sciendo DOI: 10.2478/ats-2020-0022 AGRICULTURA TROPICA ET SUBTROPICA, 53/4, 215–228, 2020

Original Research Article

Agronomic and productivity efficiency of two animal manure sources on intercropped maize-groundnut in the derived savannah

Emmanuel Ukaobasi **Mbah**[1,2], Calistus **Keke**[2], Eme Godswill Ogbonnaya **Ogidi**[1,3]

[1]*College of Crop and Soil Sciences, Department of Agronomy, Michael Okpara University of Agriculture, Umudike, P.M.B. 40444, Umuahia, Abia State, Nigeria*
[2]*Department of Crop Production Technology, Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria*
[3]*Crop Improvement Department, Rubber Research Institute of Nigeria, Benin-City, Edo State, Nigeria*

Correspondence to:
E. U. Mbah, College of Crop and Soil Sciences, Department of Agronomy, Michael Okpara University of Agriculture, Umudike, P.M.B. 40444, Umuahia, Abia State, Nigeria, E-mail: emmaukmbah@gmail.com; Phone No.: +234 803 4608 421

Abstract

Two animal manure sources (swine and sheep/goat manures) each at 5 Mt·ha^{-1}, were applied in mono- and intercropped maize (*Zea mays* L.) and groundnut (*Arachis hypogea* L.). A general control (no manure treatment of the component crops was established) for productivity assessment. The trial, conducted at the Federal College of Agriculture, Ishiagu (04° 30′ N, 06° 45′ E, 150 m above sea level), in the derived savannah plains, Ishiagu, Nigeria in 2012 and 2013 mid-cropping seasons used a randomised complete block design with three replications. It assessed the agronomic performance, cropping system (CS) and plant nutrient (PN) productivity of maize-groundnut in mono-and intercrop as influenced by two animal manure sources. The two-year combined analysis indicated that animal manure sources significantly ($P < 0.05$) increased growth and yield components of the crop species in the systems. Swine manure application gave the significantly ($P < 0.05$) highest maize grain yield in both mono- and intercropped strategies in contrast to sheep/goat manure that had the highest grain yield in both cropping strategies in groundnut. The biological and economic productivity indices of the cropping system (CS) and plant nutrient (PN) indicated that the application of sheep/goat manure in the maize/groundnut mixture exhibited greater intercrop advantage whose total CS and PN land equivalent ratios (LERs) were higher by 4.79% and 13.57%, respectively, relative to swine manure application. Therefore, the application of animal manure demands encouragement in maize-groundnut intercrop, especially sheep/goat manure as it enhances crop yield, food security and protein intake of people living in Sub-Saharan Africa practicing different strokes of farming system technology. The results of this study showed that intercropping system exhibited positive growth, yield, biological and economic advantages over monocropping of the component species. The study further indicated that intercropped maize/groundnut that received sheep/goat manure exhibited the highest cropping system and plant nutrient yield advantage and agronomic efficiency compared to swine manure alone under the same environment.

Keywords: Cropping-system; inter-relationship; land equivalent ratio; plant-nutrient.

INTRODUCTION

Intercropping is the growing of two or more crops simultaneously on the same piece of land (field), which involves crop intensification in both time and space dimensions (Mead and Willey, 1980; Keating and Carberry, 1993; Silwana and Lucas, 2002; Alom et al., 2009). The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources that would otherwise not be utilised by a single crop and it requires taking into consideration factors such as soil, climate, selection of compatible crops and varieties (Seran and Brintha, 2010). Hence, when crops are carefully selected, agronomic and economic benefits are achieved.

Maize (*Zea mays* L.) and groundnut (*Arachis hypogea* L.) are important field food crops in Nigeria. Grains from maize are used as food for human and animal consumption as well as an industrial raw material for the production of starch, oil, gluten, flour, alcohol and lignocelluloses for other purposes. Groundnut, which is a highly valued grain-legume, is grown for its underground pods that are rich in protein and oil for human consumption. According to Singh and Ajeigbe (2007), prostrate or semi-prostrate groundnut cultivars play an important role as a good ground cover crop and live mulch to check soil erosion and weed infestation as well as lower soil temperatures and conserve moisture (Makinde et al., 2009; Karuma et al., 2011). Also, it is a veritable nitrogen fixer that boosts the fertility of the soil at harvest.

Studies on simple intercropping systems (two component crops) by Ennin et al. (2002), Muoneke et al. (2007) on maize-soybean, Vesterager et al. (2008) on maize-cowpea, Mbah and Ogidi (2012) on cassava-soybean intercrops as well as complex intercropping (three or more component crops) studies by Dapaah et al. (2003) on cassava-maize-soybean-cowpea showed that cereals and legumes are fast canopy-forming and quickly growing crops that have different growth statures, hence their demand for environmental resources occurs at different growth stages, which implies that the crop species produced higher total grain yield than growing either crop in a mono-culture. Furthermore, Vesterager et al. (2008) and Dahmardeh et al. (2010) reported that maize and cowpea intercropping is beneficial on nitrogen poor soils because the amounts of soil nutrients, especially nitrogen contents are increased compared to mono-cropping of maize.

The biological basis for intercropping involves complementarity of resources used by the two crops (Chinaka and Obiefuna, 2000). The partitioning of limiting resources among crop species occurs whenever they are grown in associations leading to intercrop advantage relative to monocropping in both grain or forage production (Eskandari and Ghanbari, 2009). Data from Jiao et al. (2008) indicated that the maize-groundnut intercropping enhanced the efficient utilisation of strong light by maize and weak light by groundnut resulting in yield advantage. According to Keating and Carberry (1993) advantages achieved in soybean-cum-maize intercropping system can be attributed to a better use of solar radiation, quick absorption of soil nutrients (Willey, 1990) and mineral water (Morris and Garrity, 1993; Ogindo and Walker, 2005) during the growth period of the component crops relative to mono-cropping.

The productivity in intercropping is a major factor, which determines crop performance and yield relative to mono-cropping. A number of indices such as land equivalent ratio (LER), land equivalent coefficient (LEC), gross monetary return (GMR), monetary advantage index (MAI) among many others have been used to assess crop species in mixes. The objectives of this study were to examine the agronomic efficiency of two animal manure sources (swine and sheep/goat manures) on growth and yield of component crops (maize and groundnut) and to determine the cropping system and plant nutrient productivity of the systems and their improvement model in the mix.

MATERIALS AND METHODS

Description of experimental site

A rain-fed field experiment was carried out in 2012 and 2013 farming seasons at the Department of Crop Production Technology, Federal College of Agriculture, Ishiagu (07° 31' E, 05° 56' N, 150 m asl.), in the derived savannah plains, Ishiagu, Ebonyi State, Nigeria. The experimental site is characterised by a bi-modal pattern of rainfall that allows cropping activities from April till October of each year while November to March are characterised by little or no rainfall. Air temperature and sunshine hours did not appear significantly limiting during the period of the study while the vegetation is that of derived savannah.

The experimental site was ploughed, harrowed and levelled. There were eight experimental plots, each measuring 3 × 3 m (9 m^2) with 0.5 m and 1.0 m spacing between the plots and blocks, respectively. Soil samples were collected randomly from the plots to a depth of –20 cm and bulked into a composite sample. A sub-sample was taken from the bulk for laboratory analysis of the physico-chemical properties of the soil (Table 1). The soil type is Ultisol (Paleusltult) and its texture is sandy loam according to the Federal Department of Agricultural Land Resources (FDALR), Kaduna (1985).

