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Growth and Yield Responses of Cocoyam (*Colocasia esculenta* (L.) Schott) to Organic Wastes in the Humid Agro-Ecological Zone of South-Eastern Nigeria

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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

Aim: To evaluate the growth and yield responses of cocoyam to different rates of application of cow dung and rice husk.
Study Design: 2 x 4 factorial arrangement in a randomized complete block design replicated three times.
Place and Duration of Study: The experiment was conducted in National Horticultural Research Institute (NIHORT), Mbato sub Station, Okigwe, Imo State, Nigeria in 2012 and 2013 cropping seasons.
Methodology: The treatments comprised of two manure sources (cow dung and rice husk) at four levels (0, 10, 20 and 30 t/ha) each. The treatments were assigned randomly to the plots and

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incorporated into the soil two weeks before planting. Data were collected on plant height, number of leaves, leaf area, leaf area index, number of suckers, number of corms, corm weight and corm yield. The data collected were subjected to ANOVA at 5% probability level.
Results: Cocoyam growth and yield increased significantly (*P* = 0.05) with increased application of cow dung up to 20 t/ha when the soil had 0.03% N and 0.65% OM in 2012, but not beyond the rate of 10 t/ha in 2013 when the soil had 0.06% N and 1.22% OM. Average of the two years of cropping gave optimum yield of 18.0 t/ha at 20 t/ha cow dung rate. This rate increased yield by 58% over the control. Rice husk applied at 30 t/ha significantly (*P* = 0.05) increased cocoyam growth compared to the other rates while cocoyam yield was not significantly increased above the rate of 20 t/ha rice husk in 2013. 20 t/ha rice husk recorded yield of 17 t/ha, which was higher than the control by 19%, on the average.
Conclusion: Results of this investigation showed that cow dung and rice husk are potential organic soil amendments for increasing cocoyam production. It is therefore reasonable to recommend the use of 10-20 t/ha cow dung and 20 t/ha rice husk in the cultivation of cocoyam in humid agro-ecological zone of South-eastern Nigeria.

Keywords: Cocoyam; cow dung; corm yield; rice husk; soil fertility.

1. INTRODUCTION

Cocoyam (*Colocasia esculenta* [L.] Schott) is a staple food in many developing countries. It is cultivated in the tropical and sub-tropical regions of the world [1]. Among the tuber crops of economic importance, cocoyam ranks third after yam and cassava [2]. Cocoyam is grown for its edible corms, cormels and leaves as well as other traditional uses [3]. Its corms and cormels are eaten in the same way as yams and sweet potatoes, although it is not as highly valued [4]. Fresh cocoyam contains about 70-80 percent water, 20-75 percent carbohydrate and 1.5-3.0 percent protein; it also contains significant amounts of vitamin C, thiamine, riboflavin, niacin and carotene [5]. Nutritionally, cocoyam is superior to cassava and yam in the possession of higher protein content, mineral and vitamin contents. It contains over 80% and 240% higher digestible crude protein than yam and cassava, respectively [6].

In spite of the nutritional advantages of cocoyam and its potential for poverty alleviation, relatively little research has been devoted to it; thus, its potentials as an important staple food crop and associated nutritional and health benefits has remained under exploited [7]. In recent times however, there has been significant increases in the production of cocoyam in West and Central Africa due to increased area under cultivation rather than increase in crop yield per land area; thus, the average yield per land area is relatively low [7]. The reason being that cocoyam production in these areas is often on marginal soils with minimal input of fertilizer whether organic or inorganic. Increasing yield per land area can be achieved by increasing cropping intensity on existing farmlands and by applying fertilizer in order to increase soil fertility.

However, efforts to supplement the soil nutrient status with inorganic fertilizers have not been sustainable due to high cost and infrequent availability of chemical fertilizers, especially by the poor resource farmers who are known to cultivate this crop [8]. Soil degradation, increased soil acidity, nutrient leaching and soil nutrient imbalance associated with the continuous use of inorganic fertilizers and their polluting effects on the environment have also made these fertilizers unsuitable for maintenance of soil fertility [9]. Hence, the focus on the use of organic manures, which are cheap, readily available and affordable and environmental friendly and offers long term benefit of maintaining soil fertility status.

