



## Response of Cocoyam (*Xanthosoma mafafa*) Growth, Yield Parameters and Soil Physical Properties of Ultisol at Umudike, Southeastern Nigeria

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### Authors' contributions

*This work was carried out in collaboration among all authors. Authors ICS and ADO designed the study. Author ICS wrote the protocol and the first draft of the manuscript. Authors OAD and JEO managed the literature searches while author ICS managed the analyses of the study. All authors read and approved the final manuscript.*

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### ABSTRACT

**Aim:** To determine the effect of different rates of sawdust (SD) and poultry manure (PM) applied on some soil physical properties of acid sandy Ultisol, and some growth parameters and yield of cocoyam.

**Study Design:** 2 x 5 factorial arrangement in a randomized complete block design replicated three times.

**Place and Duration of Study:** The experiment was conducted in Eastern farm of Michael Okpara University of Agriculture, Umudike during 2014 and 2015 planting seasons.

**Methodology:** The treatments comprised of two manure sources at five levels each: sawdust (0, 2, 10, 15 and 20t/ha) and poultry manure (0, 2, 4, 6 and 8t/ha). The treatments were assigned randomly to the plots and incorporated into the soil two weeks before planting. Data were collected

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on plant height, number of leaves, leaf area, corms, cormels and total yield. Soil samples were collected with core samplers for physical properties such as Soil Bulk density and Total Porosity. All the data collected were subjected to ANOVA for factorial experiment in RCBD at 5% probability level.

**Results:** The result showed that the interactions of poultry manure and sawdust significantly ( $p < 0.05$ ) improved soil bulk density and total porosity with the lowest value obtained with 0t/ha SD + 8t/ha PM in both 2014 and 2015. The result showed that the interactions of poultry manure and sawdust significantly ( $p < 0.05$ ) increased the leaf area with the highest value obtained with 20t/ha SD + 8t/ha PM in both 2014 and 2015. Also, only the increasing rates of treatment applied significantly ( $p < 0.05$ ) increased the number of leaves, plant height, leaf area and cocoyam yield with the highest value obtained with 20t/ha SD + 8t/ha PM. Also, the various rates of treatment application significantly ( $p < 0.05$ ) increased the cocoyam yield (weight of corms and cormels) with the highest value obtained with 20t/ha SD + 8t/ha PM.

**Conclusion:** Improvement in growth and yield of cocoyam resulted from the improved nutrient status of the soil as a result of the amendments applied.

**Keywords:** Soil physical and chemical properties; organic wastes; cocoyam plant growth and corm yield.

## 1. INTRODUCTION

Modern farming is emphasizing organic farming because organic wastes can virtually supply all the nutrients required by plants and improve soil physical, chemical and biological conditions for sustainable crop production and environmental safety [1]. The use of agro-wastes as soil amendments is a sustainable means of improving soil fertility and productivity and exemplifies a strategy for converting wastes to resources.

Sawdust, though impacts good structural attributes to soil, have little or relatively low effects on soil chemical properties due to its low surface area as well as low degradability due to high carbon and low nitrogen content. It could cause nitrogen immobilization, resulting in depressed plant growth and reduced microbial respiration [2]. Eneje and Ezeakolam [3] observed the increase in organic carbon in soil with the application of sawdust as an organic amendment.

Poultry manure has been adjusted to be the most valuable of all organic manures produced by livestock [4]. Moreover, the nutrient contents of poultry manure are among the highest of all animal manures, and the use of poultry manure as soil amendment for agricultural crops will provide appreciable quantities of all the major plant nutrients. It also improves biological activities, soil tilth and soil chemical properties [5]. Poultry manure supplies the essential nutrients especially nitrogen, phosphorus and potassium required for maximum crop production [6].

Cocoyam (*Xanthosoma mafafa*) contains over 80% and 240% higher digestible crude protein than yam and cassava respectively as well as higher amount of essential minerals such as Calcium, Magnesium and Phosphorus [7]. Cocoyam has the smallest starch grain size (1 - 4 $\mu$ ) relative to yam (10 - 70 $\mu$ ) and cassava (15 - 17 $\mu$ ) [1]. This confers on cocoyam both higher digestibility and biodegradability, making it suitable food for potentially allergic infants and persons with gastro-intestine disorders. It is also used in the treatment of diabetes. [1]. The leaf of cocoyam is a rich source of calcium, phosphorus, iron, vitamin C, riboflavin, niacin and thiamin [8].