Experimental materials

The organic manures used in the study were sourced from the Farm Unit, Animal Production Department, Federal College of Agriculture, Ishiagu, Nigeria. The swine manure (applied at the rate of 5 $Mt \cdot ha^{-1}$) was obtained from the swine pens whereas the combined sheep-goat manure which was in the ratio of 50:50 (applied at the rate of 5 $Mt \cdot ha^{-1}$) was secured from the small ruminant pens. Prior to application, samples of the organic manure sources were taken from the bulk for laboratory analysis to ascertain their nutritive status (Table 1). The organic manure sources were applied to the prepared experimental site and incorporated into the soil five days before planting. Proper mixing of the manure with soil was important to ensure even distribution and mineralization of the organic materials before the maize and groundnut seeds were sown. A control plot of the component crops with no manure application was also established.

Planting and maintenance of the experimental plots

Maize [*OBA SUPER 2* (Hybrid)] and early maturing erect groundnut (*SAMNUT 21*) were sown as follows viz: monocrop maize + no manure, monocrop groundnut + no manure, monocrop maize + swine manure, monocrop groundnut + swine manure, monocrop maize + goat + sheep manure, monocrop groundnut + goat + sheep manure, intercrop

Table 1. Averaged across two cropping seasons (2012 and 2013) of some chemical properties of the soil (0–20 cm) of the experimental site and chemical composition of the animal manure sources

Analysed material	Chemical properties								
	Org. Matter (%)	Org. Carbon (%)	Total N (%)	Available P (cmol·kg⁻¹)	Exchangeable bases (cmol·kg⁻¹)				
					Ca	K	Mg	Na	EA
Soil	1.36	0.79	0.08	18.60	3.80	0.146	1.40	0.109	1.72
Swine manure	19.4[a]	9.7	1.50 %	0.838 %	2.56 %	0.63 %	0.97 %	0.29 %	-
Sheep/goat manure	21.5	11.0	2.17 %	0.728 %	3.21 %	0.44 %	1.28 %	0.20 %	-

Source: Soil Science Laboratory, National Root Crops Research Institute, Umudike, Abia State. a, Analysis were not carried out on these parameters.

Table 2. Yield components of maize in mono- and intercrop as influenced by the application of two animal manure sources

Cropping strategy	Height of cob on plant (cm)	Cob length (cm)	No. seeds·m^{-2}	Seed veight·m^{2} (Mt ha^{-1})	100-seed weight (g)
Mono-crop maize + no manure	106.5	14.5	1996	5.32	29
Mono-crop maize + swine manure	98.6	17.63	2697	8.26	32
Mono-crop maize + sheep/goat manure	109.5	11.84	1931	5.68	30
Maize/groundnut + swine manure	97.9	16.11	2313	7.76	34
Maize/groundnut + sheep/goat manure	94.5	14.42	2259	6.02	31
F Pr.	0.305^{ns}	0.015*	0.061*	0.018*	0.307^{ns}
SED	7.41	1.238	229.1	0.782	2.418
LSD$_{(0.05)}$	ns	2.854	528.3	1.803	ns

SED = Standard error of difference between two means. ns and *, non-significant and significant at $P < 0.5$, respectively.

Table 3. Yield components of groundnut in mono- and intercrop as influenced by the application of two animal manure sources

Cropping strategy	No. pegs·m^{-2}	No. pods·m^{-2}	No. seeds·m^{-2}	Seed veight·m^{2} (Mt ha^{-1})	Pod weight·m^{2} (g)
Mono-crop groundnut + no manure	430.68	314	570	1.92	286
Mono-crop groundnut + swine manure	446.68	284	485	1.64	240
Mono-crop groundnut + sheep/goat manure	614.64	463	821	2.72	360
Maize/groundnut + swine manure	450.68	328	571	1.79	236
Maize/groundnut + sheep/goat manure	520.16	387	668	2.08	300
F Pr.	0.024*	0.021*	0.006**	0.037*	0.089ns
SED	47.6	42.9	63.1	0.2868	42.8
LSD$_{(0.05)}$	109.7	98.9	145.4	0.6613	98.8

SED = Standard error of difference between two means. *, **, Significant at $P < 0.5$ and 0.1, respectively.

maize + groundnut + swine manure, intercrop maize + groundnut + goat + sheep manure. The treatments were randomly allocated into the experimental plots by piece of paper method and the experiment was laid out in a randomised complete block design (RCBD) with three replications.

Each plot had 4 ridges and each ridge was 3 m long and 0.75 m wide (2.25 m^2). The seeds of maize and groundnut were sown the same day at the distance of 50 × 75 cm and 25 × 75 cm intra- and inter-row hill spacing, respectively, which gave a plant population of 53,333 plants·ha^{-1} at two-plants per stand for maize and 53,333 plants·ha^{-1} for groundnut at one-plant per stand. The maize seeds were sown only on the furrow side of the ridges while groundnut was sown on the flattened crest of the ridges. The monocrops were sown at the same time with the intercrop at the recommended plant population (53,333 plants·ha^{-1} for both maize and groundnut). Higher populations of maize and groundnut were sown and the seedlings thinned at 14-days after sowing to correspond with the required component crop plant population in the treatment plots, which gave 48 plant stands $plot^{-1}$ for maize and groundnut each. The first weeding operation was carried out at 3 weeks after planting (WAP) manually with hoe while the second weeding was done at 6 WAP.

Data collection

Growth indicators were recorded at 3, 5, 7 and 9 WAP on the components crops from three randomly sampled maize and groundnut plants each. The samples were collected from the inner rows and tagged. Plant height (cm) was measured with a metre rule as the length from the base of the crop (ground level) to the tip of the plant whereas the number of green leaves and stems per plant were obtained by counting. The stem girth (cm) of maize was measured with the aid of a calibrated Vernier caliper at 30 cm above the ground level. At maize harvest, the height of cob on plant (cm), cob length (cm), number of seeds·m^2, weight of seeds·m^2 (g), 100-seed weight (g) and grain yield at 13% moisture content (Mt·ha^{-1}) extrapolated from the net plot yield were recorded. From the groundnut component, at 9 WAP, the number of flowers and pegs per square metre were counted, and the above ground dry weight (g) obtained from two destructively sampled groundnut plants, oven-dried until a constant weight was achieved. At groundnut harvest, the number of pods·m^2, the number of seeds·m^2, the weight of pods·m^2 (g), the weight of seeds·m^2 (g) and the grain yield (Mt·ha^{-1}) extrapolated from the net plot yield were recorded.

Productivity assessment of the systems

The productivity derived from the yield data of monocrop maize and groundnut and their intercropping was determined on cropping system (CS) and plant nutrition (PN) using the following indices: Land equivalent ratio (LER), which is the ratio of area needed under monocropping to that of intercropping at the same management status to produce an equivalent yield. LER was calculated for cropping system (CS) and plant nutrition (PN) following a modified procedure of Mead and Willey (1980):

[i] LER = LMz + LGt = {(YiMz / YmMz) + (YiGt / YmGt)}, where, LMz and LGt = Partial LERs of crops 'Mz' (maize) and 'Gt' (groundnut); YiMz and YiGt are yields of intercropped maize and groundnut, respectively, whereas, YmMz and YmGt are yields of monocrop maize and groundnut, respectively. The values of LER greater than unity indicate a yield advantage (Willey, 1979; Ofori and Stern, 1987).

Land equivalent coefficient (LEC) assessed the measure of interaction as it relates to the strength of relationship between the component crops. LEC was computed on CS and PN with the formula:

[ii] LEC = LMz * LGt, where, LMz and LGt are the partial LERs of maize and groundnut, respectively. For a two-crop mixture, the minimum expected productivity coefficient (PC) is 25%, which shows that a yield advantage according to Adetiloye (1989) is achieved if LEC value exceeds 0.25.

