World Academy of Science, Engineering and Technology
International Journal of Agricultural and Biosystems Engineering
Vol:10, No:3, 2016

Effect of Cocoa Pod Ash and Poultry Manure on Soil Properties and Cocoyam Productivity of Nutrient-Depleted Tropical Alfisol

T. M. Agbede, A. O. Adekiya

***Abstract*—**An experiment was carried out for three consecutive years at Owo, southwest Nigeria. The objective of the investigation was to determine the effect of Cocoa Pod Ash (CPA) and Poultry Manure (PM) applied solely and their combined form, as sources of fertilizers on soil properties, leaf nutrient composition, growth and yield of cocoyam. Three soil amendments: CPA, PM (sole forms), CPA and PM (mixture), were applied at 7.5 t ha^{-1} with an inorganic fertilizer (NPK 15-15-15) at 400 kg ha^{-1} as a reference and a natural soil fertility, NSF (control), arranged in a randomized complete block design with three replications. Results showed that soil amendments significantly increased ($p = 0.05$) corm and cormel weights and growth of cocoyam, soil and leaf N, P, K, Ca and Mg, soil pH and organic carbon (OC) concentrations compared with the NSF (control). The mixture of CPA+PM treatment increased corm and cormel weights, plant height and leaf area of cocoyam by 40, 39, 42, and 48%, respectively, compared with inorganic fertilizer (NPK) and 13, 12, 15 and 7%, respectively, compared with PM alone. Sole or mixed forms of soil amendments showed remarkable improvement in soil physical properties compared with NPK and the NSF (control). The mixture of CPA+PM applied at 7.5 t ha^{-1} was the most effective treatment in improving cocoyam yield and growth parameters, soil and leaf nutrient composition.

***Keywords*—**Cocoa pod ash, cocoyam, poultry manure, soil and leaf nutrient composition.

I. Introduction

COCOYAM (*Xanthosoma sagittifolium* (L.) Schott) belongs to the family Araceae and it is a major staple food crop in Nigeria (a leading producer of cocoyam), South Pacific Islands and some parts of Asia [1], [2]. Nutritionally, cocoyams are rich in carbohydrates, protein, vitamin C, thiamine, riboflavin, niacin, calcium, phosphorus and iron [3]. Cocoyam is highly valued because of its wide range of uses, which include the edible corms, cormels, leaves and the young stems. The corms and cormels are eaten boiled, fried, baked and roasted. In West Africa, the boiled cocoyam is sometimes pounded to produce a paste similar to pounded yam and eaten in the same manner. The corms and cormels may be peeled, dried and ground into flour and thus stored in a semi-processed form. The young leaves and petioles are made into soup, while the corms, cormels and leaves after curing can also be used as animal feed [4]. The leaves are also widely used as spinach in the preparation of stews and sauces. Cocoyams are the cheapest and handiest source of carbohydrate in meals. They are recommended for aged people, diabetics, convalescents and most gastro-intestinal disorder patients. Cocoyam is a good carbohydrate base for infant foods on account of their small-sized starch grains which are easily digested compared to yam (*Dioscorea* spp.), cassava (*Manihot* spp.) or sweet potato (*Ipomoea batatas*) [5]. Cocoyam apart from being important as a source of energy in the diet of millions of people and livestock, it also has cultural and socio-economic significant for its uses in traditional ceremonies [6].

In spite of the great economic importance of the crop, its potential yields to meet the global demand for the corms and cormels have not been achieved because of the increasing decline in soil fertility levels and lack of soil management requirements for continuous cocoyam cultivation. Cocoyam, being a root crop has a high requirement for K just like yam and cassava [7], [8]. Efforts to supplement the soil nutrient status with inorganic fertilizers have not been sustainable due to high cost of purchasing chemical fertilizers especially by the poor resource farmers and acute scarcity at time of planting. Continuous application of chemical fertilizers also enhances soil acidity, nutrient imbalance, nutrient leaching and degradation of soil physical properties and organic matter [9], [10]. Hence, there is need to identify locally available organic fertilizers which can be used by the poor resource farmers to improve the fertility of their soils.