Large quantities of agro-wastes such as cow dung and rice husk are available in Nigeria and some of these wastes pose disposal problems. These wastes can be utilized as sources of nutrients for crops since they contain nutrient elements needed for improvement in soil fertility and consequently crop yields. Many researchers have shown the effectiveness of some of these agro-wastes in improving crop yields including cocoyam [10,11,8]. However, the utilization of these wastes by farmers is still poor despite their nutrient composition [12].

Cocoyam like every other tuber crop is a heavy feeder, exploiting large volume of soil for nutrient and water and responds very well to input of fertilizer, whether organic or inorganic [13]. Uwah et al. [10] reported significant increases in growth and yield of cocoyam (*Colocasia esculenta*) following application of poultry manure and rice husk at the highest rate of 15 t/ha each. They also reported that combined application of 10 t/ha poultry manure and 15 t/ha rice husk gave optimum growth and yield of cocoyam in South eastern Nigeria. Similarly, Hamma et al. [14] reported improvement in cocoyam (*Colocasia esculenta*) growth and yield due to poultry manure application of 10 t/ha in North West of Nigeria. In another study in South West, Nigeria, Ojeniyi et al. [15] recorded optimum performance of cocoyam (*Xanthosoma saggitifolium*) at poultry manure rate of 7.5 t/ha. There is dearth of research on the effect of cow dung and rice husk in cocoyam productivity. The objectives therefore were to determine the influence organic manures (cow dung and rice husk) on the growth and yield of cocoyam in a nutrient-depleted soil and also the optimum rate of application of these manures in cocoyam production.

2. MATERIALS AND METHODS

The experiment was carried out at National Horticultural Research Institute (NIHORT), Mbato sub-station, Okigwe, Imo State, Nigeria. NIHORT is located at latitude 5°33'N and longitude 7°23'E and 139 m above sea level. The area is characterized as a humid rainforest zone and the soil is sandy loam. The total annual rainfalls for 2012 and 2013 were 1902.8 mm and 2210.0 mm, respectively while the total rainfalls during the period of experimentation (April to December) for 2012 and 2013 were 1775.6 mm and 2009.0 mm, respectively.

2.1 Land Preparation and Soil Sampling

The site was double-ploughed and ridged before it was marked into blocks and plots according to the experimental design. Each gross plot measured 4 m x 3 m (12 m^2) with a net plot of 2 m x 2 m. Prior to the commencement of the experiment in each year, soil samples were collected with a soil auger to a depth of 0 - 20 cm from different locations of the experimental site and bulked into composite sample at each year of sampling. The composite soil sample was air dried, passed through 2 mm sieve and then analyzed for its physico-chemical properties (Table 1).

2.2 Experimental Design and Treatments Allocation

The experimental design was a 2 x 4 factorial arrangement in a randomized complete block design. The treatments consisted of four levels (0, 10, 20 and 30 t/ha) each of application of cow dung and rice husk and their combinations. Thus, a total of sixteen treatment combinations were used and each treatment was replicated three times. The treatments were assigned randomly to the plots. The experimental layout is shown in Fig. 1.

Fig. 1. The experimental layout

Table 1. Some physicochemical properties of the experimental soil in 2012 and 2013

Property	2012	2013
Sand (%)	66.80	65.80
Silt (%)	14.40	13.40
Clay (%)	18.80	20.80
Textural class	Sandy loam	Sandy clay loam
pH (in 1:2.5 soil / H_2O)	4.4	5.7
P (mg/kg)	32.40	21.80
N (%)	0.03	0.06
OC (%)	0.30	0.71
OM (%)	0.65	1.22
Ca (cmol/kg)	3.60	3.80
Mg (cmol/kg)	0.40	0.40
K (cmol/kg)	0.031	0.034
Na (cmol/kg)	0.26	0.447

2.3 Soil Amendments and their Nutrients Composition

Composite samples of the organic materials (cow dung and rice husk) used were air dried, crushed and sieved separately and then analyzed in the laboratory for their nutrient compositions (Table 2).