The agronomic efficiency (AE) of CS and PN was calculated according to the procedure outlined by Ladha et al. (2005) and Vanlauwe et al. (2011) to determine the variation in cropping system and organic manure source efficiency. AE on CS and PN was computed with the formula:

[iii] $AE_{(CS)}$ (kg·ha^{-1}) = (Yield of intercropped maize or groundnut – Yield of mono-cropped maize or groundnut) / Amount of animal manure (OM) applied. $AE_{(PN)}$ (kg·ha^{-1}) = (Yield of intercropped maize or groundnut with animal manure – Yield of mono-cropped maize or groundnut without animal manure) / Amount of corresponding animal manure applied. The economic advantage of the systems was computed using gross monetary return (GMR) (₦·ha^{-1}) for maize and groundnut based on the prevailing farm-gate price per unit weight of the individual produce which the farmer gained in Ishiagu, Nigeria. Partial and total GMR was computed on CS and PN for the component crops.

The percentage land saved was computed on CS and PN, which indicated the amount of land saved from intercropping, that could be used for other agricultural purposes (Willey, 1985):

[iv] Land saved (%) = 100 – (1/LER) * 100.

Monetary advantage index (MAI) for CS and PN was used to assess the yield of maize and groundnut in intercropping and mono-cropping systems and their economic return in terms of monetary value to ascertain whether maize yield and additional groundnut yield were profitable or not. MAI was calculated with the formula:

[v] MAI = (PMz * PGt) * (LER – 1) / LER, where, PMz = Pmz * Ymz; PGt = Pgt * Ygt; Pmz = Prevailing farm-gate market price of maize; Pgt = Prevailing farm-gate market price of groundnut. Ymz = Yield of maize; Ygt = Yield of groundnut. The higher the index value the more advantageous or profitable is the cropping system (Mahapatra, 2011).

Intercrop susceptibility index (ISI) for CS and PN of the component crops were calculated with the formula:

[vi] ISI = [1 – (YI / YM)] / 1 (Mean of Yi / Ym),

where, YI = yield of component crop (maize or groundnut) in intercrop, YM = yield of component crop in monocrop, Yi = mean yield of component crop in intercropping, Ym = mean yield of component crop in mono-cropping.

Statistical analysis

The vegetative and reproductive data collected in 2012 and 2013 cropping seasons were pooled and the mean used for subsequent analysis. The data from the component crops were subjected to one-way analysis of variance using GLM SAS Version 9.2 (SAS Institute, 2007). Multiple comparison tests were performed according to Fisher's protected least significant difference at the significance level of $P < 0.05$ (Obi, 2002). The variables of the component crops were subjected to Pearson's correlation analysis to determine the inter-relationships between them using SPSS statistical package for Windows version 17.0 (2010). The following linear model was used for statistical analysis:

$$X_{ijk} = \mu + A_i + \beta_j + \epsilon_{ijk},$$

where,

X_{ijk} = Individual observation, μ = Mean of animal manure source, A_i = Effect of animal manure source, β_j = Effect of block, ϵ_{ijk} = Experimental error.

RESULTS AND DISCUSSION

Results from the analysis of variance (Fig. 1a, b, c) indicated that animal manure sources significantly ($P < 0.05$) increased plant height of maize only at 3 weeks after planting (WAP) contrary to the other sampled dates, number of leaves plant^{-1} at 5, 7 and 9 WAP and stem girth at all sampled dates. Among the treatments, monocropped maize that received swine manure had taller plants at 3 WAP and highest number of leaves plant^{-1} at all the significantly sampled dates. However, the biggest stem girth was recorded when monocropped maize received sheep/goat manure at all the sampled dates except at 3 WAP. The results corroborated similar studies by Ghosh (2004) on groundnut/cereal fodder, Awal et al. (2006) on maize/peanut and Bhagad et al. (2006) on groundnut/sweet-corn intercrops as well as Adeleke et al. (2013) on maize/cowpea (*Vigna unguiculata*) under different environments in which they submitted that growth variations recorded in maize in intercropping system may be attributed to a more

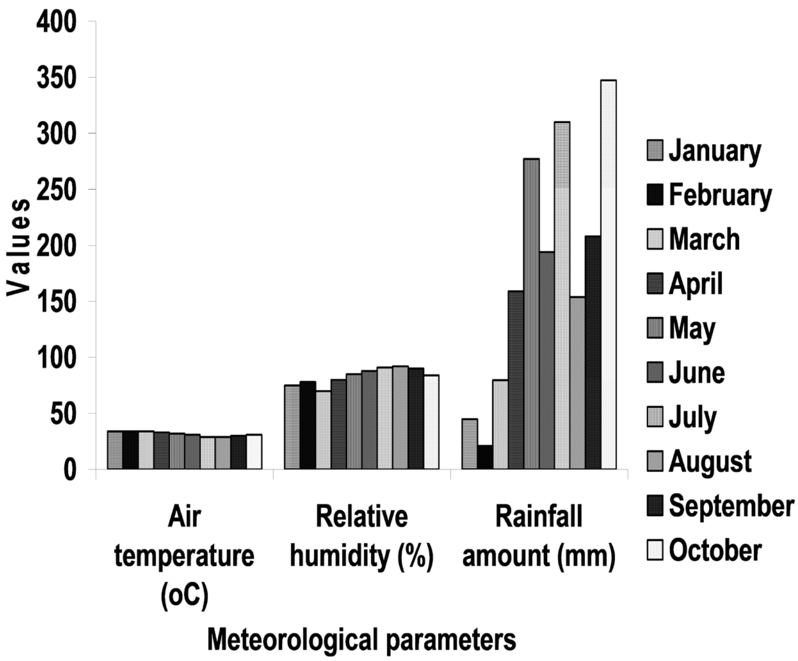

Figure 1. Monthly mean air temperature (°C), relative humidity (%) and rainfall amount (mm) across two cropping seasons (2012 and 2013) at the field trial site, Ishiagu (07° 31' E, 05° 56' N, 150 m a.s.l.), Nigeria. Source: Meteorological Unit, Federal College of Agriculture, Ishiagu, Ebonyi State, Nigeria.