Sawdust as an organic amendment is not frequently used because of its high carbon:nitrogen ratio. It is an important organic waste in the ecosystem because of its high carbon content. The supply of nitrogen with poultry manure can help prevent nitrogen immobilization by the high carbon content of sawdust. This will be of great benefit to soils with low organic matter content, resulting in increased yield of cocoyam.

The objective of this study is to determine the effect of sawdust and poultry manure combinations on some growth parameters and yield of cocoyam and soil physical properties.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

The experiment was conducted at Michael Okpara University of Agriculture Research farm

in Umudike (Longitude 07°33' E, Latitude 05°29' N, Altitude 122 m). The climate is essentially tropical humid climate. The area has a total rainfall of 2177mm per annum, annual average temperature of about 26°C. The rainfall pattern is bimodal: a long wet season from April to July is interrupted by a short "August break" followed by another short rainy season from September to October or early November. Dry season stretches from early November to March [9].

## 2.2 Experimental Layout

The field was cleared, ploughed, harrowed and ridged. The ridges were made at 1m apart in a plot size of 4m by 4m with a furrow of 0.5 m. The total experimental area was 1496 m<sup>2</sup> (68 m by 22 m). The treatments comprised of sawdust (SD), sourced from Timber shade, Umuahia, was applied at five levels namely 0, 2, 4, 6 and 8 t/ha and poultry manure (PM), which was sourced from National Root Crop Research Institute Umudike, was applied at five levels namely 0, 5, 10, 15 and 20 t/ha, which were combined to produce 25 treatment combinations. The treatment combinations were laid out in Randomized Complete Block Design (RBCD) and replicated three times in a factorial experiment.

## 2.3 Planting and Weeding

The test crop for the experiment was cocoyam (*Xanthosoma mafafa*), which was sourced from National Root Crop Research Institute Umudike, was planted at a spacing of 1m by 1m with one corm sown per planting hole on the crest of the ridge at the depth of 15 cm, given a total plant population of 16 plants per plot. Weeding was manually done with hoe at 2, 8, 13 and 17 weeks after planting.

## 2.4 Collection of Growth and Yield Data

Data were collected on plant height, number of leaves, and leaf area using the method of [10] at 4, 8, 12 and 16 weeks after planting and the average measurements were used. Also, data on yield of cocoyam corms and cormels were collected at harvest.

## 2.5 Soil Sample and Collection

Composite soil samples were collected before treatment application for the characterization of the experimental site. Soil samples were collected with core samplers for physical

properties such as Soil Bulk density and Total Porosity.

## 2.6 Data Analysis

All the data collected were subjected to analysis of variance (ANOVA) for factorial experiment in RCBD using GENSTAT software and the treatment means were separated using the Fisher's Least Significant Different (FLSD) at 5% probability level.

## 3. RESULTS AND DISCUSSION

### 3.1 The Soil Physicochemical and Organic Wastes Properties Measured from the Experiment

The properties of the soil measured from the experiment (Table 1) indicate that the soil is Sandy loam, slightly acidic, with low organic carbon, nitrogen, available phosphorus and exchangeable bases. The analysis of the organic amendments used in the study (Table 2) showed that poultry manure has higher values in total N, available P and exchangeable bases (K, Na, Mg and Ca) while sawdust has higher values in organic carbon, organic matter and C:N ratio.

### 3.2 Effect of Organic Wastes on Soil Physical Properties

The soil Bulk Density decreased were significant ( $p < 0.05$ ) over control with application of the increasing rates of organic wastes (Table 3) with the lowest value obtained with 0t/ha SD + 8t/ha PM in both planting seasons. The application of Poultry Manure with increased rates of 8t/ha lowered the soil bulk density in both planting seasons. Sawdust application at different rates were significant ( $p < 0.05$ ) decreased Bulk Density with the lowest values recorded with the application of 5t/ha SD in both planting seasons.

The soil Total Porosity increased were significant ( $p < 0.05$ ) over control with application increasing rates of organic wastes (Table 4), with the highest value obtained with 0t/ha SD + 8t/ha PM in both planting seasons. The soil Total Porosity increased were significant ( $p < 0.05$ ) over control with application of Poultry Manure at increasing rates, and the highest value was obtained with 8t/ha PM in both planting seasons. Also, the application of Sawdust at different rates were significant ( $p < 0.05$ ) increased Total Porosity with the highest value recorded with the application of 5t/ha SD in both planting seasons.