2.4 Crop Husbandry

The cow dung and rice husk were incorporated into the soils of the experimental plots in a single

Table 2. Nutrient composition of the organic materials used in 2012 and 2013

Property	Cow dung		Rice husk	
	2012	2013	2012	2013
Nitrogen (%)	2.54	2.24	1.92	1.68
Phosphorus (%)	1.34	1.67	1.40	1.84
Potassium (%)	1.16	0.65	1.24	0.85
Sodium (%)	0.42	0.35	0.25	0.23
Calcium (%)	1.56	2.80	1.82	3.20
Magnesium (%)	0.46	0.61	0.52	1.20
Organic Carbon (%)	29.41	17.84	48.22	29.80
OM (%)	50.70	30.76	83.13	51.37
C:N	11.57	7.96	25.11	17.73

dose application based on the treatment combinations, at two weeks before planting to allow proper decomposition. Cocoyam cormels var. NCe001 sourced from National Root Crops Research Institute, Umudike, Abia State, were planted on the crest of ridges on 12th May in 2012 and 9th May in 2013 at a depth of 15 cm and at a spacing of 0.5 m and 1.0 m. one cormel weighing 35 – 45 g was planted per hole resulting in about twenty-four plants per plot and a total of about 20,000 plants per hectare. Supply of missing stands was done at 3 weeks after planting (WAP). All plots were kept weed free by manual weeding.

2.5 Data Collection

Five plants were randomly selected and tagged at 1 MAP from each of the net plots and used for the growth parameter measurements. Growth parameters evaluated were plant height, number of leaves, leaf area, leaf area index at 1, 3 and 5 MAP, number of suckers at 3 MAP. The leaf area was determined using the formula of Biradar et al. [16] 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 [16].

Yield attributes measured included number of tubers, tuber weight (kg/plant) and tuber yield (t/ha). These were measured at physiological maturity of the crop. The total number of corms and cormels produced by each plant were physically counted and recorded as the number of tubers; their weights were determined and recorded as the tuber weight and thereafter converted to tuber yield in tons per hectare.

2.6 Data Analysis

Data collected were subjected to analysis of variance using Genstat Discovery (Edition 3) Package of 2007. Significant means were separated and compared using Fisher's Least Significant Difference (F-LSD) at probability level of 0.05.

3. RESULTS

3.1 Growth Parameters

At 1 MAP, application of cow dung at 20 and 30 t/ha recorded statistically same plant height values that were significantly (P = 0.05) higher than the control in 2012 (Table 3). However, at 3 and 5 MAP, all cases of cow dung application significantly (P = 0.05) increased cocoyam plant height over no application. Furthermore, at 3 and 5 MAP, application of cow dung at the higher rates of 20 and 30 t/ha resulted in taller cocoyam plants than the application of the lower rate of 10 t/ha. In 2013, differences in plant height were significant (P = 0.05) from 3 MAP. Application of cow dung irrespective of the rates recorded similar values but higher plant height than the control at 3 and 5 MAP. On the other hand, rice husk treatment significantly (P = 0.05) affected cocoyam plant height at 5 MAP only in 2012. Application of rice husk significantly increased cocoyam plant height compared to the control; whereas all cases of applied rice husk recorded statistically similar plant height values. However, in 2013 rice husk application had significant effect on plant height in all the months sampled (Table 3). All cases of rice husk application recorded similar plant height values at 1 MAP. But at 3 and 5 MAP, application of 30 t/ha resulted in significantly taller plants than the lower rates of 10 and 20 t/ha.

