. J. Biotechn.* 6(16): 1885-1887.
- Ranbir SR, Singh B, Negi SC (2001). Management of maize/legume intercropping under mid-hill sub-humid conditions. *India J. Agric. Res.* 35(2):100-103.
- Samba T, Coulibay BS, Koné A, Bagayoko M, Kouyaté Z (2007). Increasing the productivity and sustainability of millet based cropping systems in the Sahelian zones of West Africa. In: *Advances in Integrated Soil Fertility Management in Sub-Saharan Africa*. Bationo A (editor): Challenges and Opportunities, 567-574.
- Sesay A (2000). Effects of planting time and fertilizer application on the productivity of intercropped cowpea and maize in a Sub-humid Zone. *UNISWA Res. J. Agric. Sci. Technol.* 3(2): 54-62.
- Shahbazi M, Sarajuoghi M (2012). Evaluating maize yield in intercropping with mungbean. *Annals of Biol. Res.* 3(3):1434-1436.
- Silwana TT, Lucas EO (2002). The effect of planting combinations and weeding and yield of component crops of maize-bean and maize-pumpkin intercrops. *J. Agric. Sci.* 138:193-200.
- Silwana TT, Lucas EO, Olaniyan AB (2007). The effects of inorganic and organic fertilizers on the growth and development of component crops in maize/bean intercrop in Eastern Cape of South Africa. *J. Food, Agric. Environ.* (5)1: 267-272.
- Song YN, Zhang FS, Marschner P, Fan FL, Gao HM, Bao XG, Sun JH, Li L (2007). Effect of intercropping on crop yield and chemical and microbiological properties in rhizosphere of wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and faba bean (*Vicia faba* L.). *Biol. Fert. Soils*, 43(5): 565-574.
- Tsubo M, Walker S (2003). Shade effects on *Phaseolus vulgaris* L. intercropped with *Zea mays* L. under well-watered conditions. *J. Agron. Crop Sci.* 190:168-176.
- Tsubo M, Walker S, Ogindo HO (2005). A simulation model of cereal-legume intercropping systems for semi-arid regions. II. Model application. *Field Crops Res.* 93(1): 23-33.
- Ullah A, Bhatti NA, Gurmani ZA, Imran H (2007). Studies on planting patterns of maize (*Zea mays* L.) facilitating legumes intercropping. *J. Agric. Res.* 45:113-118.
- Undie UL, Uwah DF, Attoe EE (2012). Effect of intercropping and crop arrangement on yield and productivity of late season maize/soybean mixtures in the humid environment of South Southern Nigeria. *J. Agric. Sci.* 4(4): 37 - 50.
- Workayehu T (2014). Legume-based cropping for sustainable production, economic benefit and reducing climate change impacts in southern Ethiopia. *J. Agric. Crop Res.* 2(1): 11-21.