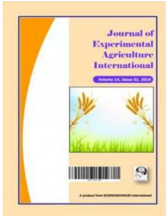


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# Varietal Effect of Cowpea and Cow Dung Application Rates on the Productivity of Cocoyam/Cowpea Intercrop

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors MOI and DAO designed the study. Author MOI wrote the protocol and the first draft of the manuscript. Author DAO managed the literature searches while author COM managed the analyses of the study. All authors read and approved the final manuscript.*

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## ABSTRACT

The varietal effect of cowpea and cow dung application rates on the productivity of cocoyam/cowpea intercrop were investigated in 2012 and 2013 cropping seasons at National Horticultural Research Institute (NIHORT), Mbato sub-Station, Imo State, Nigeria. The experiment was a factorial arrangement in a randomized complete block design with three replications. The treatments were four levels (0, 10, 20 and 30 t/ha) of application of cow dung and two cowpea varieties of different growth habits (climbing *Akidienu* and erect IT97K-499-35) intercropped with cocoyam. The sole crops were included in other to access the productivity of the intercrop. Cocoyam growth and yield parameters assessed included plant height, leaf area index (LAI), number of corms, corm weight and corm yield while cowpea parameters evaluated were plant height, shoot and root dry weights, number of pods/plant, fresh pod weight, fresh pod yield, number

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of seeds/pod, 100 seeds weight and seed yield. Intercropping cocoyam with climbing *Akidienu* significantly (*P* < .05) increased cocoyam plant height but decreased significantly (*P* < .05) leaf area index (LAI) by 50% and corm yield by 44% on average. However, intercropping cocoyam with erect IT97K-499-35 had no significant effect on cocoyam plant height but significantly decreased LAI by 17% and corms yield by 23%. Fresh pod and seed yields were not affected by intercropping except in 2012 where fresh pod yield of erect IT97K-499-35 intercropped with cocoyam was significantly increased by 17% over the sole crop yield. Generally, erect IT97K-499-35 produced higher fresh pod and seed yields than climbing *Akidienu* in both cropping systems. Application of cow dung at 20 t/ha gave optimum corm yield while pod and seed yields of the cowpea varieties were improved by the lower rate of 10 t/ha. Cocoyam mixed with erect IT97K-499-35 produced the highest mean total LER of 2.53; LEC of 1.44 and ATER of 1.58 when cow dung was applied at 20 t/ha.

*Keywords: Cocoyam; cowpea; cow dung; intercropping; productivity; intercropping efficiency.*

## 1. INTRODUCTION

Limited availability of land for crop production, along with declining yield per unit area have heightened concerns about introduction of cropping systems, which are sustainable and economically viable. A possible way of increasing productivity would be through multiple cropping systems like intercropping which is one of the options to feed more mouths. In Nigeria, intercropping is a common practice among the traditional farmers. It is a strategy adopted to ensure sustainable agriculture and supply of products for human use. According to Marer et al*.* [1], the main concept of intercropping is to get increased total productivity per unit area and time, besides equitable and judicious utilization of land resources and farming inputs including labour. The most common goal of intercropping therefore is to produce greater yield on a given piece of land by making use of resources that would otherwise not be utilized by a single crop.

Cocoyams are mostly planted in combination with other crops. Knipsheer and Wilson [2] observed that common combinations involving cocoyam in Nigeria are cocoyam/maize/ vegetables in Anambra State, yam/cocoyam/ vegetables in Imo state, plantain or banana with cocoyam/maize/vegetables in Rivers State. Intercropping cocoyam with cocoa occurs in Ondo state while growing it in associations with kola and citrus is popular in Imo, Anambra and Ondo States. In a research carried out by Arene et al*.* [3] on cocoyam intercropped with maize, they observed that while yield of cocoyam was depressed by intercropping with maize, the yield of maize was unaffected by the population of cocoyam. Udealor [4] investigated the effects of melon intercropped as live mulch on cocoyam and found that the yield of cocoyam was increased while that of melon significantly reduced. Erhabor and Filson [5] in their own study reported that intercropping cocoyam with oil palm gave corm yield that was not significantly different from the sole crop whereas cocoyam corm yield was significantly depressed when it was intercropped with oil palm + soybean or oil palm + soybean + maize.

Many cowpea intercropping systems have been reported [6]. In a survey of cropping systems in west and central Africa, 15 major cropping systems involving cowpea were identified [7]. In an earlier survey, Henriet et al*.* [8] reported the existence of 43 crop mixtures involving cowpea in the Sudan savanna of Nigeria with millet/cowpea mixture being predominant. Arnon [9] estimated that about 98% of cowpea grown in Africa is in association with other crops. Cowpea is an important component in most cereal-legume cropping systems because of its residual nitrogen benefit originating from the decay of its leaf litter, roots and root nodules [10]. Its shade tolerance and compatibility as an intercrop make it the crop of choice for arid zones [11].

There is scarcity of published information on the productivity of cocoyam in cocoyam/cowpea intercrop. The objective was to determine the effects of cowpea varieties and cow dung application rates on the productivity of cocoyam/cowpea intercrop.

## 2. MATERIALS AND METHODS

### 2.1 Study Location and Collection of Planting Materials

The experiment was carried out at National Horticultural Research Institute (NIHORT), Mbato sub-Station, Okigwe, Imo State, Nigeria in 2012 and 2013 cropping year. NIHORT is located at latitude 5°33 [1] N and longitude 7°23 [1] E and 139 m above sea level. The area is characterized as a humid rainforest zone and the soil is sandy loam. The experimental site had bushy vegetation at the time it was ploughed and used for this experiment. The cocoyam (*Colocasia esculenta* var. NCe001) cormels used in this experiment were sourced from National Root Crops Research Institute, Umudike, Nigeria. Two varieties of cowpea of different growth habits-climbing *Akidienu* and erect IT97K-499-35 were used. The climbing *Akidienu* was bought from a local market in Imo State, Nigeria while the erect IT97K-499-35 was obtained from International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria.