**Table 1. Physical and chemical properties of soil used for the experiment before treatment application**

Soil properties	2014 planting season	2015 planting season
Sand (%)	77.62	78.79
Silt (%)	10.50	7.84
Clay (%)	11.88	13.37
Textural class	Sandy loam	Sandy loam
Soil pH (water)	5.28	5.31
Soil pH (salt)	4.07	4.10
Organic carbon (%)	1.57	1.75
Organic matter (%)	2.71	3.01
Total N (%)	0.14	0.14
Available P (mg/kg)	7.80	8.20
Exchangeable acidity (cmol <sup>+</sup> /kg)	3.61	3.12
Potassium (cmol <sup>+</sup> /kg)	0.05	0.06
Calcium (cmol <sup>+</sup> /kg)	2.10	2.30
Magnesium (cmol <sup>+</sup> /kg)	1.20	2.00
Sodium (cmol <sup>+</sup> /kg)	0.13	0.16
Bulk density (g/cm <sup>3</sup> )	1.31	1.28
Total porosity (%)	50.68	51.55

**Table 2. Chemical properties of organic amendment used for the study**

Properties	Poultry manure	Sawdust
Organic carbon (%)	14.47	46.42
Organic matter (%)	24.95	80.03
Total N (%)	1.85	0.30
C: N ratio	7.82	154.73
Available P (mg/kg)	0.80	0.34
Potassium (cmol <sup>+</sup> /kg)	2.76	0.98
Calcium (cmol <sup>+</sup> /kg)	13.80	2.60
Magnesium (cmol <sup>+</sup> /kg)	2.80	2.10
Sodium (cmol <sup>+</sup> /kg)	1.37	0.90

The reduction in soil BD and increased TP could be attributed to the increased microbial activity associated with increased nutrient availability due to the soil amendments applied, leading to the pulverization of soil. The increased soil TP is associated with the reduction in soil BD because of the direct relationship between them. Similar results have been reported by Eneje and Ezeakolam [3] and Onwudike et al. [11] with application of organic wastes.

### 3.3 Effect of Organic Wastes on Number of Leaves, Leaf Area and Plant Height of Cocoyam

The results of the effects of organic wastes on number of leaves (Table 5), leaf area (Table 6) and cocoyam plant height (Table 7) indicate that there was statistical difference ( $p < 0.05$ ) in all these growth parameters with the highest value obtained with 20t/ha SD + 8t/ha PM in both planting seasons.

The increasing rates of PM application recorded higher cocoyam number of leaves values that were significant ( $p < 0.05$ ) over control. The poultry manure application at 8t/ha recorded highest cocoyam number of leaves value in all the planting seasons. Likewise, the application of SD at increasing rates recorded higher cocoyam number of leaves values that were significant ( $p < 0.05$ ) over control. The Sawdust application at 20t/ha recorded highest cocoyam number of leaves value in all the planting seasons.

The increasing rates of PM application recorded higher cocoyam leaf area values that were significant ( $p < 0.05$ ) over control. The poultry manure application at 8t/ha recorded highest cocoyam leaf area value in both 2014 and 2015. Likewise, the application of SD at various rates recorded higher cocoyam leaf area values that were significant ( $p < 0.05$ ) over control. The Sawdust application at 20t/ha recorded highest cocoyam leaf area value.

**Table 3. Effect of sawdust and poultry manure on soil bulk density (g/cm<sup>3</sup>)**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	1.568	1.137	1.038	1.029	1.016	1.036	1.471	0.951	0.955	0.936	0.949	1.054
2	1.008	1.006	1.007	1.005	1.004	1.009	0.905	0.907	0.905	0.907	0.904	0.906
4	1.011	1.008	1.006	1.004	1.004	1.007	0.908	0.906	0.906	0.908	0.903	0.906
6	0.978	0.982	0.969	0.998	1.001	0.986	0.877	0.880	0.867	0.902	0.903	0.886
8	0.848	0.920	0.951	0.938	0.938	0.919	0.807	0.817	0.834	0.838	0.838	0.827
Mean	1.083	0.991	0.994	0.995	0.992		0.994	0.892	0.893	0.898	0.899	
LSD (0.05) for SD = 0.006							LSD (0.05) for SD = 0.006					
LSD (0.05) for PM = 0.006							LSD (0.05) for PM = 0.006					
LSD (0.05) for SD × PM = 0.014							LSD (0.05) for SD × PM = 0.014					

