Vol. 16(7), pp. 952-962, July, 2020
DOI: 10.5897/AJAR2019.14612
Article Number: AEF963B64186
ISSN: 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Effect of agricultural wastes on some soil physicochemical properties of ultisol, growth parameters and yield of cocoyam (*Xanthosoma mafafa*) at Umudike, southeastern Nigeria

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Received 25 November, 2019; Accepted 7 February, 2020

This research was conducted on a degraded Ultisol at the Eastern farm of Michael Okpara University of Agriculture, Umudike during 2014 and 2015 planting seasons, to determine the effect of different rates of sawdust and poultry manure application on soil physicochemical properties of acid sandy Ultisol, and growth and yield of cocoyam. The treatments comprised of two organic amendments at five levels each: Sawdust (0, 2, 10, 15 and 20 t/ha) and poultry manure (0, 2, 4, 6 and 8 t/ha), which were combined to produce 24 treatment combinations and a control. The treatments were assigned randomly to the plots and incorporated into the soil two weeks before planting. The treatment combinations were laid out in Randomized Complete Block Design (RBCD) and replicated three times in a factorial experiment. Data were collected 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 using soil auger at 0 to 15 cm, at the end of the experiment for chemical analysis such as soil pH, organic carbon, available phosphorus, total nitrogen, exchangeable acidity and total exchangeable cations such as K^{+}, Ca^{2+}, Mg^{2+} and Na^{+}. The soil physicochemical properties were significantly improved with mostly higher rates of sawdust and poultry manure over control, which positively modified cocoyam growth and yield. The cocoyam leaf area, plant height, number of leaves, corms, cormels and total cocoyam yield increased significantly with application of 8 t/ha PM. The total cocoyam yield amounted to 17.73 t/ha in 2014 and 15.15 t/ha in 2015. Results of this research showed that agro-wastes such as poultry manure and sawdust have the potentials for increasing cocoyam production and soil fertility.

Key words: Sawdust, poultry manure, bulk density, total nitrogen, soil fertility.

INTRODUCTION

Food is a basic necessity of man and its production largely depend on soil fertility. Consequently, management of soil fertility is pre-requisite for continuous food production and sustainability of soil resources. Soil fertility

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depletion is mainly due to intensive and continuous cropping with application of low levels of fertilizer, causing a negative balance between nutrition supply and extraction from the soil. Continuous cropping makes tropical soils highly vulnerable to soil degradation. Hence, they are characterized by low organic matter, low pH, high erosion and structurally unstable aggregates with limited capacity to hold water (Oguike et al., 2006). Soil degradation increases soil acidity, nutrient leaching and soil nutrient imbalance. These are associated with the continuous use of inorganic fertilizers and the polluting effects of the fertilizers on the environment have also made these fertilizers unsuitable for maintenance of soil fertility (Agbede et al., 2013). The use of agro-wastes as soil amendments is a sustainable means of improving soil fertility and productivity. It therefore imperative to incorporate animal manure, recycle secondary crop products and other organic wastes to improve soil fertility and enhanced crop yield (Mbah et al., 2010).

Sawdust, though impacts good structural attributes to the 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 (Eneje and Ukwuoma, 2005). An increase in organic carbon in soil was observed with the application of sawdust as an organic amendment (Eneje and Ezeakolam, 2009).

Poultry manure has been regarded as the most valuable of all organic manures produced by livestock (Okonkwo et al, 2009). Moreover, the nutrient content of poultry manure is 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 fertility and soil chemical properties (Omisore et al., 2009). Poultry manure supplies the essential nutrients especially nitrogen, phosphorus and potassium required for maximum crop production (Ibeawuchi 2010).

Cocoyam (*Xanthosoma mafafa*) is a staple food grown for its edible corms, cormels and leaves. Fresh cocoyam and its leaf contains about 70 to 80% water, 20 to 75% carbohydrate and 1.5 to 3.0% protein, significant amounts of vitamin C, iron, calcium, phosphorus, thiamine, riboflavin, niacin and carotene (Udo 2005; Chukwu, 2010). It 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 (Chukwu and Nwosu, 2008; Okoye et al., 2008). Cocoyam has the smallest starch grain size (1-4 micrometer) relative to yam (10-70 µm) and cassava (15-17 micrometer) (1 - 4 µ) relative to yam (10 - 70 µ) and cassava (15 - 17 µ). This confers on cocoyam both higher digestibility and biodegradability, making it suitable food for potentially allergic infants and persons with gastro-intestine disorders and for the treatment of diabetes (FAO, 1990).