## 2.2 Land Preparation

In each year, the site was double-ploughed and ridged with a tractor. The experimental area was mapped into three blocks, which represent the replicates and each block was divided into twenty experimental plots, thus giving a total of sixty plots. Each plot was 4 m x 3 m (12 $m^2$) with a net plot of 2 m x 2 m. Each plot was properly labeled on the basis of treatment assigned to it for proper data collection.

## 2.3 Experimental Design and Treatments

The experiment was a factorial arrangement in a randomized complete block design with three replications. Four levels of cow dung (0, 10, 20, and 30 t/ha) and two varieties of cowpea with varying growth habits (climbing *Akidienu* and erect IT97K-499-19) intercropped with cocoyam were used as the treatments. The sole crops were included as treatments so as to assess the productivity of the intercrop system. A total of twenty treatment combinations were used. The treatments were assigned randomly to the plots. The cow dung was incorporated into the soils of the experimental plots in a single application, based on the treatment combinations at two weeks before planting to allow decomposition.

## 2.4 Cultural Conditions

The cocoyam cormels and the different cowpea varieties were planted the same day on 20$^{th}$ June in 2012 and 9$^{th}$ May in 2013. The cocoyam cormels were planted on ridges at a depth of 15 cm. One cormel was planted per hole at a planting distance of 1 m x 1 m. There were twelve plants per plot resulting in a total of about 10,000 plants per hectare. The cowpea varieties were sown three seeds per hole at a depth of 3 cm and at a planting distance of 1 m x 0.25 m in between the cocoyam corms. The resulting seedlings were thinned down to one per hole at 2 weeks after planting (WAP) resulting in a total of 40,000 plants per hectare. The same planting depths and distances were used for the sole crops. Supply of missing stands was done at 3 WAP. The cowpea seedlings were allowed to climb freely on the cocoyam. Weeding was done manually with hoe. The cowpea seedlings were protected from insect attack by spraying with Deltamethrine 12.5 EC from 2 WAP.

## 2.5 Records of Agronomic Measurements

Data were collected on the following plant growth and yield attributes of cocoyam: plant height, leaf area index (LAI), number of corms per plant, corm weight (g/corm) and corm yield (t/ha). The plants in each of the net plots were used for the measurements. Plant height was measured with a meter rule from the base of the stem to the top of the canopy. The leaf area index (LAI) was determined by first determining the leaf area using the formula of Biradar et al. [12] as:

$$\text{Leaf Area} = 0.917\ (LW).$$

Where L and W are length and width of the cocoyam leaf.

Leaf area index was calculated by dividing the total leaf area by the area occupied by the plant [12]. At physiological maturity (6 MAP), the cocoyam plants from the net plots were harvested, the number of corms/cormels were physically counted and recorded. The corms/cormels were weighed to obtain the corms weight and thereafter the weights were converted to tons per hectare to obtain the corms yield.

For the cowpea, the following data were collected: plant height, root and shoot dry weights, number of pods per plant, pod weight, pod yield, number of seeds per pod, 100 seed weight and seed yield. Five cowpea plants per cowpea variety were randomly selected from each plot. Height of the selected cowpea plants were measured at I MAP from the base of the stem at soil level to the terminal bud of the main stem with the aid of a measuring tape. The mean was calculated and recorded accordingly. The root and shoot dry weights of the cowpea varieties were determined at 1 MAP. The plants selected for height determination was used for these measurements. The plants were carefully uprooted, dipped in a bucket of water to remove soil particles and then separated into roots and shoots. The roots and shoots were chopped into smaller pieces and packaged in properly labeled envelopes. The envelopes containing the samples were dried in an electric oven at a temperature of 65℃ until a constant weight was achieved. The samples were allowed to cool and thereafter weighed and their weights recorded.

For Yield measurements, ten plants were selected from the net plot and tagged. Fresh green pods of the cowpea varieties were harvested from these plants weekly as the pods mature from 2 MAP. The number of pods was counted and the average determined and recorded. At each harvest, the fresh green pods were weighed with an electronic balance and the mean weights recorded. The weight of pods was converted to tons per hectare to obtain the pod yield. The number of seeds per pod was determined by randomly selecting ten pods from each plot. The selected pods were split longitudinally into two and the seeds in each pod counted and the average number of seeds obtained was recorded. 100 seeds weight were determined by shelling harvested dry pods from each plot. The shelled seeds were sun-dried and mixed properly after which 100 seeds were randomly selected from the seed lot, weighed using an electronic balance and the mean weight recorded.

## 2.6 Assessment of Intercrop Productivity

### 2.6.1 Land equivalent ratio (LER)

The LER was calculated from the yield data using the formula of Trenbath [13] as shown in the equation below:

$$LER = ab/a + ba/b$$

Where a = sole crop yield of cocoyam; ab = intercrop yield of cocoyam; b = sole crop yield of cowpea; ba = intercrop yield of cowpea

### 2.6.2 Land equivalent coefficient (LEC)

This was calculated as the product of LERs of the intercrop component as proposed by Adetiloye and Ezedinma [14]. Thus:

$$LEC = ab/a \times ba/b$$

### 2.6.3 Area x time equivalent ratio (ATER)

This was calculated using the formula of Hiebsch and McCollum [15] as:

$$ATER = [(RYa \times Da) + (RYb \times Db)] / D$$

Where: RYa = cocoyam relative yield; Da = cocoyam duration; RYb = cowpea relative yield; Db = cowpea duration; D = duration of the whole intercrop

## 2.7 Data Analyses

Data collected were subjected to analysis of variance using Genstat Discovery Edition 3 Package of 2007 and significant means were separated and compared using Fisher's Least Significant Difference (F-LSD) at 5% probability level.

# 3. RESULTS AND DISCUSSION

## 3.1 Cocoyam Growth Characteristics, Yield and Yield Components

At 1 and 2 MAP, intercropping cocoyam with climbing *Akidienu* produced significantly taller cocoyam plants than sole cropping in both years (Table 1). Cocoyam also produced taller plants in climbing *Akidienu* than in the erect IT97K-499-35 at 1 MAP in 2013. Cocoyam intercropped with erect IT97K-499-35 and the sole cocoyam had significantly the same plant heights in the two years of cropping. Cow dung irrespective of rates produced significantly the same plant height values, which were significantly higher than that of zero application in all sampling dates in both years (Table 1). Climbing *Akidienu* being a climber and the taller plant in the mixture occupied the higher canopy and probably shaded the cocoyam plant, which in response to the shade grew taller than the sole crop in order to receive light. Okpara et al. [16] made similar observations and attributed the greater cocoyam plant height under intercropping to competition and modification of the microenvironment at full coverage of cowpea. The lack of effect of intercropping on cocoyam plant height at 3 MAP may probably be due to reduced competition for light as the associated crop had reached maturity at this time and had shedded some leaves.