In 2012 and at 1 MAP, cow dung applied at 20 and 30 t/ha produced number of leaves that were not significantly (P = 0.05) different but significantly (P = 0.05) higher than the number of leaves produced by the control plants (Table 4). At 3 MAP, application of cow dung up to 20 t/ha increased significantly (P = 0.05) the number of leaves but above this rate no significant increase was observed; while at 5 MAP, increasing above 10 t/ha did result in a significant increase in number of leaves of cocoyam. However in 2013, application of cow dung at 10 t/ha gave significantly (P = 0.05) higher number of leaves compared to the higher rate of 30 t/ha at 1 MAP. At 3 and 5 MAP, application of cow dung no matter the rate recorded similar values but higher number of leaves than the control. Rice husk effect on number of leaves per cocoyam plant was significant (P = 0.05) only at 3 and 5 MAP in 2012 and at all the sampled months in 2013 (Table 4). In 2012, the different rates of applied rice husk recorded similar values but higher number of leaves than the control. In 2013, all cases of rice husk application resulted in significantly (P = 0.05) higher number of leaves than the control except at 3 MAP where 10 t/ha

Table 3. Effect of cow dung and rice husk on plant height (cm) of cocoyam at 1, 3 and 5 MAP in 2012 and 2013 cropping years

Treatment	Months after planting					
	1	3	5	1	3	5
	2012			2013		
Cow dung (t/ha)						
0	12.0	48.0	50.2	19.8	58.3	59.1
10	13.5	57.8	61.3	19.7	66.5	67.9
20	14.5	63.9	65.6	18.1	64.6	68.1
30	14.9	66.0	67.0	17.8	67.3	71.2
$LSD_{(0.05)}$	2.0	4.5	3.4	NS	4.3	3.8
Rice husk (t/ha)						
0	12.8	56.9	57.1	16.6	58.0	60.4
10	14.3	60.3	61.3	19.1	61.9	64.1
20	14.5	59.9	62.2	19.7	64.8	67.7
30	13.3	58.6	63.6	20.0	72.1	74.2
$LSD_{(0.05)}$	NS	NS	3.4	2.5	4.3	3.8
C x R	NS	NS	NS	NS	NS	NS

Table 4. Effect of cow dung and rice husk on number of leaves per cocoyam plant at 1, 3 and 5 MAP in 2012 and 2013

Treatment	Months after planting					
	1	3	5	1	3	5
	2012			2013		
Cow dung (t/ha)						
0	3.6	15.7	20.2	5.6	22.7	24.9
10	4.0	22.4	28.4	5.7	26.1	30.0
20	4.2	26.3	29.5	5.2	26.9	31.3
30	4.3	28.1	31.2	4.8	27.6	31.8
$LSD_{(0.05)}$	0.4	2.8	3.3	0.6	3.0	3.5
Rice husk (t/ha)						
0	3.9	20.3	21.9	4.5	21.6	24.4
10	4.1	23.4	26.3	5.4	23.9	28.5
20	4.1	24.6	29.5	5.5	26.5	31.8
30	4.0	24.2	31.3	5.8	31.2	33.1
$LSD_{(0.05)}$	NS	2.8	3.3	0.6	3.0	3.5
C x R	NS	NS	NS	NS	NS	NS

of applied rice husk and the control recorded similar values. Furthermore, rice husk applied at the rate of 30 t/ha recorded significantly (*P* = 0.05) higher number of leaves (31.2) than the lower rates of 10 t/ha (23.9) and 20 t/ha (26.5) at 3 MAP and 10 t/ha (28.5) at 5 MAP.

Cow dung effect on leaf area was significant from 3 MAP in 2012. Application of cow dung regardless of the rate increased significantly (*P* = 0.05) leaf area of cocoyam relative to the control (Table 5). However, at 5 MAP, increasing cow dung rate above 20 t/ha did not result in further increase in leaf area. In 2013, effect of cow dung on leaf area was significant at 1 and 5 MAP. At 1 MAP, cow dung application at 10 t/ha recorded significantly (*P* = 0.05) higher leaf area compared to the higher rates of 20 and 30 t/ha. At 5 MAP however, all cases of cow dung application recorded statistically similar leaf area value but significantly (P = 0.05) higher value than the control. Effect of rice husk application on leaf area was significant in 2013 only (Table 5). At 1 and 3 MAP, application of rice husk irrespective of the rate gave significantly (*P* = 0.05) higher leaf area relative to the control. At 5 MAP, application of rice husk at 20 and 30 t/ha recorded significantly (P = 0.05) higher leaf area value compared to the control. Furthermore, application of 30 t/ha rice husk recorded significantly (P = 0.05) higher leaf area compared to the lower rate of 10 t/ha.