Enormous quantities of organic wastes such as cocoa pod husk are available in Nigeria where they pose disposal problems and environmental hazards, and are at the same time effective source of nutrient for root crop like cocoyam. Organic wastes such as cocoa pod husk has not received much research attention. About 800,000 tonnes of cocoa pod husks are generated annually in Nigeria and often wasted [11]. It is known to harbour fungus (*Phytophthora palmivora*) causing black pod disease in cocoa. Its use as organic manure form may directly or indirectly transmit black pod disease to other farms. Hence, cocoa pods are burnt into ash as a method of ensuring proper sanitation and for the control black pod disease of cocoa. In [12], it was found that CPA increased the growth of maize. Animal manures especially that of PM have received much research attention in crop nutrition and had been found to be effective sources of nutrients for crops [13], [14]. Research information on the sole and integrated use of

T. M. Agbede is with the Department of Agricultural Technology, Rufus Giwa Polytechnic, Owo, 341001, Nigeria (phone: +234 8038171300; e-mail: agbedetaiwomichael@yahoo.com).

A. O. Adekiya is with the Department of Crop and Soil Sciences, Landmark University, P. M. B. 1001, Omu-Aran, Kwara State, Nigeria (phone: +234 8034813715; e-mail: adekiya2009@yahoo.com).

CPA and PM for the production of cocoyam is yet to receive research attention. Cocoyam like any other root and tuber crops is a heavy feeder, exploiting a large volume of soil for nutrient and water [15]. Therefore, continuous cultivation of crop like cocoyam on the same soil lead to nutrient depletion, degradation of soil quality and consequent low yield. According to [16], for a target yield of 21.1 t ha^{-1}, cocoyam (corm + cormel) removes 100.0, 28.6, 145.2, 40.0 and 18.2 kg ha^{-1} of N, P, K, Ca and Mg, respectively from soil. This calls for fertility-enhancing technologies including the application of organic manures/fertilizers. Hence, the objective of this study was to evaluate the effect of CPA and PM on soil properties, leaf nutrient composition, growth and yield of cocoyam grown on an Alfisol of southwestern Nigeria.

II. Materials and Methods

A. Site Description, Trial Design and Duration, Treatments, Field Layout and Crop Husbandry

The experiments were carried out at the Teaching and Research Farm of Rufus Giwa Polytechnic, Owo (latitude 7^0 12'N, longitude 5^0 35'E), Ondo State, southwestern Nigeria during 2012, 2013 and 2014 growing seasons. The average rainfall varied from 1000-1240 mm. The rainy season starts in March, lasting till October, while the dry season is between November and February with temperature ranging from 24 to 32°C. The soil of the experimental site belongs to an Alfisol classified as Oxic Tropuldalf [17] or Luvisol [18] derived from quartzite, gneiss and schist [19]. Composite upper soil layer (0-15 cm) samples from the experimental site were taken to determine the physical and chemical properties of the soil before cropping. The site was cropped to a variety of crops such as yam (*Dioscorea rotundata* Poir), cowpea (*Vigna unguiculata* Walp), cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), melon (*Colosynthis citrullus* L.), etc. for at least 12 years without fertilizer application before the initiation of this study. The trials were conducted for three cropping seasons of 2012, 2013 and 2014 on the same site.