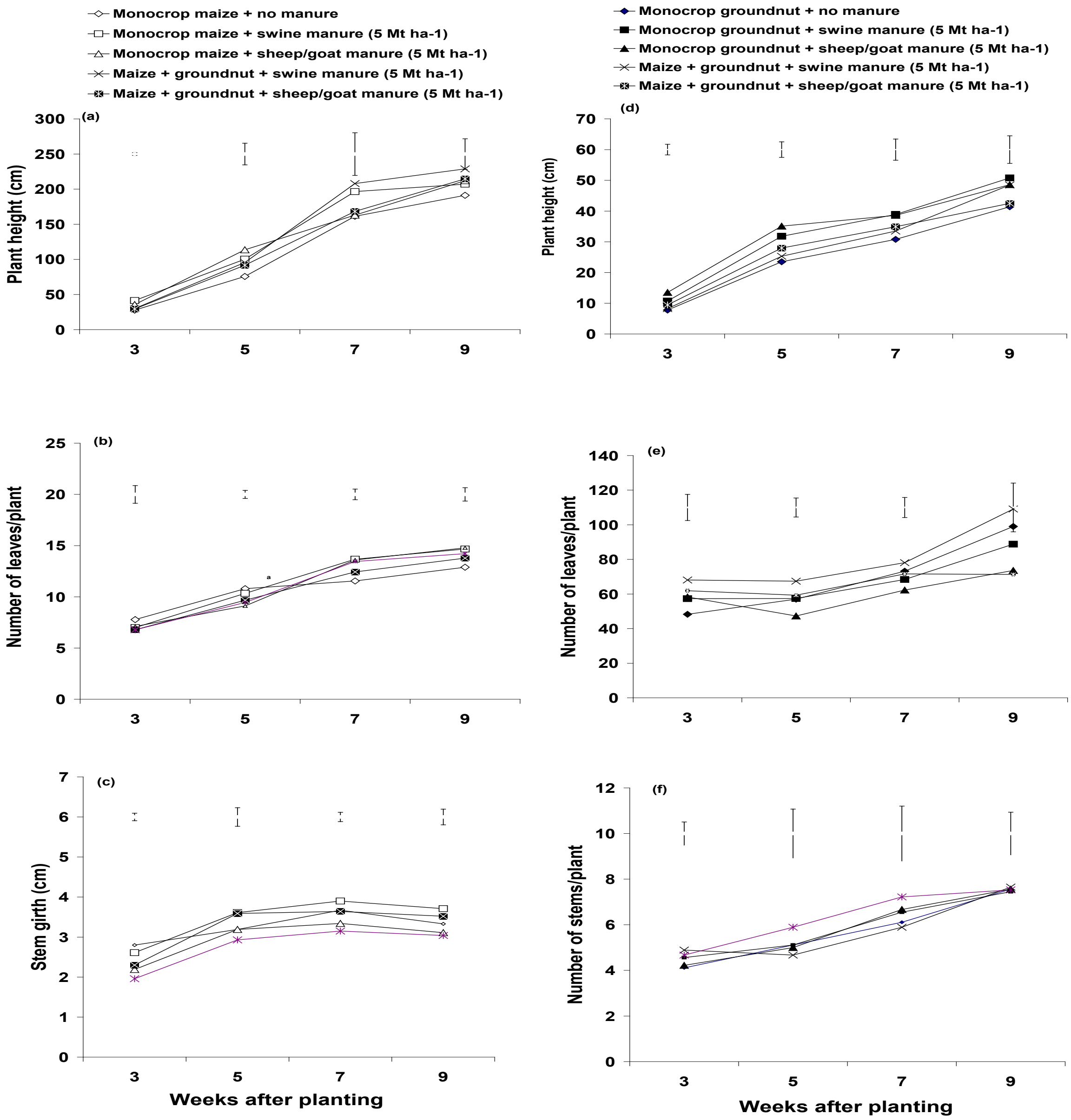

Figure 2. Effect of animal manure sources on averaged across two cropping seasons means (a) plant height (cm), (b) number of leaves plant^{-1}, (c) stem girth (cm) of maize and (d) plant height (cm), (e) number of leaves plant^{-1}, (f) number of stems plant^{-1} of groundnut in maize-groundnut intercrop. Error bars indicate standard error of difference between two means.

efficient use of growth resources (light, moisture, space, soil nutrients among others).

Animal manure sources significantly affected the cob length, the number of seeds·m^{-2}, the weight of seeds·m^{-2} and grain yield of maize. Monocropped maize that was treated with swine manure exhibited the longest cob length, the highest number of seeds·m^{-2}, the weightiest seed·m^{-2} and grain yield compared with the other treatments. However, there was no significant ($P > 0.05$) difference between the animal manure sources amongst the intercropped maize treatments. The study has shown that intercropping maize and groundnut using animal manure sources positively affected yield and yield components of maize, which corroborated previous works by Tsubo et al. (2004), Dwomon and Quainoo (2012), Dolijanović et al. (2013) and Nasiri et al. (2014) who reported that intercropping exhibited worthwhile yield advantage over sole cropping, which may be due to efficiency of environmental exposure of the crops and available soil nutrients as well as the concentration of minerals in the soil. More so, the animal manure sources enhanced

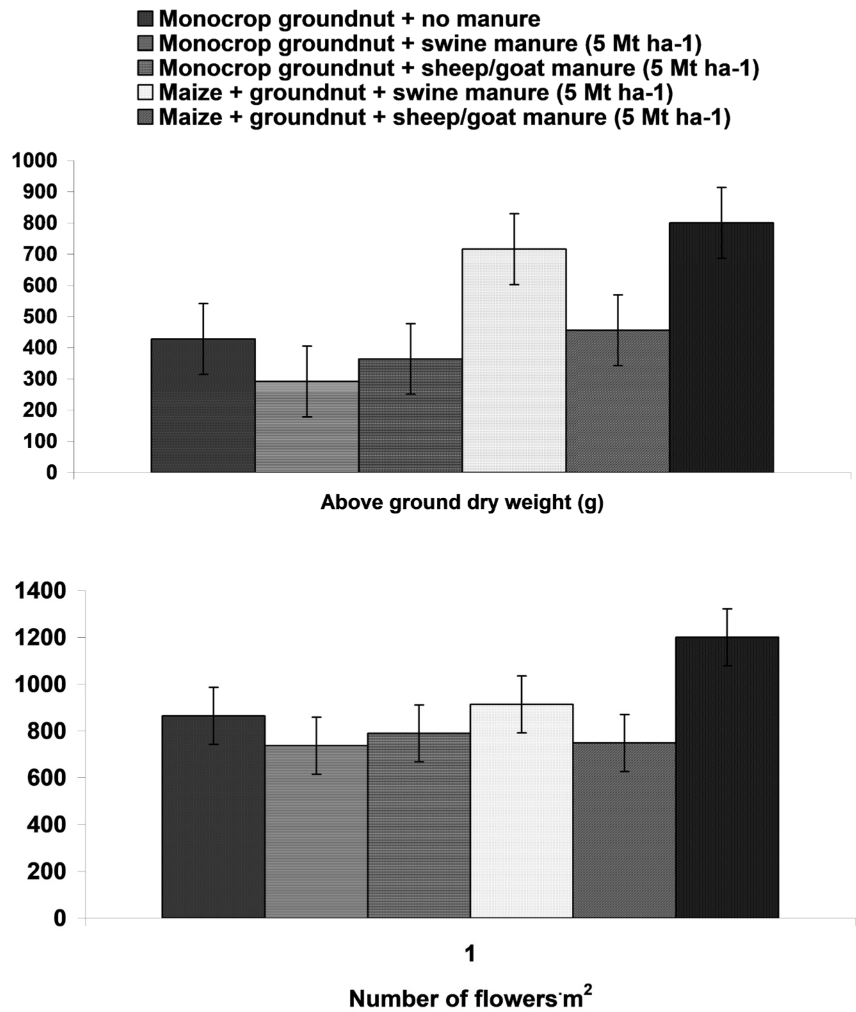

Figure 3. Effect of animal manure sources on (a) above ground dry weight and (b) number of flowers·m^{-2} of groundnut in maize-groundnut intercrop. Error bars indicate standard error of difference between two means.

the structure and nutrient recovery potentials of the soil, which benefited the crops.

The analysis of variance of groundnut growth attributes showed that except plant height (9 WAP), number of leaves plant^{-1} (3 WAP) and number of stems plant^{-1} at all the sampled ages (Fig. 1d, e, f); animal manure sources significantly ($P < 0.05$) affected plant height and number of leaves plant^{-1}. Plant height of groundnut in the control plot (no manure application) was consistently smaller at the sampled ages relative to the other treatments whereas maize-groundnut intercrop with swine manure application had consistently the highest number of leaves plant^{-1} at 5, 7 and 9 WAP compared with the other treatments. Above ground dry weight (AGDW) and number of flowers·m^{-2} were significantly increased by animal manure sources. AGDW of groundnut ranged from 292 g·m^{-2} (monocrop groundnut + swine manure) to 716 g·m^{-2} (intercrop groundnut + swine manure) while number of flowers·m^{-2} ranged from 736.88 to 913.32 under the same treatments. Similar to our results, Agegnehu et al. (2006) in barley (*Hordeum vulgare*)/faba bean (*Vicia faba*) mixed cropping, Ghosh et al. (2009) in soybean/sorghum and Egbe and Bar-Anyam (2011) in pigeon-pea (*Cajanus cajan*)/sorghum (*Sorghum bicolor*) intercrops as well as Dahmardeh (2013) in maize/peanut mix found that growth performance and high above ground dry matter yield of groundnut could be attributed to the presence and level of mineralization of the animal manures applied to the cropping systems. Furthermore, the animal manures improved not only the soil structure but also the phosphorus (P) availability, especially, the P adsorption and desorption amounts, which invariably enhanced the performance of groundnut in both mono-and-intercropped systems.