Sawdust as an organic amendment is not frequently used because of its high carbon to nitrogen ratio. It is an important byproduct in processing timber and is high in 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 greater improvement in soil physicochemical properties and cocoyam growth and yield.

The objective of this study was to determine the effect of sawdust and poultry manure combinations on some soil physicochemical properties of acid sandy Ultisol and on some growth parameters and yield of cocoyam.

MATERIALS AND METHODS

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. The area has a total rainfall of 2177 mm 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 (NRCRI, 2015).

Experimental layout

The field was mechanically cleared, ploughed, harrowed and ridged in both 2014 and 2015 planting seasons. The ridges were made at 1 m apart in a plot size of 4 m by 4 m with a furrow of 0.5 m. The total experimental area was 1496 m^2 (68 m by 22 m). The treatments comprised of sawdust (SD), sourced from Timber shade, Umuahia: the treatments were applied at five levels including 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 including 0, 5, 10, 15 and 20 t/ha, which were combined to produce 24 treatment combinations and a control. These treatment applications was done in 2014 and repeated in 2015. The treatment combinations were laid out in Randomized Complete Block Design (RBCD) and replicated three times in a factorial experiment.

Soil sampling and collecting

A composite soil sample was 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. Soil samples were collected using soil auger at 0 to 15 cm, at the end of the experiment for chemical analysis. The soil samples were air-dried at room temperature, and sieved through a 2 mm sieve. The soil pH was determined in 1:2.5 soil- to- water ratio using pH meter (Thomas, 1996). The organic carbon was determined using dichromate wet oxidation method of

Walkey – Black as explained by Nelson and Sommers (1996). Available phosphorus was determined by Bray 2 method as described by Bray and Kurtz (1945). Total nitrogen was determined using Kjeldahl method (Bremner, 1996). Exchangeable cations such as K^+, Ca^{2+}, Mg^{2+}, and Na^+ were determined according to Summer and Miller (1996).

Planting and weeding

The test crop for the experiment was cocoyam which was sourced from National Root Crop Research Institute Umudike: was planted at a spacing of 1 m by 1 m 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.

Collection of growth and yield data

Data were collected on plant height, number of leaves, and leaf area using the method of Agueguia (2008) at 4, 8, 12 and 16 weeks after planting and the average measurements were used. Also, data on total yield of cocoyam (corms and cormels) were collected at harvest at 10 months.

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.

RESULTS

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

Effect of sawdust and poultry manure on soil physical properties

The soil bulk density decreased significantly ($p < 0.05$) over control with application of poultry manure at various rates, but the lowest values obtained were 0.991 gcm^{-3} in 2014 and 0.892 gcm^{-3} in 2015 with 2 t/ha PM (Table 3). Also, the application of sawdust at different rates significantly ($p<0.05$) decreased bulk density with the lowest values of 0.919 gcm^{-3} in 2014 and 0.827 gcm^{-3} in 2015 recorded with the application of 20 t/ha SD. The lowest values recorded with SD were lower than that of PM in both planting seasons. The interactions of SD and PM also have significant effect on the soil Bulk Density.

The soil total porosity increased significantly ($p < 0.05$) over control with application of poultry manure at various rates, but the highest values obtained were 62.60% in 2014 and 66.36% in 2015 with 2 t/ha poultry manure (Table 3). Also, the application of SD at different rates significantly ($p<0.05$) increased total porosity with the highest values of 65.32% in 2014 and 66.79% in 2015 recorded with the application of 20 t/ha SD. The highest values recorded with SD were higher than that of PM in both planting seasons. The interactions of SD and PM also have significant effect on the soil total porosity.

Effect of sawdust and poultry manure on soil chemical properties

Effect of sawdust and poultry manure on soil pH (water), exchangeable acidity and available phosphorus

The soil pH increased significantly ($p < 0.05$) over control with application of Poultry Manure at various rate, and the highest values obtained were 6.33 with 8 t/ha PM in 2014 and 7.63 with 2 t/ha PM in 2015 (Table 4). Likewise, the application of sawdust at different rates significantly ($p<0.05$) increased soil pH with the highest values of 6.07 in 2014 and 7.66 in 2015 recorded with the application of 20 t/ha SD. The interactions of SD and PM also have significant effect on the soil pH.