In 2012, intercropping cocoyam with any of the cowpea varieties significantly decreased cocoyam LAI at 2 and 3 MAP (Table 2). However, in 2013, LAI of cocoyam was significantly decreased by intercropping cocoyam with climbing *Akidienu* at 2 and 3 MAP. Sole cocoyam and cocoyam intercropped with erect IT97K-499-35 produced significantly the same LAI values. LAI was significantly higher when cow dung was applied regardless of the rates than the control at all sampling dates (Table 2). Increasing cow dung rate above 10 t/ha did not produce any significant increase in LAI.

Results on yield and yield attributes of cocoyam are shown in Table 3. The number of corms produced per plant decreased significantly due to intercropping cocoyam with any of the cowpea varieties in 2012. Combining cocoyam with erect IT97K-499-35 produced significantly ($p < 0.05$) higher number of corms than cocoyam mixed with climbing *Akidienu*. Similarly, in 2013, intercropping cocoyam with climbing *Akidienu* produced significantly lower number of corms compared to sole cropping and to cocoyam combined with erect IT97K-499-35. However, number of corms produced by sole cocoyam and cocoyam mixed with erect IT97K-499-35 were statistically similar. In both cropping seasons, application of cow dung regardless of rates produced significantly the same number of corms, which were significantly ($p < 0.05$) higher than that of no manure application. Interactions between intercropping cocoyam with cowpea and cow dung did not produce any significant ($p < 0.05$) effect on number of corms harvested per plant.

Intercropping cocoyam with climbing *Akidienu* produced greater weight of corms in 2012 in relation to intercropping with erect IT97K-499-35 and sole cropping. Regardless of cowpea growth habit, corms weight produced under intercropping was significantly the same in 2013, although sole cropping gave corms weight value that was higher significantly ($p < 0.05$) than that of intercropping with climbing *Akidienu*. Application of cow dung had no significant effect on corms weight in 2012 cropping season. However, in 2013, cow dung application irrespective of rates gave significantly the same corms weight values that were significantly higher than zero application. Interactions between intercropping and cow dung was significant ($p < 0.05$) only in 2013 cropping season. Combining cocoyam with erect IT97K-499-35 plus 20 t/ha cow dung rate produced corms weight value of 44.0 g/corm, which was higher than that produced under intercropping/sole cropping without manure and intercropping with climbing *Akidienu* irrespective of the cow dung rates (except 30 t/ha cow dung).

In 2012, corms yield was significantly reduced by 44% and 31% when cocoyam was intercropped with climbing *Akidienu* and erect IT97K-499-35, respectively. Similarly, in 2013, combining cocoyam with *Akidienu* significantly ($p < 0.05$) decreased corms yield by 45%, whereas, intercropping cocoyam with erect IT97K-499-35 resulted in slight reduction in corms yield by 17%. However, average of the cropping seasons gave corms yields of 6.8 t/ha, 3.8 t/ha and 5.3 t/ha in sole cocoyam, cocoyam mixed with *Akidienu* and cocoyam mixed with IT97K-499-35, respectively (Table 4). Therefore, on average, corm yield reductions were 44% and 22% in *Akidienu* and IT97K-499-35, respectively. Corm yield increased significantly with application of cow dung up to 20 t/ha, beyond which there was no further yield advantage. Average of the two years produced corm yields of 2.6, 5.1, 6.8 and 6.8 t/ha with cow dung rates of 0, 10, 20 and 30 t/ha, respectively.

Intercropping reduced on average cocoyam LAI at 3 MAP by 50% in climbing *Akidienu* and 17% in erect IT97K-499-35 as well as corm yield by 44% in climbing *Akidienu* and 23% erect IT97K-499-35. This result supports other findings [17;18] in which intercropping reduced yields due to competition for growth resources. The greater reduction in LAI and corm yield when cocoyam was intercropped with climbing *Akidienu* cowpea is attributable to the growth habit of the latter, which used the former as support and hampered the development of new leaves and expansion of old leaves. This has negative effects on photosynthesis as LAI is the force that determines the capacity of the plant to trap energy for photosynthesis [19].

Application of cow dung at 10 and 20 t/ha produced yields that were higher by 96% and 161%, respectively, over no cow dung application Interaction between intercropping and cow dung on corm yield was not significant in both years. Generally, application of cow dung at 10 t/ha improved cocoyam growth while higher rate of 20 t/ha increased corm yield over the lower rate of 10 t/ha and control by 32% and 165%, respectively, on average. Beneficial attributes of organic manures have been reported to include supply of nutrients necessary for crop growth and development, improvement of physical, chemical and biological properties of the soil and the decrease in nutrient loss through leaching by forming chelates with some metal elements [20;21;22].

### 3.2 Cowpea Growth and Yield

Results on growth characteristics of cowpea are depicted in Table 5. Plant height of the cowpea varieties was not significantly affected by intercropping in both cropping seasons. Across the cropping systems however, climbing *Akidienu* produced significantly ($p < 0.05$) greater plant height than erect IT97K-499-35. Cow dung application irrespective of the rates recorded statistically similar plant heights, which were significantly higher than no application. Interactions were significant, with climbing *Akidienu* intercrop at 10 t/ha cow dung rate producing tallest plants while erect IT97K-499-35 regardless of cropping system at no manure application gave shortest plants on average.

Shoot dry matter production was not significantly ($p < 0.05$) affected by intercropping in both years but cow dung had significant effect on it. Incremental application of cow dung up to 20 t/ha significantly increased shoot dry matter production in 2012 beyond which no significant increase occurred. Nevertheless, in 2013, application of cow dung at 30 t/ha significantly increased shoot dry matter over no application and the lower rate of 10 t/ha. Shoot dry matter produced by cow dung rates of 30 and 20 t/ha were significantly the same.