Animal manure sources significantly affected number of pegs·m^2, number of pods·m^{-2}, number of seeds·m^{-2} weight of seeds·m^{-2}, weight of pods·m^{-2} and grain yield of groundnut ha^{-1} (Table 4). Among the treatments, yield and yield components of groundnut in both mono- and intercrops that received sheep/goat manure were the highest compared with the other treatments. The results corroborate with related studies by Silwana and Lucas (2002) on

Table 4. Pearson's correlation matrix between vegetative and reproductive characters of maize as influenced by the application of two animal manure sources

Plant attributes	Grain yield ($Mt{\cdot}ha^{-1}$)	Seed weight $\cdot m^{-2}$ (g)	100–seed weight (g)	No. seeds$\cdot m^{-2}$	Cob length (cm)	Plant height (cm)	No. leaves$\cdot$ plant^{-1}	Steam girth (cm)
							9 WAP	
Grain yield ($Mt{\cdot}ha^{-1}$)	1.00							
Seed weight$\cdot m^{-2}$ (g)	0.82**	1.00						
100–seed weight (g)	0.56*	0.61*	1.00					
No. seeds$\cdot m^{-2}$	0.68**	0.79**	0.37	1.00				
Cob length (cm)	0.69**	0.81**	0.34	0.67**	1.00			
Plant height at 9 WAP (cm)	0.06	0.01	–0.40	–0.12	0.13	1.00		
No. leaves$\cdot$plant^{-1} at 9 WAP	–0.46	–0.53*	–0.69**	–0.17	–0.25	0.04	1.00	
Steam girth at 9 WAP (cm)	–0.38	–0.42	–0.35	–0.47	–0.27	0.13	0.57*	1.00

** Correlation is significant at the 0.01 level (2-tailed),
* Correlation is significant at the 0.05 level (2-tailed), ns. Non-significant

Table 5. Pearson's correlation matrix between vegetative and reproductive characters of groundnut as influenced by the application of two animal manure sources

Plant attributes	Grain yield ($Mt{\cdot}ha^{-1}$)	Pod weight $\cdot m^{-2}$ (g)	Seed weight $\cdot m^{-2}$ (g)	No. pegs $\cdot m^{-2}$	No. pods $\cdot m^{-2}$	No. seeds $\cdot m^{-2}$	Above ground dry weight $\cdot m^{-2}$ (g)	No. flowers $\cdot m^{-2}$	Plant height (cm)	No. stem $\cdot$plant^{-1}	No. leaves $\cdot$plant^{-1}
										9 WAP	
Grain yield ($Mt{\cdot}ha^{-1}$)	1.00										
Pod weight$\cdot m^{-2}$ (g)	–0.16	1.00									
Seed weight$\cdot m^{-2}$ (g)	–0.16	0.96**	1.00								
No. pegs$\cdot m^{-2}$	–0.16	0.48	.48	1.00							
No. pods$\cdot m^{-2}$	–0.23	0.88**	.83**	.416	1.00						
No. seeds$\cdot m^{-2}$	–0.22	0.78**	.75**	.431	.948**	1.00					
Above ground dry weight$\cdot m^{-2}$ (g)	–0.09	0.71**	.71**	.265	.797**	.772**	1.00				
No. flowers$\cdot m^{-2}$	–0.01	0.56*	.49	.358	.701**	.620*	.642**	1.00			
Plant height (cm) (9 WAP)	–0.19	0.06	.01	.289	–.209	–.360	–.430	–.244	1.00		
No. stems$\cdot$plant^{-1} (9 WAP)	–0.011	–0.39	–.38	.113	–.288	–.289	–.347	–.291	.035	1.00	
No. leaves$\cdot$plant^{-1} (9 WAP)	0.10	–0.57*	–.64*	–.058	–.525*	–.594*	–.435	–.249	.150	.646**	1.00

** Correlation is significant at the 0.01 level (2-tailed),
* Correlation is significant at the 0.05 level (2-tailed), ns. non-significant.

maize/bean and maize/pumpkin (*Cucurbita moschata*) intercrops, Mohanty et al. (2006) on groundnut/corn, Jeyakumaran and Seran (2007) on capsicum (*Capsicum annum*)/bushitao (*Vigna unguiculata*) as well as Waleligh (2013) on common bean/maize and mungbean (*Vigna radiata*)/maize intercrops in which they reported that animal manure application in different intercropping systems induced higher total crop yield relative to sole cropping due to little inter-specific competition for resources with the N-fixing legume component crop.

The correlation analysis between all the pairs of variables (Table 5) indicated that grain yield of maize had a positive and highly significant ($P \leq 0.05$) correlation with seed weight cob^{-1}, number of seeds cob^{-1} and cob length and showed a significant and positive association with 100-seed weight. Seed weight of maize cob^{-1} exhibited a positive and significant correlation with 100-seed weight, number of seeds cob^{-1} and cob length but showed a negative and significant correlation with number of leaves plant^{-1} at 9 WAP. The other variables exhibited different degrees of associations amongst themselves. Grain yield of groundnut exhibited negative and non-significant ($P \geq 0.05$) correlation with all the variables tested except number of leaves plant^{-1} that was positive. Across the two seasons, correlation showed a highly significant

Table 6. Land equivalent ratio for cropping system (CS) and plant nutrient (PN), land equivalent coefficient for CS and PN, and agronomic efficiency for CS and PN of maize and groundnut in mono- and intercrop as influenced by the application of two animal manure sources

Cropping strategy	Land equivalent ratio (LER)						Land equivalent coefficient		Agronomic efficiency (AE)			
	Cropping system (CS)†			Plant nutrient (PN)‡			CS	PN	Cropping system (CS)		Plant nutrient (PN)	
	Partial[a]		Total[b]	†Partial[a]		Total[b]			Mz	Gt	Mz	Gt
	Mz	Gt		Mz	Gt							
Monocrop maize + no manure	1.00	–[c]	1.00	–	–	–	–	–	–	–	–	–
Monocrop groundnut + no manure	–	1.00	1.00	–	–	–	–	–	–	–	–	–
Monocrop maize + swine manure	1.00	–	–	1.00	–	1.00	–	–	–	–	–	–
Monocrop groundnut + swine manure	–	1.00	–	1.00	–	1.00	–	–	–	–	–	–
Monocrop maize + sheep/goat manure	1.00	–	–	–	1.00	1.00	–	–	–	–	–	–
Monocrop groundnut + sheep/goat manure	–	1.00	–	–	1.00	1.00	–	–	–	–	–	–
Maize/groundnut + swine manure	0.94	0.65	1.59	0.58	0.63	1.21	0.61	0.37	0.24	0.09	0.09	0.08
Maize/groundnut + sheep/goat manure	0.80	0.87	1.67	0.62	0.78	1.40	0.70	0.48	0.30	0.15	0.23	0.01

[†a] Partial cropping system (CS) LERs for maize (Mz) and groundnut (Gt) were obtained by dividing each intercrop yield by its corresponding mono-crop yield with no animal manure application.
[‡a] Partial plant nutrient (PN) LERs for maize (Mz) and groundnut (Gt) were obtained by dividing each intercrop yield by its corresponding mono-crop yield with the corresponding animal manure application.
[†b] Total (CS) LER was the sum of the partial (CS) LERs from Mz and Gt in the intercrop while [‡b] Total (PN) LER was the sum of the partial (PN) LERs from Mz and Gt in the intercrop.
[c] no measurements taken from the corresponding plots because the representative component crop (maize or groundnut) was not planted in that plot (mono-crop).