Initially at 1 MAP, there was no significant effect of cow dung application on leaf area index (LAI), but effect became more apparent as from 3 MAP in 2012 (Table 6). As from 3MAP, application of cow dung regardless of rates increased significantly (*P* = 0.05) LAI compared to no cow dung application, while the different rates of cow dung recorded statistically similar values. In 2013, application of cow dung at 10 t/ha produced significantly (*P* = 0.05) higher LAI than the higher manure rates of 20 or 30 t/ha at 1 MAP. At 3 and 5 MAP in 2013, application of cow dung gave higher LAI than no manure application. LAI was not significantly affected by the application of rice husk at the different months of cocoyam growth in 2012 except at 5 MAP (Table 6). Rice husk applied at the rate of 30 t/ha recorded significantly (*P* = 0.05) higher LAI than the lower rates of 10 and 20 t/ha, while 20 t/ha of applied rice husk increased significantly the number of leaves compared to the control. However, in 2013, rice husk application gave significantly (*P* = 0.05) higher LAI than plots without rice husk application at all the sampled periods. Increasing rice husk above 10 t/ha did not significantly increase LAI at 1 MAP, but at 3 and 5 MAP, application of rice husk at 30 t/ha increased significantly LAI relative to the lower rates of 10 and 20 t/ha, which recorded similar values.

Application of cow dung increased significantly (*P* = 0.05) the number of suckers produced per cocoyam plant in 2012 and 2013 cropping seasons (Table 5). In 2012, increasing the rate of application of cow dung from 0 to 20 t/ha significantly increased the number of suckers

Table 5. Effect of cow dung and rice husk on leaf area (cm^2) of cocoyam at 1, 3 and 5 MAP in 2012 and 2013

Treatment	Months after planting					
	1	3	5	1	3	5
	2012			2013		
Cow dung (t/ha)						
0	123.9	496.9	598.7	256.2	679.9	876.7
10	152.3	727.8	857.3	277.5	722.8	1085.0
20	175.2	817.7	977.5	225.2	669.4	1180.0
30	185.1	839.3	1044.3	228.3	677.3	1253.54
$LSD_{(0.05)}$	NS	122.7	106.1	47.1	NS	188.04
Rice husk (t/ha)						
0	139.2	716.5	818.5	202.8	542.4	897.8
10	170.25	740.4	898.9	264.1	673.9	1005.2
20	177.9	722.15	890.2	262.2	740.9	1124.8
30	149.3	702.7	869.7	258.2	792.3	1367.5
$LSD_{(0.05)}$	NS	NS	NS	47.08	122.7	188.0
C x R	NS	NS	NS	NS	NS	NS

compared to the control. However in 2013, application of cow dung regardless of the rate recorded similar values but higher number of suckers than the control. Effect of rice husk on number of suckers was significant only in 2013 (Table 7). Application of rice husk at 30 t/ha recorded significantly (*P* = 0.05) higher number of suckers compared to the other rates while 10 t/ha and 20 t/ha of applied rice husk recorded similar values but significantly higher number of suckers relative to the control.

3.2 Yield Attributes

In 2012, the number of tubers produced per plant increased significantly (*P* = 0.05) with application of cow dung up to 20 t/ha (Table 7). However, in 2013, application of cow dung at different rates recorded significantly (*P* = 0.05) higher number of tubers relative to the control. Generally, application of the different cow dung rates produced similar values but higher number of tubers than without manure application. The effect of rice husk on number of tubers harvested in 2013 was such that application of 30 t/ha significantly (*P* = 0.05) had higher values than application of 10 or 20t/ha, which also produced more tubers than no rice husk application. Interactions between cow dung and rice husk did not have any significant effect on number of corms in both years.