**Table 4. Effect of sawdust and poultry manure on soil total porosity (%)**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	40.818	50.918	60.818	61.170	61.673	57.079	44.490	64.126	63.963	64.664	63.811	60.211
2	61.962	62.271	62.013	62.421	62.168	62.127	65.862	65.774	65.836	65.786	65.887	65.829
4	61.862	61.975	62.037	62.113	62.113	62.020	65.723	65.824	65.799	65.748	65.912	65.801
6	63.094	62.943	63.447	62.327	62.213	62.805	66.918	67.038	67.295	65.962	65.937	66.630
8	68.000	65.271	64.126	64.591	62.616	65.321	69.547	69.157	68.538	68.365	68.377	68.795
Mean	59.147	62.675	62.488	62.524	62.557		62.504	66.284	66.284	66.105	65.985	
LSD (0.05) for SD = 0.273							LSD (0.05) for SD = 0.256					
LSD (0.05) for PM = 0.273							LSD (0.05) for PM = 0.256					
LSD (0.05) for SD × PM = 0.610							LSD (0.05) for SD × PM = 0.573					

**Table 5. Effect of sawdust and poultry manure on number of cocoyam leaves**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	10.00	15.33	15.67	17.33	21.33	15.93	8.67	17.67	18.00	19.33	23.33	17.40
2	15.00	17.00	19.00	21.33	27.33	20.07	18.00	20.33	21.67	24.33	30.33	22.93
4	15.33	16.67	18.00	20.00	28.33	19.67	17.33	20.33	21.00	23.33	31.00	22.60
6	17.00	19.00	23.33	25.00	30.67	23.00	19.00	21.33	23.33	27.33	33.67	24.93
8	18.33	21.67	23.33	25.67	32.00	24.20	20.33	23.67	26.00	28.00	35.67	26.73
Mean	15.33	17.93	19.87	21.87	27.93		16.67	20.67	22.00	24.47	30.80	
LSD (0.05) for SD = 1.70							LSD (0.05) for SD = 1.57					
LSD (0.05) for PM = 1.70							LSD (0.05) for PM = 1.57					
LSD (0.05) for SD × PM = NS							LSD (0.05) for SD × PM = NS					

**Table 6. Effect of sawdust and poultry manure on cocoyam leaf area (cm<sup>2</sup>)**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	550	1142	1381	1660	2051	1357	684	1162	1398	1681	2071	1399
2	1543	1795	1995	2310	2920	2113	1564	1815	2016	2331	2940	2133
4	1708	2066	2391	3258	3512	2587	1729	2086	2412	3278	3532	2608
6	2206	2669	2948	3459	4312	3119	2226	2690	2968	3479	4333	3139
8	2199	3086	3886	4517	5414	3820	2220	3107	3906	4537	5437	3841
Mean	1641	2151	2520	3041	3642		1685	2172	2540	3061	3662	
LSD (0.05) for SD = 223.6							LSD (0.05) for SD = 216.6					
LSD (0.05) for PM = 223.6							LSD (0.05) for PM = 216.6					
LSD (0.05) for SD × PM = 500.1							LSD (0.05) for SD × PM = 484.2					

**Table 7. Effect of sawdust and poultry manure on cocoyam height (cm)**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	30.43	49.57	55.57	62.27	69.80	53.53	31.60	56.93	63.87	67.83	78.03	59.65
2	61.50	65.53	70.33	75.90	89.27	72.51	63.10	66.00	70.37	77.30	89.07	73.17
4	63.17	72.53	78.30	89.20	103.37	81.31	64.80	73.13	79.23	88.57	104.07	81.96
6	74.13	84.13	87.40	96.57	106.83	89.81	98.23	95.13	101.33	109.43	119.33	104.69
8	72.60	82.77	101.53	109.83	118.27	97.00	98.23	95.13	101.33	109.43	119.33	104.69
Mean	60.37	70.91	78.63	86.75	97.51		66.55	75.10	80.60	88.01	99.83	
LSD (0.05) for SD = 3.98							LSD (0.05) for SD = 3.22					
LSD (0.05) for PM = 3.98							LSD (0.05) for PM = 3.22					
LSD (0.05) for SD × PM = NS							LSD (0.05) for SD × PM = NS					