($P < 0.01$) and positive association between Pod weight·m^{-2} and some growth and yield attributes (seed weight·m^{-2}, number of pods·m^{-2}, number of seeds·m^{-2} and above ground dry weight·m^{-2}). The same trend was recorded between seed weight·m^{-2} and number of pods·m^{-2}, number of seeds·m^{-2} and above ground dry weight·m^{-2}. Also, a very strong correlation was recorded between number of pods·m^{-2} and number of seeds·m^{-2} with correlation coefficients (r) of 0.948, above ground dry weight·m^{-2} (r = 797) and number of flowers·m^{-2} (r = 701). The other variables exhibited varying degrees of associations amongst themselves.

Total cropping system and plant nutrient land equivalent ratios (LERs) were all above unity (Table 6), an indication that yield advantage was derived from the intercropping system relative to monocropping. Intercropped maize/groundnut that received sheep/goat manure exhibited highest yield advantage contrary to swine manure application under the same environment. The trend was consistently similar in both cropping system (CS) and plant nutrient (PN) LERs and land equivalent coefficients (LECs). Agronomic efficiency of the maize component was relatively higher compared with groundnut in the CS and PN agronomic efficiency. Maize/groundnut intercrop applied with sheep/goat manure exhibited higher agronomic efficiency relative to swine manure application, especially under CS than PN. The higher LERs recorded in intercropping suggested according to Hauggaard-Nielsen et al. (2001) on pea/barley, Takim (2012) on maize/cowpea, Mbah and Ogbodo (2013) on sweet corn/vegetable cowpea as well as Salehi et al. (2018) on fenugreek (*Trigonella foenum-graecum* L.)/buckwheat (*Fagopyrum esculentum*) intercrops that crops grown in mixes do not compete for the same resource niche hence are more efficient in their use of growth resources, which translates to a positive biological productivity.

The partial gross monetary returns (GMRs) of the individual component crops (maize and groundnut) in monocrops were higher than their corresponding components in the intercrops (Table 7). However, total GMRs of the component crops in the intercrops were higher compared with the monocrops. Similar

Table 7. Grain yield of maize and groundnut (Mt·ha^{-1}), gross monetary return (₦:K), percentage land saved, variable total cost of production, net return and benefit cost ratio of maize and groundnut in mono- and intercrop as influenced by the application of two animal manure sources

Cropping system	Grain yield (Mt·ha^{-1})		Gross monetary return (GMR) (₦:K)			% land saved	Variable total cost of production (TVCP) (₦·ha^{-1})	Net return[b] (NR) (₦·ha^{-1})	Benefit cost ratio (BCR)
	Maize	Groundnut	Partial[†]		Total[‡]				
			Mz[a]	Gt[b]					
Monocrop maize + no manure	1.22	–[c]	146,400	–	146,400	–	87,300	59,100	0.40
Monocrop groundnut + no manure	–	1.97	–	354,600	354,600	–	100,100	254,500	0.72
Monocrop maize + swine manure	1.99	–	238,800	–	238,800	–	98,150	140,650	0.59
Monocrop groundnut + swine manure	–	2.04		367.200	367.200	–	110,848	256,352	0.70
Monocrop maize/ sheep + goat manure	1.57	–	188.400		188.400	–	104,450	83,950	0.45
Monocrop groundnut + sheep/goat manure	–	2.20	–	396,000	396,000	–	112,380	283,620	0.72
Maize/groundnut + swine manure	1.15	1.28	138,000	230,400	368,400	17.36	120,500	247,900	0.67
Maize/groundnut + sheep/ goat manure	0.98	1.72	117,600	309,600	427,200	28.57	115,470	311,730	0.73
F Pr.	0.021*	0.039*	–	–	–	–	–	–	–
SED	0.2446	0.2447	–	–	–	–	–	–	–
LSD$_{(0.05)}$	0.5640	0.5642	–	–	–	–	–	–	–

Grain yield at 13 % moisture content.
Maize (Mz) and groundnut (Gt) sold at prevailing farm-gate market prices of ₦120:00 kg^{-1} and ₦180:00 kg^{-1}, respectively.
[†a], [†b] Partial GMR for maize (Mz) and groundnut (Gt), respectively and they were obtained by multiplying each crop yield with the prevailing farm-gate market price.
[‡] Total GMR was obtained as the sum of the partial GMRs from Mz and Gt in the mono-or intercrop as the case may be.
[c] no measurements were taken from the corresponding plots because the component crop (maize or groundnut) was not planted or represented in that plot (monocrop).
[b] Net return (NR) was the difference between TGMR and variable TCP of component crops in mono- and intercrop patterns while BCR is the ratio of NR and TCP.

trend was recorded in both CS and PN GMRs. Highest total GMRs, were obtained under sheep/goat manure application relative to swine manure application in CS and PN gross monetary return, respectively. The highest percentage of land saved that could be used for other purposes was recorded under CS while among the intercropping treatments maize/groundnut with sheep/goat application saved more arable land relative to maize/groundnut with swine manure application. The computed biological and economic productivity findings corroborated similar intercropping studies by Sarkar and Pal (2004) on groundnut/pigeonpea (*Cajanus cajan*), Langat et al. (2006) on groundnut/sorghum (*Sorghum bicolor*), Alom et al. (2009) on hybrid maize/groundnut and Dolijanovic et al. (2013) on the advantages of maize/soybean (*Glycine max*) intercropping systems, Neugschwandtner and Kaul (2015) on oat (*Avena sativa*)/pea (*Pisum sativum*) intercrops as well as Takele et al. (2017) on legumes/maize intercrops under fertilised conditions in which they reported that growing component crops (cereals and legumes) in intercrop enhanced not only yield but also land and nutrient use efficiency as well as monetary returns to the farmer.

Monetary advantage index (MAI) and intercrop susceptibility index (ISI) in CS and PN were all positive and showed yield advantage (Table 8). In CS and PN monetary advantage index, the groundnut component was higher than maize. Also, stronger MAI was recorded under CS relative to PN. Total MAI between the mixes indicated that maize/groundnut intercrop with sheep/goat manure exhibited higher MAI in CS and PN, which were higher by 23.6% and 46.6%, relative to CS and PN MAI, respectively. The ISI was highest under maize/groundnut intercrop with sheep/goat manure application compared with the intercrop with swine manure treatment. Similarly, Tsubo et al. (2004) studies on maize/bean mix in South Africa, Razzaque et al. (2007) on groundnut/chilli (*Capsicum annuum*) in India, Dwomon and Quainoo (2012) on

Table 8. Monetary advantage index and intercrop susceptibility index of maize and groundnut in intercrop as influenced by the application of two animal manure sources

Cropping strategy	Monetary advantage index (MAI)						Intercrop susceptibility index (ISI)			
	Cropping system (CS)			Plant nutrient (PN)			Cropping system (CS)		Plant nutrient (PN)	
	Partial[†]		Total[‡]	Partial[†]		Total[‡]				
	Maize	Groundnut		Maize	Groundnut		Maize	Groundnut	Maize	Groundnut
Monocrop maize + no manure	–[a]	–	–	–	–	–	–	–	–	–
Monocrop groundnut + no manure	–	–	–	–	–	–	–	–	–	–
Monocrop maize + swine manure	–	–	–	–	–	–	–	–	–	–
Monocrop groundnut + swine manure	–	–	–	–	–	–	–	–	–	–
Monocrop maize/ sheep + goat manure	–	–	–	–	–	–	–	–	–	–
Monocrop groundnut + sheep/ goat manure	–	–	–	–	–	–	–	–	–	–
Maize/ groundnut + swine manure	51,207.55	85,494.34	136,701.89	23,950.41	39,986.78	63,937.19	0.03	0.15	0.23	0.16
Maize/ groundnut + sheep/ goat manure	49,227.91	129,600.91	178,827.91	33,600.00	88,457.14	122,057.14	0.28	0.18	0.60	0.34

[†] Partial cropping system (CS) and plant nutrient (PN) MAI for maize and groundnut was obtained according to the formular for MAI based on the prevailing farm-gate market price.