The Soil Exchangeable Acidity decreased significantly ($p < 0.05$) over control with application of poultry manure at various rates, but the lowest values obtained were 1.093 cmol+/kg with 8 t/ha PM in 2014 and 1.501 cmol+/kg in 2015 with 6 t/ha PM (Table 4). Also, the application of sawdust at different rates significantly ($p<0.05$) decreased Soil Exchangeable Acidity with the lowest values of 2.003 cmol+/kg with in 2014 and 1.763 cmol+/kg in 2015 recorded with the application of 20 t/ha SD. The lowest values recorded with PM were lower than that of SD in both planting seasons. The interactions of SD and PM also have significant effect on the soil exchangeable acidity.

The Soil Available Phosphorus increased significantly ($p < 0.05$) over control with application of poultry manure at various rate, but the highest values obtained were 14.546 mg/kg in 2014 with 8 t/ha PM and 21.854 mg/kg in 2015 with 6 t/ha PM (Table 4). Also, the application of Sawdust at different rates significantly ($p<0.05$) increased Soil Available Phosphorus with the highest values of 10.904 mg/kg in 2014 and 17.964 mg/kg in 2015 recorded with the application of 20 t/ha SD. The highest values recorded with PM were higher than that of SD in both planting seasons. The interactions of SD and PM also have significant effect on the soil available phosphorus.

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 (0.01$CaCl_2$)	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+/kg)	3.61	3.12
Potassium (cmol+/kg)	0.05	0.06
Calcium (cmol+/kg)	2.10	2.30
Magnesium (cmol+/kg)	1.20	2.00
Sodium (cmol+/kg)	0.13	0.16
Bulk density (g/cm3)	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+/kg)	2.76	0.98
Calcium (cmol+/kg)	13.80	2.60
Magnesium (cmol+/kg)	2.80	2.10
Sodium (cmol+/kg)	1.37	0.90

Effect of sawdust and poultry manure on soil organic matter, total n and total exchangeable bases

The soil organic matter increased significantly ($p < 0.05$) over control with application of poultry manure at various rate, but the highest values obtained were 1.183% in 2014 with 4t/ha PM and 5.352% in 2015 with 8 t/ha PM (Table 5). Also, the application of sawdust at different rates significantly ($p<0.05$) increased Soil Organic Matter with the highest values of 1.404% in 2014 and 6.226% in 2015 recorded with the application of 20 t/ha SD. The highest values recorded with PM were higher than that of SD in both planting seasons. The interactions of SD and PM also have significant effect on the Soil Organic Matter.

The soil nitrogen increased significantly ($p < 0.05$) over control with application of poultry manure at various rate, but the highest values obtained were 0.245% in 2014 and 0.187% in 2015 with 8 t/ha PM (Table 5). Also, the application of sawdust at different rates significantly ($p<0.05$) increased soil nitrogen with the highest values of 0.215% in 2014 and 0.167% in 2015 recorded with the application of 20 t/ha SD. The highest values recorded with PM were higher than that of SD in both planting seasons. The interactions of SD and PM also have significant effect on the soil nitrogen.

The soil total exchangeable bases increased significantly ($p < 0.05$) over control with application of poultry manure at various rate, but the highest values obtained were 8.304 cmol+/kg in 2014 with 8 t/ha PM and

Table 3. Effect of sawdust and poultry manure on soil bulk density and total porosity in 2014 and 2015 planting seasons.

Treatments	Bulk density (g/cm^3)		Total Porosity (%)	
	2014	2015	2014	2015
Poultry manure				
0	1.083	0.994	59.13	62.64
2	0.991	0.892	62.60	66.08
4	0.994	0.893	62.49	66.36
6	0.995	0.898	62.45	66.11
8	0.992	0.899	62.57	66.34
LSD 0.05 PM	0.006	0.006	0.273	0.256
Sawdust (t/ha)				
0	1.036	1.054	60.90	60.23
5	1.009	0.906	61.92	65.81
10	1.007	0.906	62.00	65.81
15	0.986	0.886	62.79	66.57
20	0.919	0.827	65.32	66.79
LSD 0.05 SD	0.006	0.006	0.273	0.256
LSD 0.05 SD * PM	0.014	0.014	0.610	0.573

Table 4. Effect of sawdust and poultry manure on soil pH (water), exchangeable acidity and available phosphorus.