Similarly, application of cow dung significantly (*P* = 0.05) affected the weight of tubers in both cropping seasons (Table 8). In 2012, weight of tubers increased significantly with increasing application of cow dung up to 20 t/ha, beyond which no significant increase occurred. In 2013, raising cow dung rate above 10 t/ha did not yield any significant changes in weight of tubers per plant. Application of rice husk at the higher rates of 20 and 30t/ha had significantly (*P* = 0.05) higher tuber weight than the control. Cow dung and rice husk interaction effect was not significant on tuber weight in both years.

Tubers yield largely followed the same trends as tuber weight in response to cow dung application in the two cropping seasons (Table 8). Tubers yield increased significantly as cow dung rate increased up-to 20 t/ha in 2012 and not beyond 10 t/ha in 2013. Average of the two cropping seasons gave tuber yields of 15.7 t/ha and 18.0 t/ha at cow dung rates of 10 and 20 t/ha, respectively. Average yield when no cow dung was applied was 11.4 t/ha and increases in cow dung rate from zero to 10 t/ha, increased corm yield by 38%, while a further increase to 20 t/ha increased yield by 58%. Raising the cow dung rate further to 30 t/ha, however gave a marginal increase of 7% in yield in comparison with 10 t/ha manure rate. Similarly, corm yield in 2013 increased significantly (*P* = 0.05) with application of rice husk up to 20 t/ha relative to no application of rice husk. Application of rice husk at the highest rate of 30 t/ha did not produce further yield advantage over 20 t/ha. Application of rice husk at 20 t/ha recorded tuber yield value of 22.0 t/ha in 2013. Interactions between cow dung and rice husk on tuber yield were not significant in both years but tuber yields were generally higher in 2013.

Table 6. Effect of cow dung and rice husk on leaf area index (LAI) of cocoyam at 1, 3 and 5 MAP in 2012 and 2013

Treatment	Months after planting					
	1	3	5	1	3	5
	2012			2013		
Cow dung (t/ha)						
0	0.11	1.43	2.40	0.30	2.73	3.02
10	0.15	2.88	3.32	0.33	3.40	3.84
20	0.18	3.37	3.55	0.24	3.36	3.98
30	0.18	3.42	3.77	0.22	3.50	4.16
$LSD_{(0.05)}$	NS	0.61	0.51	0.07	0.49	0.49
Rice husk (t/ha)						
0	0.13	2.49	2.68	0.19	2.57	2.86
10	0.17	2.83	3.12	0.29	3.05	3.65
20	0.17	3.00	3.33	0.29	3.36	3.97
30	0.15	2.79	3.92	0.31	4.02	4.52
$LSD_{(0.05)}$	NS	NS	0.51	0.07	0.49	0.49
C x R	NS	NS	NS	NS	NS	NS

Table 7. Effect of cow dung and rice husk on number of suckers (at 3 MAP) and number of corms per plant (at harvest) in 2012 and 2013

Treatment	Number of suckers/plant		Number of tubers/plant	
	2012	2013	2012	2013
Cow dung (t/ha)				
0	3.16	4.53	10.81	19.81
10	4.42	5.17	13.92	22.17
20	5.17	5.18	17.50	22.33
30	5.21	5.40	18.19	23.96
$LSD_{(0.05)}$	0.52	0.60	2.21	2.08
Rice husk (t/ha)				
0	4.29	4.46	15.12	18.52
10	4.65	4.79	15.60	21.27
20	4.58	5.16	16.02	22.65
30	4.43	5.88	13.67	25.83
$LSD_{(0.05)}$	NS	0.60	NS	2.08
C x R	NS	NS	NS	NS

Table 8. Effect of cow dung and rice husk on weight of tubers (kg/plant) and tuber yield (t/ha) at harvest in 2012 and 2013