[‡] Total (CS) and (PN) MAI was obtained as the sum of the partial MAI from Mz and Gt in the intercrop.

[a] no measurements were taken from the corresponding plots because the component crops (maize or groundnut) were not planted or represented in that plot (mono-crop).

maize/groundnut in Ghana, Gabastshele et al. (2012) on maize/cowpea in Botswana, Nasiri et al. (2014) on sweet-corn/berseem clover (*Trifolium alpestre*) in Poland as well as Alemayehu et al. (2016) on maize/common bean/lupine (*Lipinus luteus*) in Ethiopia further reinforced the positive advantages of intercropping systems under varying environments and conditions. Hence, resource-poor farmers in Sub-Saharan Africa are encouraged to engage in the cropping system for improved sustainability in production and their economic well-being.

CONCLUSION

The application of animal manure sources (swine and sheep/goat manures) enhanced the performance, yield and productivity as well as agronomic efficiency of intercropping maize with groundnut. The combined analysis showed that intercropping system exhibited positive growth, yield, biological and economic advantages over monocropping of the component species. The study further indicated that intercropped maize/groundnut that received sheep/goat manure exhibited the highest cropping system and plant nutrient yield advantage and agronomic efficiency compared to swine manure under the same environment. Therefore, achievement of high yield and productivity advantages in maize and groundnut intercropping through the application of animal manures can be encouraged amongst farmers in Sub-Saharan Africa, especially those engaged in different types of cereal and legume farming strategies.

REFERENCES

Adeleke M. A., Ogunlela V. B., Olufajo O. O., Iwuafor E. N. O. (2013): Analysis of growth of intercrop species in maize (*Zea mays* L.)/cowpea (*Vigna unguiculata* L. Walp) intercropping system as influenced by crop arrangement and proportion in semi-arid Nigeria. Research Journal of Agriculture and Environmental Management 2: 412–419.

Adetiloye P. O. (1989): A review of current competition indices and models for formulating component proportions in intercropping. Cassava based cropping systems research II. International Institute of Tropical Agriculture, Ibadan, Nigeria.

Agegnehu G., Ghizaw A., Sinebo W. (2006): Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian high lands. European Journal of Agronomy 25: 202–207.

Alemayehu A., Tamado T., Nigusie D., Yigzaw D., Kinde T., Wortmann C. S. (2016): Maize-common bean/lupine intercrop productivity and profitability in maize-based cropping system of Northwestern Ethiopia. Ethiopian Journal of Science and Technology 9: 69–85.

Alom M. S., Paul N. K., Quayyum M. A. (2009): Performances of different hybrid maize *(Zea mays* L.) varieties under intercropping systems with groundnut *(Arachis hypogaea* L.). Bangladesh Journal of Agricultural Research 34: 585–595.

Awal M. A., Koshi H., Ikeda T. (2006): Radiation interception and use by maize/peanut intercrop canopy. Agriculture, Forestry and Meteorology 139: 74–83

Bhagad S. B., Chavan S. A., Zagade M. V., Dahiphale A. V. (2006): Intercropping groundnut and sweetcorn at different fertility levels and row proportions. Indian Journal of Crop Science 1: 151–153

Chinaka C. C., Obiefuna J. C. (2000): Evaluation of optimum population and biological efficiency of sweet potato in sweet potato/maize intercropping system. Nigeria Agricultural Journal 31: 158–165.

Dahmardeh M. A. (2013): Intercropping two varieties of maize (*Zea mays* L.) and peanut (*Arachis hypoaea* L.): Biomass yield and intercropping advantage. International Journal of Agriculture and Forestry 3: 7–11.

Dahmardeh M. A., Glanbani B., Syanhsar A., Ramrodi M. (2010): The role of intercropping maize (*Zea mays* L.) and cowpea (*Vigna unguiculata* L.) on yield and soil chemical properties. African Journal of Agricultural Research 5: 631–636

Dapaah H. K., Asufu-Agyei J. N., Ennin S. A., Yamoah C. (2003): Yield stability of cassava, maize, soybean and cowpea intercrops. Journal of Agricultural Science 140: 73–82.

Dolijanović Ž., Oljača S., Kovačević D., Simić M, Momirović N, Jovanović Ž. (2013): Dependence of the productivity of maize and soybean intercropping systems on hybrid type and plant arrangement pattern. Genetika 45: 135–144. DOI: 10.2298/GENSR1301135D

Dwomon B., Quainoo A. K. (2012): Effect of spatial arrangement on the yield of maize and groundnut intercrop in the northern guinea savanna agro-ecological zone of Ghana. International Journal of Life Science Botany and Pharmaceutical Research 1: 76–85.

Egbe O. M., Bar-Anyam M. N. (2011): Effects of sowing density of intercropped pigeonpea with sorghum on biomass yield and nitrogen fixation in southern guinea savanna of Nigeria. Production Agriculture and Technology 7: 1–14.

Ennin S. A., Clegg M. D., Francis C. A. (2002): Resource utilization in soybean/maize intercrops. African Crop Science Journal 10: 251–261.

Eskandari H., Ghanbari A. (2009): Intercropping of maize (*Zea mays* L.) ans cowpea (*Vigna sinensis*) as whole-crop forage: Effect of different planting pattern on whole dry matter production and maize forage quality. Notulae Botanicae Horti Agrobotanici Cluj-Napoca 37: 152–155.

FDALR (Federal Department of Agricultural Land Resources) (1985): The reconnaissance soil survey of Nigeria, Kaduna, Nigeria. Federal Department of Agricultural Land Resources, Kaduna, Nigeria.

Gabastshele M. I., Marokane T. K., Mojeremane W. (2012): Effects of intercropping on the performance of maize and cowpeas in Botswana Journal of Agriculture and Forestry 2: 307–310. doi.org1.0.5923/j.ijaf.20120206.07.

Ghosh P. K. (2004): Growth, yield, competition and economics of groundnut/cereal fodder intercropping systems in the semi-arid tropics of India. Field Crops Research 88: 227–237.

Ghosh P. K., Tripathi A. K., Bandyopadhyay K. K., Manna M. C. (2009): Assessment of nutrient competition and nutrient requirement in soybean/sorghum intercropping system. European Journal of Agronomy 3: 43–50.

Hauggaard-Nielsen H., Ambus P., Jensen E. S. (2001): Temporal and spatial distribution of roots and competition for nitrogen in pea-barley intercrops – a field study employing P-32 technique. Plant and Soil 236: 63–74.

Jeyakumaran J., Seran T. H. (2007): Studies on intercropping capsicum (*Capsicum annum* L.) with bushitao (*Vigna unguiculata* L.). Proceedings of the 6th Annual Research Session, Oct. 18–19, Trincomalee Campus EUSL, pp. 431–440.