Treatments	Soil pH		Exchangeable acidity (cmol+/kg)		Available P (mg/kg)	
	2014	2015	2014	2015	2014	2015
Poultry manure						
0	5.68	7.47	3.785	2.462	2.026	12.086
2	5.90	7.63	3.462	2.109	2.942	10.802
4	6.03	7.60	2.156	2.231	7.863	13.727
6	6.14	7.60	1.459	1.501	9.032	21.854
8	6.33	7.54	1.093	1.677	14.546	20.045
LSD 0.05 PM	0.028	0.026	0.036	0.028	0.098	0.250
Sawdust (t/ha)						
0	5.92	7.45	2.751	2.097	3.734	14.447
5	5.98	7.55	2.565	2.114	5.437	14.465
10	6.05	7.53	2.380	1.9997	6.683	17.582
15	6.05	7.65	2.257	2.011	9.492	14.055
20	6.07	7.66	2.003	1.763	10.904	17.964
LSD 0.05 SD	0.028	0.026	0.036	0.028	0.098	0.250
LSD 0.05 SD * PM	0.063	0.059	0.081	0.062	0.220	0.557

8.402 cmol+/kg in 2015 with 4 t/ha PM (Table 5). Also, the application of Sawdust at different rates significantly ($p<0.05$) increased soil total exchangeable bases with the highest values of 7.723 cmol+/kg in 2014 with 20 t/ha SD and 8.367 cmol+/kg in 2015 with 15 t/ha SD. The highest values recorded with PM were higher than that of SD in both planting seasons. The interactions of SD and PM also have significant effect on the soil total exchangeable bases.

Cocoyam growth parameters

Effect of sawdust and poultry manure on leaf area of cocoyam

The various rates of poultry manure application recorded higher cocoyam leaf area values that were significant ($p<0.05$) over control (Table 6). The poultry manure application at 8 t/ha recorded highest cocoyam leaf area

Table 5. Effect of sawdust and poultry manure on soil organic matter, total nitrogen and total exchangeable bases.

Treatments	Soil organic matter (%)		Total nitrogen (%)		TEB (cmol+/kg)	
	2014	2015	2014	2015	2014	2015
Poultry manure						
0	0.857	4.975	0.154	0.130	6.885	7.935
2	1.168	5.314	0.180	0.161	8.299	8.067
4	1.183	4.966	0.191	0.158	7.233	8.402
6	1.030	5.096	0.198	0.175	7.101	7.808
8	1.177	5.352	0.245	0.187	8.304	8.188
LSD 0.05 PM	0.029	0.035	0.003	0.005	0.032	0.171
Sawdust (t/ha)						
0	0.756	4.417	0.168	0.162	7.429	7.648
5	1.264	4.827	0.187	0.164	7.538	8.026
10	0.847	4.687	0.194	0.165	7.497	8.314
15	1.087	5.612	0.203	0.153	7.634	8.367
20	1.404	6.226	0.215	0.167	7.723	8.046
LSD 0.05 SD	0.029	0.035	0.003	0.005	0.032	0.171
LSD 0.05 SD * PM	0.065	0.077	0.007	0.010	0.072	0.381

Table 6. Effect of sawdust and poultry manure on leaf area of Cocoyam (cm^2).

Treatments	Months after Planting (MAP)							
	1	2	3	4	1	2	3	4
	2014				2015			
Poultry manure								
0	433	847	1357	1640	455	883	1399	1700
2	845	1373	2113	2324	874	1394	2133	2346
4	1124	1681	2587	2872	1144	1701	2608	2893
6	1396	1935	3119	3280	1417	1956	3139	3301
8	1606	2173	3820	3947	1629	2193	3841	3966
LSD 0.05 PM	100.9	146.7	223.6	220.0	100.0	143.8	216.6	208.6
Sawdust (t/ha)								
0	581	1020	1641	1711	605	1053	1685	1770
5	825	1344	2151	2354	845	1364	2172	2364
10	1067	1578	2520	2824	1087	1599	2540	2845
15	1280	1816	3041	3309	1300	1837	3061	3330
20	1664	2254	3642	3877	1683	2273	3662	3898
LSD 0.05 SD	100.9	146.7	223.6	220.0	100.0	143.8	216.6	208.6
LSD 0.05 SD * PM	225.6	NS	500.1	492.0	223.7	NS	484.2	466.5