The experiment each year consisted of five treatments, concerned with three main comparisons – natural soil fertility (NSF, the control), soil with inorganic fertilizer (NPK-15-15-15) added, and soil with organic fertilizers added, which, in turn, had three comparisons: animal manure (PM), plant-derived residue (CPA, CP) and mixtures of the two, (CPA with PM). Cocoyam is a high nutrient requiring plant, and it benefits greatly from liberal use of organic and inorganic manures [15]. Therefore, organic manures were applied at 7.5 t ha^{-1}, based on recommendation for high nutrient requiring tuber crop like cocoyam [20], [21], while inorganic fertilizer was applied at 400 kg ha^{-1}, based on field recommendation for cocoyam production on a nutrient-depleted soil [15]. The five treatments compared were: (a) control, natural soil fertility (NSF), is a relatively degraded soil condition because of prior land use; (b) inorganic fertilizer (NPK 15-15-15; 15 N, 15 $P_2 0_5$, 15 $K_2 0$) at 400 kg ha^{-1}; (c) PM at 7.5 t ha^{-1}; (d) CPA at 7.5 t ha^{-1} and (e) CPA at 3.5 t ha^{-1} mixed with PM at 3.5 t ha^{-1}. The five treatments were laid out in a randomized complete block design and replicated three times.

After manual clearing and packing of debris away from the site, soil mounds were formed at 1 m x 1 m spacing in April each year. Each mound was approximately 1 m wide at the base and about 0.75 m high. The size of each of the 15 plots was 7 m x 6 m, giving a plant population of 42 plants per plot. Blocks were 1 m apart and the plots were 0.5 m apart. Planting was done immediately after construction of mounds in each year. One cocoyam cormel weighing about 150 g was planted per hole on 3 April 2012, 6 April 2013 and 8 April 2014, respectively. The organic amendments/organic fertilizers were applied in ring form at planting, thoroughly worked into the soil with a hoe. The NPK 15-15-15 fertilizer was applied in ring a form in two equal doses. The first dose was applied at 1 month after planting, while the second dose was applied at 2 months later when tuber expansion, rapid stem and leaf development were in progress. Weeding was done manually with a hoe at 45 and 110 days after planting in each experiment. The same treatment was applied to each plot for the three years.

Twenty plants were selected per plot for determination of plant height, number of leaves and leaf area per plant at 168 days after planting (DAP) when the cocoyam plant reached its peak growth. Plant height was measured from the ground level to the shoot apex by a ruler. Number of leaves was determined by counting the number of leaves on each cocoyam plant and leaf area was estimated using the mathematical model developed by [22] between linear measurements of leaves. It relates leaf area (Y) to the product of length (L) and breadth (B).

$$Y = k\,(LB) \quad (1)$$

where the constant, k = 0.923 + 0.004

The corm and cormel yields were determined by harvesting twenty cocoyam plants per plot and separated them into corms and cormels. They were washed and cleaned to remove traces of sand before weighing on a top loading balance to determine their fresh weights.

B. Soils, Soil Inputs, and Leaf Analysis of Cocoyam Plant

Two months after planting cocoyam, determination of bulk density, total porosity and gravimetric water content in all plots was commenced and repeated at 2-month intervals on four occasions for each year. Five undisturbed core samples were collected at 0-15 cm depth from the centre of each plot at random and about 15 cm away from each cocoyam mound using steel coring tubes (4 cm diameter, 15 cm high), and the samples were used to evaluate bulk density, total porosity and gravimetric water content after oven-drying at 100°C for 24 h. Total porosity was calculated from the values of bulk density and particle density of 2.65 mg m^{-3}.

Before the start of the experiment in 2012, surface soil (0-15 cm) samples were randomly collected from 10 different points on the experimental site. Disturbed soil samples were collected randomly at 0-15 cm depth from the centre of each plot on mounds at five sites per plot at harvest in 2014 (third crop). The soil samples were bulked, air-dried and sieved using a 2-mm sieve for routine chemical analysis, as described by [23]. Particle-size analysis was carried out for textural class using the hydrometer method. Soil pH was determined in a soil/water (1: 2) suspension using a digital electronic pH meter. Soil OC was determined by the Walkley and Black procedure by wet oxidation using chromic acid digestion. Total N was determined using micro-Kjeldahl digestion and distillation techniques, available P was determined by Bray-1 extraction followed by molybdenum blue colorimetry. Exchangeable K, Ca and Mg were extracted with a 1 M NH_4OA_C, pH 7 solution. Thereafter, K was analysed with a flame photometer and Ca and Mg were determined with an atomic absorption spectrophotometer.