Treatment	Tuber weight (kg/plant)		Tuber yield (t/ha)	
	2012	2013	2012	2013
Cow dung (t/ha)				
0	0.339	0.799	6.79	15.98
10	0.495	1.079	9.90	21.58
20	0.666	1.131	13.33	22.62
30	0.713	1.206	14.23	24.12
$LSD_{(0.05)}$	0.116	0.150	2.24	3.00
Rice husk (t/ha)				
0	0.543	0.882	10.85	17.65
10	0.597	1.027	11.92	20.54
20	0.588	1.100	11.79	22.00
30	0.485	1.206	9.69	24.12
$LSD_{(0.05)}$	NS	0.150	NS	3.00
C x R	NS	NS	NS	NS

On average, tuber yield increased significantly with cow dung application up to 20 t/ha, beyond which no further yield improvement occurred (Table 9). Tuber yield obtained from application of cow dung at 20 t/ha was 18 t/ha and this was higher than the yields from application of 0 and 10 t/ha cow dung rates by 58% and 14%, respectively. Similarly, application of rice husk at 20 t/ha produced significantly higher tuber yield over no rice husk application. All cases of applied rice husk gave similar tuber yield values. Interactions produced no significant effects on tuber yield.

4. DISCUSSION

Cocoyam growth as well as yield were remarkably enhanced by the application of cow dung at 20 t/ha in 2012 and the lower rate of 10 t/ha in 2013. This observation agrees with the findings of other workers who concluded that organic manure increases the vegetative growth and yield of crops [11,8]. LAI determines the capacity of the plant to trap energy for photosynthesis and thus has marked effect on growth and yield of plants [17]. Maximum LAI of approximately 3.8 was recorded with 20 t/ha and

10 t/ha of applied cow dung rate in 2012 and 2013. These cow dung rates also recorded significantly the highest number of leaves (29.5 and 30.0 in 2012 and 2013, respectively) and leaf area (977.47 cm^2 and 1085.02 cm^2 in 2012 and 2013, respectively). Thus, confirming the earlier report made by Amanullah et al. [18] that LAI is a function of number of leaves and leaf size and influences the amount of assimilate a plant can produce. The LAI value obtained in this study was higher than the value of 0.1 and 0.15 reported by Uwah et al. [10] on the same crop with poultry manure rate of 15 t/ha.

Table 9. Effect of cow dung and rice husk on mean tuber yield (t/ha) (2012 and 2013)

Treatment	Mean tuber yield (t/ha)
Cow dung (t/ha)	
0	11.38
10	15.74
20	17.98
30	19.18
$LSD_{(0.05)}$	2.23
Rice husk (t/ha)	
0	14.25
10	16.23
20	16.89
30	16.91
$LSD_{(0.05)}$	2.23
C x R	NS

The significant decrease recorded in number of leaves, leaf area and leaf area index at 1 MAP in 2013 with application of higher rate of cow dung may be attributed to delayed sprouting of the cormels in plots that received higher rates of this manure. But as soon as the seedlings were established and considering the fact that they had sufficient nutrients, which were provided by the cow dung they were able to grow rapidly and perform better than the control.

Optimum yield of 13.3 t/ha in 2012 and 21.6 t/ha in 2013 were recorded by application of cow dung at 20 t/ha and 10 t/ha, respectively. These values were higher than the control by 96% and 42%, respectively. Uwah et al. [10] recorded optimum yield of 8.7 t/ha of cocoyam with application of 15 t/ha poultry manure in an alfisol in south eastern Nigeria while Onwudike et al. [11] reported optimum yields of 4.3 and 8.9 t/ha in two different years (2011 and 2013, respectively) with the application of 10 t/ha cocoa pod waste in acidic soil in south eastern Nigeria. In a similar study, Agbede and Adekiya [8] recorded total tuber weight of about 24.0 t/ha with application of 7.5 poultry manure in a tropical alfisol in south western Nigeria. However, the yields of 13.3 and 21.6 t/ha recorded in this study were higher than the average national yield of 5-7.5 t/ha; they were also higher than the yields of 4.8.5 t/ha obtainable in Ghana, lower than the yields of 23.5-35 t/ha obtainable in Egypt and compared favourably with the yields of 17.5-19 t/ha obtainable in China [7].