values at various months after planting (MAP) in 2014 and 2015, with the highest value of 3947 cm^2 in 2014 and 3966 cm^2 in 2015 recorded at four MAP. Likewise, the application of SD at various rates recorded higher cocoyam leaf area values that were significant ($p<0.05$) over control. The SD application at 20 t/ha recorded highest cocoyam leaf area values at various months after planting (MAP) in 2014 and 2015, with the highest value of 3877 cm^2 in 2014 and 3989 cm^2 in 2015 recorded at 4MAP. The interaction between PM and SD at various MAP in both planting seasons also had significant effect on cocoyam leaf area except that of the two MAP.

Effect of sawdust and poultry manure on number of leaves of cocoyam

The various rates of poultry manure application recorded

Table 7. Effect of sawdust and poultry manure on number of cocoyam leaves.

Treatments	Months after planting (MAP)							
	1	2	3	4	1	2	3	4
	2014				2015			
Poultry manure								
0	4.33	12.67	15.93	21.00	5.53	13.93	17.40	21.40
2	5.67	14.60	20.07	22.40	7.47	16.40	22.93	24.47
4	5.33	15.60	19.67	22.47	7.53	17.80	22.60	25.20
6	6.20	19.27	23.00	24.53	8.87	21.40	24.93	26.60
8	8.33	18.13	24.20	31.40	10.60	21.47	26.73	33.80
LSD 0.05 PM	0.80	1.30	1.70	2.35	0.90	0.90	1.57	2.37
Sawdust (t/ha)								
0	4.20	11.60	15.27	17.33	6.27	12.93	16.67	18.47
5	5.40	13.67	17.93	19.67	7.20	16.07	20.67	21.47
10	6.00	15.27	19.87	22.07	8.07	17.73	22.00	24.67
15	6.67	17.00	21.87	25.40	8.87	19.53	24.47	27.73
20	7.60	22.73	27.93	25.13	9.60	25.27	30.80	28.47
LSD 0.05 SD	0.80	1.30	1.70	2.35	0.90	0.90	1.57	2.37
LSD 0.05 SD * PM	NS	NS	NS	NS	NS	NS	NS	NS

higher number of cocoyam leaves values that were significant ($p<0.05$) over control (Table 7). The poultry manure application at 8 t/ha recorded highest cocoyam number of leaves at various months after planting (MAP) in 2014 and 2015, with the highest value of 31.40 in 2014 and 33.40 in 2015 recorded at four MAP. Likewise, the application of SD at various rates recorded higher cocoyam number of leaves values that were significant ($p<0.05$) over control. The sawdust application at 20 t/ha recorded highest cocoyam number of leaves values at various MAP in 2014 and 2015 except for that of four MAP in 2014, whose highest value (25.40) was obtained with 15 t/ha SD, and 28.47 t/ha SD in 2015 recorded at four MAP. The interaction between PM and SD at various MAP in both planting seasons have no significant effect on cocoyam number of leaves.

Effect of sawdust and poultry manure on cocoyam height

The various rates of PM application recorded higher cocoyam height values that were significant ($p<0.05$) over control (Table 8). The poultry manure application at 8 t/ha recorded highest cocoyam leaf area values at various MAP in 2014 and 2015, with the highest value of 111.63 cm in 2014 and 117.26 cm in 2015 recorded at four MAP. 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 20 t/ha recorded highest cocoyam leaf area values at various MAP in 2014 and 2015, with the highest value of 109.51 cm in 2014 and 110.22 cm in 2015 recorded at four MAP. The interaction between PM and SD at various MAP in both planting seasons had no significant effect on cocoyam height.