**Table 8. Effect of sawdust and poultry manure on yield of cocoyam corms (t/ha)**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	0.67	1.58	2.00	2.75	3.83	2.17	0.63	1.67	1.83	2.17	2.75	1.81
2	1.67	2.67	3.25	3.75	5.33	3.33	2.17	2.75	3.17	3.33	4.25	3.13
4	2.00	2.58	3.00	4.08	5.83	3.50	2.92	3.58	4.42	3.58	6.50	4.20
6	3.75	4.33	5.33	5.42	7.42	5.25	4.58	5.67	5.25	5.08	8.08	5.73
8	4.33	4.50	6.33	7.42	10.00	6.52	4.92	5.75	6.50	7.17	9.08	6.68
Mean	2.48	3.13	3.98	4.68	6.48		3.04	3.88	4.24	4.27	6.13	
LSD (0.05) for SD = 0.713							LSD (0.05) for SD = 0.533					
LSD (0.05) for PM = 0.713							LSD (0.05) for PM = 0.533					
LSD (0.05) for SD × PM = NS							LSD (0.05) for SD × PM = NS					

**Table 9. Effect of sawdust and poultry manure on yield of cocoyam cormels (t/ha)**

2014 cropping season							2015 cropping season					
PM (t/ha)	SD (t/ha)						SD (t/ha)					
	0	5	10	15	20	Mean	0	5	10	15	20	Mean
0	0.75	1.92	2.67	3.58	5.92	2.92	0.90	1.67	2.00	2.75	3.58	2.18
2	2.00	3.75	4.83	6.50	8.67	5.15	3.83	3.08	4.17	5.25	6.00	4.47
4	4.67	5.50	6.42	9.17	10.42	7.23	3.50	4.50	6.08	7.08	7.83	5.80
6	5.00	6.67	7.58	8.83	12.00	8.02	4.33	4.75	6.75	8.42	9.00	6.65
8	5.58	8.58	9.83	12.25	16.25	10.50	5.02	6.92	8.25	10.00	11.25	8.47
Mean	3.60	6.27	8.07	10.65	10.73		3.70	4.18	5.45	6.70	7.53	
LSD (0.05) for SD = 0.919							LSD (0.05) for SD = 0.838					
LSD (0.05) for PM = 0.919							LSD (0.05) for PM = 0.838					
LSD (0.05) for SD × PM = NS							LSD (0.05) for SD × PM = NS					



The increasing rates of PM application recorded higher cocoyam plant height values that were significantly ( $p < 0.05$ ) over control. The poultry manure application at 8t/ha recorded highest cocoyam leaf area value in 2014 and 2015. Likewise, the application of SD at various rates recorded higher cocoyam height values that were significant ( $p < 0.05$ ) over control. The Sawdust application at 20t/ha recorded highest cocoyam leaf area value in 2014 and 2015.

This might be due to the decomposition of the organic wastes and consequently, its nutrient release, which created a better soil environment for plant to take up nutrients. Similar results were reported by [11,12,13,14].

### 3.4 Effect of Organic Wastes on Yield of Cocoyam Corms and Cormels

The results of the effects of organic wastes on cocoyam corms (Table 8), and cormels (Table 9) indicate that there were significantly ( $p < 0.05$ ) highest yield value obtained with 20t/ha SD + 8t/ha PM in both planting seasons.

Cocoyam corm yield increased significantly ( $p < 0.05$ ) over control at increasing rates of poultry manure application in both 2014 and 2015 planting seasons, with the highest yield values recorded with the application of 8t/ha PM. Similarly, corm yield increased significantly ( $p < 0.05$ ) over control at various rates of sawdust application in both 2014 and 2015 planting seasons, with the highest yield values recorded with the application of 20t/ha SD.

Cocoyam cormel yield increased significantly ( $p < 0.05$ ) over control at various rates of poultry manure application in both 2014 and 2015 planting seasons, with the highest yield values recorded with the application of 8t/ha PM. Similarly, cormel yield increased significantly ( $p < 0.05$ ) over control at various rates of sawdust application in both 2014 and 2015 planting seasons, with the highest yield values recorded with the application of 20t/ha SD.

The increased yield of cocoyam corms and cormels were due to the improved soil properties (soil bulk density and soil total porosity), which made the nutrients available for plant uptake and manifested on the crop yield. Similar results were reported by [14,15,16,17,18].

## 4. CONCLUSION

The results from this study have shown that the application of organic wastes such as poultry manure and sawdust, in combination improved the soil physical properties, yield and growth parameters of cocoyam, such as leaf area, number of leaves and plant height. The organic wastes such as sawdust is important due to its high carbon content, and poultry manure, due to its high N and exchangeable bases. The supply of N through sources such as poultry manure, increases the rate organic matter decomposition and prevents N immobilization. The high organic carbon content of sawdust also produced great benefits to soils such as reduced soil bulk density and soil total porosity. Therefore, organic wastes such as poultry manure and sawdust could be used by poor farmers.

## COMPETING INTERESTS

Authors have declared that there is no competing interest.

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