Rice husk effects were not consistent on cocoyam growth and yield as significant differences occurred in one out of the two years. Application of rice husk at the highest rate of 30 t/ha in 2013 recorded the highest plant height and LAI at 5MAP while the lower rate of 20 t/ha recorded optimum corm yield of 22.0 t/ha on average. This yield was greater than the yield of 9.6 t/ha obtained by Uwah et al. [10] at rice husk rate of 15 t/ha and also the yield of 2.61 – 5.38 t/ha obtained by Onwudike et al. [11] at 10 t/ha rice mill waste. Obasi et al. [19] recommended higher rates above 6 t/ha of rice mill waste for cocoyam production in an ultisol while Uwah et al. [16] reported higher cocoyam corm yields on an acidic sandy loam alfisol with the application of 15 t/ha of rice husk. In this study, the yields obtained from application of rice husk at 10, 20 and 30 t/ha were higher by 35 – 51% over no rice husk application in 2013 cropping season. Earlier and recent research investigations on the impact of rice husk and other manures on crops [20,8] consistently showed that they are good and valuable nutrient sources which are being recommended for the improvement of growth and yield of crops.

In all, the improvement in growth and yield of cocoyam following organic soil amendment may be attributed to the slow release of nutrients by these organic soil amendments which tied the crop over the long duration of its growth and also to the balanced availability of nutrients to the plant that resulted in a favourable soil environment. These favourable conditions increased the nutrient availability and water holding capacity of the soil resulting in enhanced growth and yield [21]. Besides, organic manures have been found to improve soil physical and chemical properties, increase soil pH by their liming potential and provide trace elements which are usually deficient in continuously cropped soils [22].

Disparities in response to the application of the organic wastes in both years may be related to such factors as soil nutrient status as well as other edaphic and weather factors. For example, when the soil was sandy loam in 2012, with low pH of 4.4 and low native nitrogen of 0.03% and organic matter of 0.65%, the response was greater as yield increased with cow dung rate up to 20 t/ha. However, in 2013 when the soil was sandy clay loam and more fertile, with higher pH of 5.7 and 0.06% nitrogen and 1.22% organic matter, the response to cow dung application was lower and not above the 10 t/ha rate. For rice husk with higher C:N ratio, the low pH of 4.4 in 2012 may have hampered the rate of decomposition, resulting in poor yield response to rice husk in that year. In contrast, the higher pH of 5.5 in 2013 favoured decomposition or mineralization and resulted in yield response to rice husk application but not beyond the 10 t/ha rate. Uwah et al. [10] made similar observations in which growth and yield performance of cocoyam was better in a latter year of cropping than the previous year and attributed it partly to the differential nutrient status of the experimental sites and partly to the differences in the mineral content of manure used in the 2 years.

Although the initial soil nitrogen of 0.03% and 0.05% were below the critical value of 0.15% N reported by Ibedu et al. [23] and Chude et al. [24], rainfall and root yields were in general remarkably higher in 2013. With a rainfall of 1775.6 mm in 2012 and 2009.0 mm in 2013, the latter appeared more favourable for cocoyam cultivation. Onwueme [25] reported that cocoyams require rainfall above 2000 mm per annum for optimum yields. Besides, the lower yields of 2012 may also be partly ascribed to the greater incidence of leaf blight disease in that year. Although, reports have shown that leaf blight disease of cocoyam cause significant reduction in corm yield, evaluation of the effect of leaf blight disease was not part of our objective.

5. CONCLUSION

The results of this study indicate the effectiveness of cow dung and rice husk in improving the growth and yield of cocoyam. Optimum yield of cocoyam was recorded at cow dung rate of 10 – 20 t/h and rice husk rate of 20 t/ha. These rates are therefore recommended for cocoyam production in the humid agro-ecological zone of South-eastern Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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