Effect of sawdust and poultry manure on corms, cormels and total yield of cocoyam (t/ha) at harvest

Cocoyam corm yield increased significantly ($p<0.05$) over control (Table 9) at various rates of PM application in both 2014 and 2015 planting seasons, with the highest yield values of 6.52 t/ha in 2014 and 6.68 t/ha in 2015 with the application of 8 t/ha PM. Similarly, corm yield increased significantly ($p<0.05$) over control (Table 9) at various rates of SD application in both 2014 and 2015 planting seasons, with the highest yield values of 6.48 t/ha in 2014 and 6.13 t/ha in 2015 with the application of 20 t/ha SD. Interactions between PM and SD on corm yield was not significant in both 2014 and 2015 planting season but corm yield was generally higher with applications of PM than SD.

Cocoyam cormel yield increased significantly ($p<0.05$) over control (Table 9) at various rates of PM application in both 2014 and 2015 planting seasons, with the highest yield values of 10.73 t/ha in 2014 and 8.47 t/ha in 2015 with the application of 8 t/ha PM. Similarly, cormel yield increased significantly ($p<0.05$) over control (Table 9) at various rates of SD application in both 2014 and 2015 planting seasons, with the highest yield values of 10.65 t/ha in 2014 and 7.53 t/ha in 2015 with the application of 20 t/ha SD. Interactions between PM and SD on cormel

Table 8. Effect of sawdust and poultry manure on height of Cocoyam (cm).

Treatments	Months after planting (MAP)							
	1	2	3	4	1	2	3	4
	2014				2015			
Poultry manure								
0	17.15	37.02	53.53	66.59	21.59	42.59	59.65	67.85
2	22.71	50.25	72.51	84.51	27.66	55.65	73.71	86.17
4	25.08	59.08	81.31	93.17	30.06	62.83	81.96	94.03
6	26.35	61.52	89.81	102.57	30.75	65.30	104.69	104.12
8	30.37	68.91	97.00	111.63	35.31	78.29	104.69	117.26
LSD 0.05 PM	2.22	4.40	3.98	4.62	1.88	3.57	3.22	2.86
Sawdust (t/ha)								
0	11.29	41.64	60.37	73.06	15.53	48.38	66.55	78.40
5	19.15	48.90	70.91	84.09	24.47	54.54	75.10	86.91
10	24.23	55.13	78.63	92.89	29.15	60.23	80.60	92.77
15	31.19	61.63	86.75	98.92	35.37	65.55	88.01	101.13
20	35.81	69.47	97.51	109.51	40.84	76.02	99.83	110.22
LSD 0.05 SD	2.22	4.40	3.98	4.62	1.88	3.57	3.22	2.86
LSD 0.05 SD * PM	NS	NS	NS	NS	4.2	7.99	7.21	6.39

Table 9. Effect of sawdust and poultry manure on corms, cormels and total yield of cocoyam (t/ha) at harvest.

Treatments	Corms (t/ha)		Cormels (t/ha)		Total yield (t/ha)	
	2014	2015	2014	2015	2014	2015
Poultry manure						
0	2.17	1.81	2.92	2.18	5.09	3.99
2	3.33	3.13	5.15	4.47	8.48	7.60
4	3.50	4.20	7.23	5.80	10.73	10.00
6	5.25	5.73	8.02	6.65	13.27	12.38
8	6.52	6.68	10.73	8.47	17.25	15.15
LSD 0.05 PM	0.713	0.533	0.919	0.838	1.340	1.340
Sawdust (t/ha)						
0	2.48	3.04	3.60	3.70	6.08	6.74
5	3.13	3.88	6.27	4.18	9.40	8.06
10	3.98	4.24	8.07	5.45	12.05	9.69
15	4.68	4.27	10.50	6.70	15.18	10.97
20	6.48	6.13	10.65	7.53	17.11	13.66
LSD 0.05 SD	0.713	0.533	0.919	0.838	1.027	1.027
LSD 0.05 SD * PM	NS	NS	NS	NS	NS	NS

yield was not significant in both 2014 and 2015 planting season but cormel yield was generally higher with applications of PM than SD.

Cocoyam total yield increased significantly ($p<0.05$) over control (Table 9) at various rates of poultry manure application in both 2014 and 2015 planting seasons, with the highest yield values of 17.25 t/ha in 2014 and 15.15 t/ha in 2015 with the application of 8 t/ha PM. Similarly, cocoyam total yield increased significantly ($p<0.05$) over control (Table 9) at various rates of sawdust application in both 2014 and 2015 planting seasons, with the highest yield values of 17.11 t/ha in 2014 and 13.66 t/ha in 2015 with the application of 20 t/ha SD. Interactions between PM and SD on corm yield was not significant in both

2014 and 2015 planting season but cocoyam total yield was generally higher with applications of PM than SD.