Jiao N. Y., Zlao C., Ning T. Y., Hou L. T., Fu G. Z., Li Z. J., Clen M. C. (2008): Effects of maize-peanut intercropping on economic yield and light response of photosynthesis. Chinese Applied Ecology 19: 981–985.

Keating B. A., Carberry P. S. (1993): Resource capture and use in intercropping: solar radiation. Field Crops Research 34: 273–301.

Karuma A., Gachene C. K. K., Gicheru P. T., Mwang'ombe A. W., Mwangi H. W., Clavel D., Verhagen J., Von Kaufmann R., Francis J., Ekaya W. (2011): Effects of legume cover crop and sub-soiling on soil properties and maize (*Zea mays* L.) growth in semi arid area of Machakos district, Kenya. Tropical and Subtropical Agro-ecosystems 14: 237–243.

Ladha J. K., Pathak H., Krupnik T. J., Six J., Van Kessel C. (2005): Efficiency of fertilizer nitrogen in cereal production: Retrospect and prospects.

Advances in Agronomy 87: 85–156. doi:10.1016/S0065-2113(05)87003-8.

Langat M. C., Okiror M. A., Ouma J. P., Gesimba R. M. (2006): The effect of intercropping groundnut (*Arachis hypogea* L.) with sorghum (*Sorghum bicolor* L. Moench) on yield and cash income. Agricultura Tropica et Subtropica 39: 87–91.

Mahapatra S. C. (2011): Study of grass-legume intercropping system in terms of competitive indices and monetary advantage index under acid lateritic soil of India. American Journal of Experimental Agriculture 1: 1–6.

Makinde A., Bello N. J., Olasantan F. O., Adebisi M. A. (2009): Hydrothermal effects on the performance of maize and cucumber intercrop in a tropical wet and dry climate in Nigeria. African Journal of Agricultural Research 4: 225–235.

Mbah E. U., Ogidi E. (2012): Effect of soybean plant populations on yield and productivity of cassava and soybean grown in a cassava-based intercropping system. Tropical and Subtropical Agroecosystems 15: 241–248.

Mbah E. U., Ogbodo E. N. (2013): Assessment of intercropping sweet corn (*Zea mays* var. *saccharata*) and vegetable cowpea (*Vigna unguiculata* (L.) Walp) using competiteive indices in the derived Savanna of Southeastern Nigeria. Journal of Biology, Agriculture and Healthcare 3: 84–93.

Mead R., Willey R. W. (1980): The concept of land equivalent ratio and advantages in yield from intercropping. Experimental Agriculture 16: 217–218.

Mohanty S., Paikaray N. K., Rajan A. R. (2006): Availability and uptake of phosphorus from organic manures in groundnut (*Arachis hypogea* L.) – corn (*Zea mays* L.) sequence using radio tracer technique. Geoderma 133: 225–230.

Morris R., Garrity D. P. (1993): Resource capture and utilization in intercropping: water. Field Crop Research 34: 303–317.

Muoneke C. O., Ogwuche M. A. O., Kalu B. A. (2007): Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savanna agro-ecosystem. African Journal of Agricultural Research 2: 667–677.

Nasiri A., Nourmohamadi G., Zandi P., Siavoshi M., Dastan S. (2014): Preliminary evaluations of the yield components and productivity of sole cropped and mix-intercropped sweet corn with berseem clover as influenced by various spatial arrangements. Polish Journal of Agronomy 18: 36–44.

Neugschwandtner R. W., Kaul H. -P. (2015): Nitrogen uptake, use and utilization efficiency by oat-pea intercrops. Field Crop Research 179: 113–119.

Obi I. U. (2002): Statistical Methods of Detecting Differences between Treatment Means and Research Methodology. Issues in Laboratory and Field Experiments. Nsukka: AP Express publishers VED. 117 p.

Ofori F., Stern W. R. (1987): Maize/cowpea intercrop system: effect of nitrogen fertilizer on productivity and efficiency. Field Crops Research 14: 247–261.

Ogindo H. O., Walker S. (2005): Comparison of measured changes in seasonal soil water content by rained maize-bean intercrop and component cropping in semi-arid region in southern Africa. Physics and Chemistry of the Earth, Parts A/B/C 30: 799–808.

Razzaque M. A., Rafiquzzaman S., Bazzaz M. M., Ali M. A., Talukdar M. M. R. (2007): Study on the intercropping groundnut with chilli at different plant populations. Bangladesh Journal of Agricultural Research 32: 37–43.

SAS Institute Inc. (2007): SAS/STAT® Users' Guide, Ver. 8, 4th ed., Scholars Academic and Scientific Publishers, SAS Institute, Cary, North Carolina, U.S.A.

Salehi A., Fallah S., Neugschwandtner R. W., Mehdi B., Kaul H. -P. (2018): Growth analysis and land equivalent ratio of fenugreek buckwheat intercrops at different fertilizer types. Die Bodenkultur: Journal of Land Management, Food and Environment 69: 105–119. www.degruyter.com/view/j/boku

Sarkar R. K., Pal P. K. (2004): Effect of intercropping rice *(Oryza sativa)* with groundnut (*Arachis hypogaea*) and pigeonpea (*Cajanus cajan*) under different row orientations on rainfed uplands. Indian Journal of Agronomy 49: 147–150.

Seran T. H., Brintha I. (2010): Review on maize based intercropping. Journal of Agronomy 9: 135–145.

Silwana T. T., Lucas E. O. (2002): The effect of planting combinations and weeding and yield of component crops of maize-bean and maize-pumpkin intercrops. Journal of Agricultural Science 138: 193–200.

Singh S. B., Ajeigbe H. (2007): Improved cowpea-cereals based cropping systems for household food security and poverty reduction in West Africa. Journal of Crop Improvement 19: 157–172.

SPSS (Statistical Package for Social Sciences). (2010): SPSS for Windows. Release 17.0 Standard Version. Users' guide. SPSS Inc. Chicago, USA.

Takele E., Mekonnen Z., Tsegaye D., Abebe A. (2017): Effect of intercropping of legumes and rates of nitrogen fertilizer on yield and yield components of maize (*Zea mays* L.) at Arba Minch. 2017. American Journal of Plant Sciences 8: 2159–2179. doi.org/10.4236/ajps.2017.89145.

Takim F. O. (2012): Advantages of maize-cowpea intercropping over sole cropping through competition indices. Journal of Agriculture and Biodiversity Research 1: 53–59.

Tsubo M., Ogindo H. O., Walker S. (2004): Yield evaluation of maize-bean intercropping in a semi-arid region of South Africa. African Crop Science Journal 12: 351–358.

Vanlauwe B., Kihara J., Chivenge P., Pypers P., Coe R., Six J. (2011): Agronomic use efficiency of N fertilizer in maize-based systems in Sub-Sahara Africa within the context of integrated soil fertility management. Plant and Soil 339: 35–50.

Vesterager J. M., Niesen N. E., Hogh-Jensen H. (2008): Effects of cropping history and phosphorus sources on yield and nitrogen fixation fixation in sole and intercropped cowpea-maize systems. Nutrient Cycling in Agroecosystems 80: 61–73.

Waleligh W. (2013): Sequential intercropping of common bean and mungbean with maize in southern Ethiopia. Experimental Agriculture Journal 50: 90–106.

Willey R. W. (1979): Intercropping its importance and research needs part 1. Competition and yield advantages. Field Crop Abstracts 32: 1–10.

Willey R. W. (1985): Evaluation and presentation of intercropping advantages. Experimental Agriculture 21: 119–133.

Willey R. W. (1990): Resource use in intercropping systems. Agriculture and Water Management 17: 215–231.

Received: January 28, 2019
Accepted after revisions: November 27, 2020