Intercropping had no significant ($p < 0.05$) effect on number of pods produced by climbing *Akidienu* in both cropping years (Table 6). On the contrary, the number of pods produced per plant was significantly higher in erect IT97K-499-35 intercrop by 28% over the sole in 2012. In 2013 however, IT97K-499-35 in both sole and intercropped situation produced number of pods that were statistically similar. More so, in both cropping systems and seasons, erect IT97K-499-35 produced significantly higher number of pods per plant than climbing *Akidienu*. All cases of applied cow dung gave significantly the same number of pods, which were significantly higher than that of no application in 2012 only. Interactions were significant with erect IT97K-499-35 in both cropping systems producing more pods than climbing *Akidienu* at all cow dung rates.

In 2012, intercropping had no significant effect on weight of pods of any of the cowpea varieties rather the cowpea varieties produced pods whose weights differ significantly. Climbing *Akidienu* produced significantly higher fresh pod weight than erect IT97K-499-35 in both cropping systems (Table 6). Intercropping significantly ($p < 0.05$) reduced fresh pod weight of climbing *Akidienu* in comparison with its sole crop but had no significant effect on fresh pod weight of erect IT97K-499-35 in 2013. Erect IT97K-499-35 intercrop produced significantly higher fresh pod weight than climbing *Akidienu* in both cropping systems, whereas fresh pod weights of the sole cowpea varieties were statistically similar. Effect of cow dung on fresh pod weight was not significant in both years so also interaction.

Pod yield of the cowpea varieties was significantly affected by intercropping in 2012 cropping season only. Intercropping significantly ($p < 0.05$) increased pod yield of erect IT97K-499-35 by 19% while climbing *Akidienu* had significantly the same fresh pod yields in both cropping systems (Table 6). However, in both years, erect IT97K-499-35 consistently produced significantly higher fresh pod yields than climbing *Akidienu*. Similarly, effect of cow dung on pod yield was significant only in 2012. All cases of applied cow dung increased significantly pod yield over no application. Cow dung applied at the rate of 30 t/ha increased significantly fresh pod yield compared to the lower rates of 10 and 20 t/ah which recorded statistically similar values. Interaction effect was significant in 2012 only. Erect IT97K-499-35 in mixture with cocoyam regardless of cow dung rates produced pod yields that were significantly higher than those of its sole crop and climbing *Akidienu* in both cropping systems and at all cow dung rates.

As mean across two years, fresh pod yield of the cowpea varieties under sole and intercropped condition were not statistically different (Table 7). However, erect IT97K-499-35 produced significantly ($p < 0.05$) higher fresh pod yield in sole and intercrop condition relative to climbing *Akidienu*. Cow dung did not exert any significant effect on fresh pod yield of the cowpea genotypes on average.

Intercropping did not significantly influence the number of seeds produced per pod of any of the cowpea varieties in both years (Table 8). Notwithstanding, in the two years of cropping, climbing *Akidienu* under both cropping systems produced significantly higher number of seeds per pod than IT97K-499-35. Cow dung and interaction effects on number of seeds per pod were not significant in both years. Similarly, intercropping had no significant effect on 100 seeds weight of any of the cowpea varieties in the two years of cropping (Table 8). However, erect IT97K-499-35 consistently produced significantly ($p < 0.05$) higher 100 seed weight value compared to climbing *Akidienu* in both cropping conditions. Cow dung and interaction effects on 100 seed weight were not significant.

In the same vein, intercropping had no significant ($p < 0.05$) effect on seed yield of any of the cowpea varieties in the two years of cropping (Table 8). However, erect IT97K-499-35 in both cropping systems consistently produced seed yields that were significantly ($p < 0.05$) higher than those of climbing *Akidienu* in both cropping systems. There was over-yielding by 24% in one out of the two years by the erect IT97K-499-35 intercrop probably due to the modification of the microenvironment by the candidate cocoyam, which favoured the former. Besides, the erect IT97K-499-35 cowpea consistently gave higher fresh pod and seed yields than the climbing *Akidienu* in both cropping systems. This confirms the results of Cenpukdee and Fukai [23] and Okpara et al. [16] that cultivar performance in sole cropping is important in determining yield in intercropping. Unlike the climbing *Akidienu*, which entangled the companion cocoyam, the superior yields of the erect IT97K-499-35 may be attributed to better water utilization as a result of less evaporation, better weed control through canopy shading, better radiant energy utilization, increased photosynthesis and improved leaf distribution [24].

Cow dung application irrespective of the rates gave statistically the same seed yield values, which were significantly ($p < 0.05$) higher than that of the control in 2012. Effect of interaction between intercropping and cow dung was significant in 2012 only. Erect IT97K-499-35 combined with cocoyam and cow dung rate of 10 t/ha produced the highest seed yield while sole *Akidienu* combined with cow dung rate at 10 t/ha produced the least seed yield of 38.1 t/ha. Contrary to what was found in cocoyam yield, higher cow dung rate of 20 t/ha increased growth while pod and seed yields were not improved beyond the lower rate of 10 t/ha in the companion cowpea crops. This supports the report of Musa and Singh [25] who observed optimal increases in number of pods per plant, pod yield and grain yield of groundnut with application of lower rate of 15 t/ha cow dung compared to the higher rate of 30 t/ha cow dung.

Corm and fresh pod yields were higher in 2013 than 2012 by 44% and 220%, respectively. The poor yields obtained from both crops in 2012 were due probably to the late planting in June. Okpara and Oshilim [26] obtained similar results in which the magnitude of yield depression following delayed sowing of vegetable cowpea was most serious in June and July planting dates. The higher yields in 2013 in which planting was done in early May could be attributed to higher carbohydrate content in the plants resulting from favourable sunlight conditions prevalent early in the cropping season.