DISCUSSION

The soil bulk density and total porosity (Table 3) improved with the application of PM and SD. 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 (2009); and Onwudike et al. (2015) with application of organic wastes.

The soil pH increased with application of organic wastes such as PM and SD (Table 4). The ability of the organic manure to increase soil pH was due to the presence of basic cations contained in the organic wastes, which were released upon microbial decarboxcation. The increased soil pH observed agrees with the reports of Chigbundu et al. (2010), Adeyele et al. (2010) and Magagula et al. (2010) with the application of organic wastes.

The soil available P increased with application of organic wastes such as PM and SD. The increased soil available P may be attributed to the release of liming effects of organic wastes, through the release of calcium and magnesium from the decomposition of the organic wastes, thus precipitating $Al(OH)^3$ and increasing soil pH, thereby releasing the adsorbed P, which enhanced the availability of soil available P, and as well as the high P available in the organic wastes. Similar results were reported in other studies (Onwuka, 2008; Mbah and Mbagwu, 2006; Okonkwo et al., 2009; Ayeni et al., 2009) with the application of organic wastes.

The application of organic wastes such as PM and SD decreased soil exchangeable acidity. The reduction in soil exchangeable acidity could be attributed to the ability of the organic wastes to release of basic cations on decomposition, thus precipitating $Al(OH)^3$. Similar results were reported by Asawalam and Onyegbule (2009) and Adeyele et al. (2010) with the application of organic wastes.

The soil nitrogen increased with application of organic wastes such as PM and SD. The increased soil Total N may be due to the mineralization of organic-bound nutrients from the decomposition of the organic wastes. The increased soil total N observed agrees with the reports of Mukiibi (2008); Mbah et al. (2010) and Adeyele et al. (2010) with the application of organic wastes.

The organic wastes application such as PM and SD increased soil organic matter. The increased soil organic matter could be attributed to the high C:N ratio of the organic waste and the release of organic-bound nutrients from the decomposition of the organic wastes. The increased soil organic carbon observed agrees with the results of previous studies (Eneje and Ukwuoma, 2009; Adeyele et al, 2010; Ayuba et al., 2005) where increased organic matter has been reported with the application of organic wastes.

The soil total exchangeable bases increased with application of organic wastes such as PM and SD. The increased soil TEB could be attributed to the greater capacity of nutrient retention of the amended soils. Similar results were reported by Kparmwamp et al. (2004) and Ano and Agwu (2005) with the application of organic wastes.

The effects of organic wastes on leaf area (Table 6), number of leaves (Table 7), and plant height (Table 8) showed a greater increase in cocoyam growth parameters. 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 Uwah et al. (2011); Agbede and Adekiya (2016); Obasi et al., (2009); Onwudike et al. (2015) and Iwuagwu et al. (2017).

The results of the effects of organic wastes on cocoyam corms, cormels and cocoyam total yield (Table 9) indicate that there was a greater yield. The increased weight of cocoyam corms, cormels and total yield were due to the improved soil properties, which made the nutrients available for plant uptake and manifested on the crop yield. Similar results were reported in other studies (Chukwu et al., 2009b; Agbede and Adekiya, 2016; Ojeniyi et al., 2013; Udom and Lale, 2017; Iwuagwu et al., 2017).

Conclusion

The results from this study have shown that the incorporation of organic wastes such as PM and SD, solely or in combination improved the physicochemical properties of the soil and increased cocoyam growth and yield at an increasing rate such as 8 t/ha PM and 20 t/ha SD. The organic waste such as SD is important due to its high carbon content, and PM, due to its high N and exchangeable bases. The supply of N sources such as poultry manure, increases the rate organic matter decomposition and prevents N immobilization, and the high organic carbon content of sawdust produced great benefits to soils. Proper organic manuring requires the combinations of single manures that will encourage maximum microbial activity, to enhance the release of soil nutrients in available forms and reduce nutrient loss trough fixation, immobilization and leaching. Therefore, organic wastes such as poultry manure and sawdust could be used by poor farmers, who cannot afford fertilizers due to its high cost, for sustainable agricultural production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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