**Table 1. Effect of intercropping and cow dung on plant height (cm) of cocoyam at different sampling periods in 2012 and 2013**

| **Treatment** | **Months after planting (MAP)** | | | | | |
|---|---|---|---|---|---|---|
| **Crop combination** | **1** | **2** | **3** | **1** | **2** | **3** |
| | | **2012** | | | **2013** | |
| **Sole cocoyam** | 17.3 | 33.4 | 46.0 | 12.8 | 32.3 | 47.7 |
| Cocoyam + *Akidienu* | 20.5 | 42.6 | 51.5 | 15.0 | 38.5 | 50.8 |
| Cocoyam + IT97K-499-35 | 18.6 | 38.0 | 48.8 | 12.8 | 37.0 | 50.6 |
| Mean | 18.8 | 38.0 | 48.8 | 13.5 | 35.9 | 49.7 |
| LSD (0.05) | 2.5 | 6.0 | NS | 2.0 | 5.2 | NS |
| **Cow dung (t/ha)** | | | | | | |
| 0 | 15.0 | 28.1 | 37.6 | 10.6 | 26.7 | 38.1 |
| 10 | 19.7 | 38.1 | 49.2 | 15.2 | 40.1 | 52.2 |
| 20 | 20.4 | 42.4 | 52.2 | 14.2 | 39.3 | 53.2 |
| 30 | 20.1 | 43.3 | 55.9 | 14.2 | 37.5 | 55.3 |
| Mean | 18.8 | 38.0 | 48.7 | 13.6 | 35.9 | 49.7 |
| LSD (0.05) | 2.8 | 6.9 | 7.4 | 2.4 | 6.0 | 8.7 |

**Table 2. Effect of intercropping on LAI of cocoyam at different sampling dates in 2012 and 2013**

| Treatment | Months after planting (MAP) | | | | | |
|---|---|---|---|---|---|---|
| **Crop combination** | **1** | **2** | **3** | **1** | **2** | **3** |
| | | **2012** | | | **2013** | |
| **Sole cocoyam** | 0.10 | 0.34 | 0.99 | 0.07 | 0.36 | 1.04 |
| Cocoyam + *Akidienu* | 0.10 | 0.24 | 0.58 | 0.07 | 0.19 | 0.44 |
| Cocoyam + IT97K-499-35 | 0.10 | 0.25 | 0.76 | 0.07 | 0.36 | 0.93 |
| Mean | 0.10 | 0.27 | 0.78 | 0.07 | 0.30 | 0.80 |
| LSD (0.05) | NS | 0.08 | 0.21 | NS | 0.12 | 0.30 |
| **Cow dung (t/ha)** | | | | | | |
| 0 | 0.05 | 0.13 | 0.32 | 0.04 | 0.15 | 0.32 |
| 10 | 0.12 | 0.29 | 0.78 | 0.08 | 0.37 | 0.80 |
| 20 | 0.12 | 0.24 | 1.04 | 0.08 | 0.36 | 1.04 |
| 30 | 0.11 | 0.34 | 1.10 | 0.07 | 0.34 | 1.06 |
| Mean | 0.10 | 0.28 | 0.81 | 0.07 | 0.31 | 0.81 |
| LSD (0.05) | 0.04 | 0.10 | 0.41 | 0.02 | 0.14 | 0.34 |

**Table 3. Effect of intercropping and cow dung on yield components of cocoyam at harvest in 2012 and 2013**

| Crop combination | Cow dung (t/ha) | NC per plant | | CW (g/corm) | | CY (t/ha) | |
|---|---|---|---|---|---|---|---|
| | | **2012** | **2013** | **2012** | **2013** | **2012** | **2013** |
| Sole cocoyam | 0 | 12.3 | 12.3 | 25.6 | 28.4 | 3.1 | 3.5 |
| | 10 | 15.0 | 20.2 | 38.9 | 39.4 | 5.6 | 8.0 |
| | 20 | 20.9 | 23.3 | 32.1 | 41.7 | 6.7 | 9.7 |
| | 30 | 20.8 | 23.5 | 37.9 | 43.8 | 7.8 | 10.3 |
| | Mean | 17.3 | 19.8 | 33.6 | 38.3 | 5.8 | 7.9 |
| Cocoyam + *Akidienu* | 0 | 4.0 | 8.1 | 43.8 | 32.2 | 1.7 | 2.6 |
| | 10 | 8.3 | 11.8 | 44.9 | 33.0 | 3.0 | 3.9 |
| | 20 | 8.3 | 16.0 | 56.2 | 33.6 | 4.1 | 5.4 |
| | 30 | 9.7 | 14.3 | 45.2 | 39.7 | 4.3 | 5.6 |
| | Mean | 7.6 | 12.5 | 47.6 | 34.7 | 3.3 | 4.4 |
| Cocoyam + IT97K-499-35 | 0 | 9.0 | 9.3 | 22.2 | 24.8 | 2.0 | 2.3 |
| | 10 | 11.8 | 15.9 | 33.7 | 41.2 | 3.7 | 6.6 |
| | 20 | 14.6 | 21.0 | 34.9 | 44.0 | 5.3 | 9.4 |
| | 30 | 12.8 | 20.1 | 38.1 | 37.8 | 4.8 | 7.8 |
| | Mean | 12.1 | 16.7 | 32.2 | 36.9 | 4.0 | 6.5 |

| | | *2012* | | | *2013* | | |
|---|---|---|---|---|---|---|---|
| | | *NC* | *CW* | *NY* | *NC* | *CW* | *NY* |
| *$LSD_{(0.05)}$ for crop combination (C) mean =* | *2.8* | *9.5* | *0.7* | *3.9* | *2.8* | *1.7* | |
| *$LSD_{(0.05)}$ for cow dung (D) mean* | *=* | *3.2* | *NS* | *0.9* | *4.5* | *3.2* | *2.0* |
| *$LSD_{(0.05)}$ for C x D mean* | *=* | *NS* | *NS* | *NS* | *NS* | *5.5* | *NS* |

*NC = Number of corms; CW = Corm weight; CY = Corm yield*

## 3.3 Productivity of the System

There were yield advantages of growing cocoyam and cowpea in mixture as depicted by average total LER of 1.83 – 2.53 (Table 9), mean LEC of 0.68 - 1.44 and mean ATER of 1.09 – 1.58 (Table 10). The total land equivalent ratios and ATERs for the intercrops were greater than one and higher when cocoyam was intercropped with erect IT97K-499-35 than with climbing *Akidienu* in both years. On average, total LER increased with cow dung rates up to 20 t/ha. Partial land equivalent ratio was generally higher with cowpea than with cocoyam. Similarly, LEC and ATER increased with cow dung rates up to 20 t/ha and were higher when cocoyam was combined with erect IT97K-499-35 than with climbing *Akidienu* in both years of cropping. ATER values of the two years were lower than LER.

**Table 4. Effect of intercropping and cow dung on mean corm yield (t/ha) of cocoyam**

| Crop combination | Cow dung (t/ha) | | | | Mean |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | |
| Sole cocoyam | 3.3 | 6.8 | 8.2 | 9.0 | 6.8 |
| Cocoyam + *Akidienu* | 2.2. | 3.4 | 4.7 | 5.0 | 3.8 |
| Cocoyam + IT97K-499-35 | 2.2 | 5.2 | 7.4 | 6.3 | 5.3 |
| Mean | 2.6 | 5.1 | 6.8 | 6.8 | |

*$LSD_{(0.05)}$ for crop combination (C) mean = 1.1*
*$LSD_{(0.05)}$ for cow dung (D) mean = 1.2*
*$LSD_{(0.05)}$ for C x D mean = NS*

**Table 5. Effect of intercropping and cow dung on growth characteristics of cowpea at I MAP in 2012 and 2013**

| Crop combination | Cow dung(t/ha) | Plant height (cm) | | Root weight (g) | | Shoot weight (g) | |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| *Akidienu* + cocoyam | 0 | 25.4 | 15.7 | 0.39 | 0.61 | 2.41 | 2.99 |
| | 10 | 62.0 | 44.9 | 0.58 | 0.84 | 4.84 | 5.00 |
| | 20 | 67.4 | 35.8 | 0.73 | 0.89 | 6.05 | 6.05 |
| | 30 | 60.9 | 32.4 | 0.84 | 1.00 | 7.13 | 6.25 |
| | Mean | 53.9 | 32.2 | 0.63 | 0.84 | 5.11 | 5.07 |
| IT97K-499-35 + Cocoyam | 0 | 16.0 | 16.8 | 0.33 | 0.47 | 2.01 | 3.44 |
| | 10 | 22.1 | 14.1 | 0.33 | 0.73 | 2.14 | 4.01 |
| | 20 | 22.1 | 15.1 | 0.48 | 0.92 | 5.76 | 5.36 |
| | 30 | 23.0 | 16.1 | 0.52 | 0.96 | 5.66 | 5.59 |
| | Mean | 20.8 | 15.6 | 0.42 | 0.77 | 3.89 | 4.60 |
| Sole *Akidienu* | 0 | 27.9 | 20.7 | 0.40 | 0.51 | 2.13 | 2.71 |
| | 10 | 52.2 | 33.0 | 0.50 | 0.73 | 4.54 | 5.38 |
| | 20 | 61.6 | 30.7 | 0.70 | 0.92 | 5.74 | 5.81 |
| | 30 | 60.8 | 27.8 | 0.69 | 0.95 | 6.64 | 7.62 |
| | Mean | 50.6 | 28.0 | 0.56 | 0.78 | 4.76 | 5.38 |
| Sole IT97K-499-35 | 0 | 17.4 | 14.6 | 0.33 | 0.53 | 2.32 | 2.76 |
| | 10 | 22.6 | 15.8 | 0.43 | 0.77 | 4.13 | 4.68 |
| | 20 | 23.8 | 15.8 | 0.52 | 0.90 | 5.67 | 5.85 |
| | 30 | 24.9 | 17.8 | 0.67 | 1.05 | 6.71 | 7.68 |
| | Mean | 22.2 | 16.0 | 0.49 | 0.81 | 4.71 | 5.29 |

| | | 2012 | | | 2013 | | |
|---|---|---|---|---|---|---|---|
| | | *PH* | *RW* | *SW* | *PH* | *RW* | *SW* |
| *$LSD_{(0.05)}$ for crop combination (C) mean* | = | *7.4* | *0.09* | *NS* | *5.3* | *NS* | *NS* |
| *$LSD_{(0.05)}$ for cow dung (D) mean* | = | *7.4* | *0.09* | *1.23* | *5.3* | *0.33* | *1.92* |
| *$LSD_{(0.05)}$ for C x D mean* | = | *14.8* | *NS* | *NS* | *10.7* | *NS* | *NS* |

*PH = Plant height; RW = Root weight; SW = Shoot weight*

The LERs for all treatments were generally greater than one, indicating that the mixtures were more efficient and that more lands will be required for monocrops to produce the yields achieved in the intercropping. Many studies on intercropping have shown that intercrop may give higher and more stable yield than when any of the components is grown as sole crop i.e. over yielding, termed mutual cooperation [27;28] due to complementarity effects of the system. The LER values (1.73 – 2.53) recorded in our study were higher than the range of 1.15 – 1.20 earlier reported by Willey [29] to be of significant economic advantage in intercropping. The LEC values for all the treatments were greater than 0.25, which is regarded as the minimum expected value for the two crop combinations to be advantageous [14]. ATERs were lower compared to LER values. This confirms the reports of Cenpukdee and Fukai [23] and Mutsaers et al. [30] that LER tends to overestimate land use advantage when long duration crops are involved in an intercropping system. Asim et al. [31] in their study on cotton/cowpea mixtures used ATER to evaluate land use advantage and reported that ATER is a better tool than LER. On the whole, the highest productivity was accrued to cocoyam combined with the erect IT97K-499-35 cowpea, which produced the highest mean total LER of 2.53; LEC of 1.44 and ATER of 1.58, when cow dung was applied at 20 t/ha. The higher LER, LEC and ATER obtained from the erect IT97K-499-35 cowpea in mixture could be attributed to better establishment and display of the cowpea leaves for adequate photo-assimilate interception.

**Table 6. Effect of intercropping and cow dung on pod yield attributes of cowpea in 2012 and 2013**

| Crop combination | Cow dung (t/ha) | NP per plant | | PW (g/pod) | | PY (t/ha) | |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| *Akidienu* + cocoyam | 0 | 5.3 | 7.9 | 6.12 | 6.28 | 1.35 | 2.04 |
| | 10 | 7.2 | 8.2 | 6.06 | 5.48 | 1.75 | 1.68 |
| | 20 | 6.5 | 8.7 | 6.34 | 5.57 | 1.69 | 1.81 |
| | 30 | 7.9 | 10.1 | 6.44 | 5.89 | 1.99 | 2.45 |
| | Mean | 6.7 | 8.7 | 6.25 | 5.81 | 1.69 | 2.00 |
| IT97K-499-35 + Cocoyam | 0 | 12.0 | 34.7 | 5.42 | 8.12 | 2.47 | 11.64 |
| | 10 | 25.6 | 57.9 | 5.41 | 8.47 | 5.38 | 19.10 |
| | 20 | 27.8 | 60.3 | 5.32 | 8.08 | 5.86 | 19.19 |
| | 30 | 28.4 | 61.8 | 5.12 | 8.14 | 5.83 | 19.46 |
| | Mean | 23.4 | 53.7 | 5.32 | 8.20 | 4.89 | 17.35 |
| Sole *Akidienu* | 0 | 4.9 | 7.0 | 6.81 | 7.01 | 1.29 | 1.94 |
| | 10 | 4.9 | 6.3 | 7.20 | 6.28 | 1.41 | 1.62 |
| | 20 | 5.0 | 7.1 | 6.35 | 7.31 | 1.21 | 2.00 |
| | 30 | 6.9 | 8.4 | 6.19 | 6.93 | 1.53 | 2.39 |
| | Mean | 5.4 | 7.2 | 6.64 | 6.88 | 1.39 | 1.99 |
| Sole IT97K-499-35 | 0 | 15.5 | 36.8 | 5.50 | 7.84 | 3.42 | 13.12 |
| | 10 | 19.1 | 50.1 | 5.51 | 8.25 | 4.25 | 16.40 |
| | 20 | 18.5 | 58.0 | 5.02 | 7.02 | 3.71 | 16.74 |
| | 30 | 20.3 | 60.4 | 5.23 | 7.97 | 4.40 | 21.08 |
| | Mean | 18.4 | 51.3 | 5.32 | 7.77 | 3.94 | 16.84 |

| | | 2012 | | | 2013 | | |
|---|---|---|---|---|---|---|---|
| | | *NP* | *PW* | *PY* | *NP* | *PW* | *PY* |
| *$LSD_{(0.05)}$ for crop combination (C) mean* | = | *2.6* | *0.53* | *0.63* | *14.1* | *0.95* | *5.0* |
| *$LSD_{(0.05)}$ for cow dung (D) mean* | = | *2.6* | *NS* | *0.63* | *NS* | *NS* | *NS* |
| *$LSD_{(0.05)}$ for C x D mean* | = | *5.2* | *NS* | *1.25* | *NS* | *NS* | *NS* |

*NP = Number of pods; PW = pod weight; PY = Pod yield*

**Table 7. Effect of intercropping and cow dung on mean fresh pod yield (t/ha) of cowpea**

| Crop combination | Cow dung (t/ha) | | | | Mean |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | |
| *Akidienu* + cocoyam | 1.70 | 1.71 | 1.75 | 2.22 | 1.83 |
| IT97K-499-35 + Cocoyam | 7.05 | 12.24 | 12.53 | 12.64 | 11.12 |
| Sole *Akidienu* | 1.62 | 1.52 | 1.61 | 1.96 | 1.68 |
| Sole IT97K-499-35 | 8.27 | 10.33 | 10.22 | 12.74 | 10.39 |
| Mean | 4.66 | 6.45 | 6.53 | 7.39 | |

*$LSD_{(0.05)}$ for crop combination (C) mean = 2.61*
*$LSD_{(0.05)}$ for cow dung (D) mean = NS*
*$LSD_{(0.05)}$ for C x D mean = NS*

**Table 8. Effect of intercropping and cow dung on seed yield attributes of cowpea in 2012 and 2013**

| Crop combination | Cow dung (t/ha) | NS per pod | | 100 seed wt (g) | | SY (kg/ha) | |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 |
| *Akidienu* + cocoyam | 0 | 17.8 | 19.6 | 12.1 | 12.3 | 44.6 | 80.7 |
| | 10 | 16.8 | 18.8 | 11.5 | 11.6 | 54.6 | 76.2 |
| | 20 | 17.9 | 18.2 | 12.7 | 11.7 | 60.3 | 73.5 |
| | 30 | 17.5 | 18.2 | 11.0 | 10.2 | 62.1 | 75.9 |
| | Mean | 17.5 | 18.7 | 11.8 | 11.5 | 55.4 | 76.6 |
| IT97K-499-35 + Cocoyam | 0 | 14.3 | 14.8 | 16.1 | 20.4 | 109.4 | 436.5 |
| | 10 | 15.2 | 15.1 | 19.0 | 20.4 | 285.5 | 696.7 |
| | 20 | 14.8 | 15.1 | 16.4 | 20.7 | 235.3 | 751.7 |
| | 30 | 14.2 | 15.6 | 16.2 | 21.1 | 261.6 | 801.5 |
| | Mean | 14.6 | 15.1 | 16.9 | 20.7 | 222.9 | 671.6 |
| Sole *Akidienu* | 0 | 18.8 | 19.3 | 12.2 | 10.7 | 48.9 | 63.7 |
| | 10 | 18.0 | 19.4 | 11.0 | 10.9 | 38.1 | 49.8 |
| | 20 | 18.3 | 20.1 | 13.5 | 10.8 | 49.9 | 61.6 |
| | 30 | 16.3 | 19.9 | 11.8 | 13.1 | 54.2 | 87.4 |
| | Mean | 17.8 | 19.7 | 12.4 | 11.4 | 47.8 | 65.6 |
| Sole IT97K-499-35 | 0 | 13.8 | 14.4 | 16.2 | 19.6 | 136.5 | 451.2 |
| | 10 | 15.8 | 14.6 | 18.0 | 21.0 | 223.3 | 603.4 |
| | 20 | 15.3 | 15.0 | 16.8 | 21.6 | 190.4 | 830.5 |
| | 30 | 15.0 | 15.7 | 18.0 | 24.5 | 234.3 | 1192.7 |
| | Mean | 15.0 | 14.9 | 17.2 | 21.7 | 196.1 | 769.5 |

| | | *2012* | | | *2013* | | |
|---|---|---|---|---|---|---|---|
| | | *NSP* | *SW* | *SY* | *NSP* | *SW* | *SY* |
| *$LSD_{(0.05)}$ for crop combination (C) mean* | = | *1.64* | *1.4* | *28.3* | *1.20* | *3.5* | *331.2* |
| *$LSD_{(0.05)}$ for cow dung (D) mean* | = | *NS* | *NS* | *28.3* | *NS* | *NS* | *NS* |
| *$LSD_{(0.05)}$ for C x D mean* | = | *NS* | *NS* | *56.5* | *NS* | *NS* | *NS* |

*NSP = Number of seeds per pod; SW = 100 seed weight; SY = Seed yield*

**Table 9. Partial and total land equivalent ratio (LER) of cocoyam and cowpea intercrop in 2012 and 2013**

| Treatment | Partial LER | | | | Total LER | | Mean |
|---|---|---|---|---|---|---|---|
| | Cocoyam | | Cowpea | | | | |
| | 2012 | 2013 | 2012 | 2013 | 2012 | 2013 | |
| **Cropping system (CS)** | | | | | | | |
| Sole | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Intercrop | 0.63 | 0.73 | 1.29 | 1.33 | 1.92 | 2.06 | 1.99 |
| **Cow dung rate (CD) (t/ha)** | | | | | | | |
| 0 | 0.60 | 0.81 | 0.96 | 1.34 | 1.56 | 2.15 | 1.86 |
| 10 | 0.60 | 0.67 | 1.35 | 1.27 | 1.96 | 1.94 | 1.95 |
| 20 | 0.72 | 0.76 | 1.48 | 1.31 | 2.20 | 2.07 | 2.14 |
| 30 | 0.60 | 0.69 | 1.37 | 1.42 | 1.97 | 2.11 | 2.04 |
| **CS x CD** | | | | | | | |
| Cocoyam + *Akidienu* x 0 t/ha | 0.54 | 0.87 | 1.15 | 1.10 | 1.69 | 1.97 | 1.83 |
| Cocoyam + *Akidienu* x 10 t/ha | 0.53 | 0.50 | 1.35 | 1.35 | 1.88 | 1.85 | 1.87 |
| Cocoyam + *Akidienu* x 20 t/ha | 0.64 | 0.57 | 1.30 | 0.94 | 1.94 | 1.51 | 1.73 |
| Cocoyam + *Akidienu* x 30 t/ha | 0.59 | 0.57 | 1.24 | 1.11 | 1.83 | 1.68 | 1.76 |
| Cocoyam + IT97K-499-35 x 0 t/ha | 0.66 | 0.74 | 0.76 | 1.58 | 1.42 | 2.32 | 1.87 |
| Cocoyam + IT97K-499-35 x 10 t/ha | 0.66 | 0.84 | 1.34 | 1.18 | 2.00 | 2.02 | 2.01 |
| Cocoyam + IT97K-499-35 x 20 t/ha | 0.79 | 0.94 | 1.66 | 1.67 | 2.45 | 2.61 | 2.53 |
| Cocoyam + IT97K-499-35 x 30 t/ha | 0.60 | 0.81 | 1.50 | 1.73 | 2.10 | 2.54 | 2.32 |

**Table 10. Land equivalent coefficient (LEC) and area x time equivalent ratio (ATER) of cocoyam and cowpea intercrop in 2012 and 2013**

| Treatment | LEC | | | ATER | | |
|---|---|---|---|---|---|---|
| | 2012 | 2013 | Mean | 2012 | 2013 | Mean |
| **Cropping system (CS)** | | | | | | |
| Sole | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Intercrop | 0.81 | 0.97 | 0.89 | 1.18 | 1.30 | 1.24 |
| **Cow dung rate (CD) (t/ha)** | | | | | | |
| 0 | 0.58 | 1.09 | 0.84 | 1.01 | 1.38 | 1.20 |
| 10 | 0.81 | 0.85 | 0.83 | 1.18 | 1.21 | 1.20 |
| 20 | 1.07 | 1.00 | 1.04 | 1.35 | 1.32 | 1.34 |
| 30 | 0.82 | 0.98 | 0.90 | 1.19 | 1.30 | 1.25 |
| **CS x CD** | | | | | | |
| Cocoyam + *Akidienu* x 0 t/ha | 0.62 | 0.96 | 0.79 | 1.03 | 1.34 | 1.19 |
| Cocoyam + *Akidienu* x 10 t/ha | 0.72 | 0.68 | 0.70 | 1.11 | 1.08 | 1.10 |
| Cocoyam + *Akidienu* x 20 t/ha | 0.83 | 0.53 | 0.68 | 1.20 | 0.97 | 1.09 |
| Cocoyam + *Akidienu* x 30 t/ha | 0.73 | 0.63 | 0.68 | 1.12 | 1.05 | 1.09 |
| Cocoyam + IT97K-499-35 x 0 t/ha | 0.50 | 1.17 | 0.84 | 0.99 | 1.42 | 1.21 |
| Cocoyam + IT97K-499-35 x 10 t/ha | 0.88 | 0.90 | 0.94 | 1.23 | 1.35 | 1.29 |
| Cocoyam + IT97K-499-35 x 20 t/ha | 1.31 | 1.57 | 1.44 | 1.50 | 1.66 | 1.59 |
| Cocoyam + IT97K-499-35 x 30 t/ha | 0.90 | 1.40 | 1.15 | 1.24 | 1.55 | 1.40 |

## 4. CONCLUSION

The results showed that there was greater reduction in cocoyam corm yield when it was intercropped with climbing *Akidienu* in relation to when it was intercropped with erect IT-97K-499-35. Application of cow dung improved growth and yield of cocoyam with optimum performance at cow dung rate of 10 t/ha. Similarly, the cowpea varieties yielded optimally at cow dung rate of 10 t/ha. Combining cocoyam with erect IT-97K-499-35 plus cow dung rate at 20 t/ha recorded the highest LER and ATER and is therefore recommended.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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