Cocoa pod husks was collected from cocoa farmers in Owo, Ondo State, sun dried and burnt into ash inside a bin. PM was obtained from the Polytechnic's poultry farm. The organic materials were processed to allow decomposition. CPA was sieved to remove pebbles, stones and unburnt shafts while the PM was stacked under a shed for 1 week to allow quick mineralization. In general, the organic wastes are readily available, sustainable and inexpensive for growing commercial quantities of cocoyam.

Small, about 2 g, subsamples of each of the processed forms of the organic materials used in the experiments were analysed to determine their nutrient composition. The samples were air-dried and crushed to pass through a 2-mm sieve before analysis. The samples were analysed for organic C, total N, P, K, Ca and Mg. The percentage OC was determined by the Walkely and Black procedure using the dichromate wet oxidation method, total N was determined by micro-Kjeldahl digestion, followed by distillation and titration while the determination of other nutrients such as P, K, Ca and Mg was done using the wet digestion method based on 25-5-5 mL of $HN0_3$-H_2SO_4–$HClO_4$ acids [24]. Phosphorus was measured colorimetrically by the molybdate blue method in an auto-nalyser, K by flame photometry, and Ca and Mg by atomic absorption spectrophotometer.

In 2014 cropping season, 2 to 3 weeks old cocoyam leaves were randomly collected from ten plants per plot at 168 days after planting (when the cocoyam plant reached its peak growth [25], [26]) for chemical analysis. The leaf samples were oven-dried at 70^0C for 24 h before grinding in a Willey mill. Leaf N was determined by micro-Kjeldahl digestion. Ground leaf samples were dry ashed at 500^0C for 6 h in a muffle furnace and extracted using a HNO_3-H_2SO_4-$HClO_4$ acids mixture to determine P, K, Ca and Mg. Leaf P was determined colorimetrically using the vanadomolybdate method. K was determined using a flame photometer and Ca and Mg were determined by the EDTA titration method [24].

C. Statistical Analysis

Data collected for soil properties, leaf nutrient concentrations, growth and yield parameters were subjected to analysis of variance (ANOVA) using SPSS 15.0 and Microsoft Office Excel 2007 packages, and the separation of treatment means were determined using Duncan's multiple range test (DMRT) and the least significant difference (LSD) at $p = 0.05$ probability level.

III. Results and Discussion

A. Initial Soil Fertility Status

The soil was sandy loam in texture and had bulk density of 1.58 Mg m^{-3} and total porosity of 40.4% (Table I). Based on the established critical levels for soils in ecological zones of Nigeria, the soil was acidic with pH 5.4 compared with pH between 5.5 and 6.5 considered optimum for cocoyam [27]. The soil was low in OC, total N, available P, exchangeable K, Ca and Mg, and below threshold limit of 3.0% OM, 0.20% N, 10 mg kg^{-1} available P, 0.16 cmol kg^{-1} exchangeable K, 2.0 cmol kg^{-1} exchangeable Ca and 0.40 cmol kg^{-1} exchangeable Mg recommended for most crops [28]. Thus, indicating poor soil fertility. Hence, it is expected that application of organic fertilizer materials would enhance soil fertility and performance of cocoyam.

TABLE I
Soil Physical and Chemical Properties (0-15 cm Depth) of the Experimental Site before Experimentation in 2012

Property	Value
Sand (g kg^{-1})	682
Silt (g kg^{-1})	148
Clay (g kg^{-1})	170
Textural class	Sandy loam
Bulk density (Mg m^{-3})	1.58
Total porosity (%, v/v)	40.4
pH (H_2O)	5.4
Organic C (%)	0.98
Total N (%)	0.09
Available P (mg kg^{-1})	7.8
Exchangeable K (cmol kg^{-1})	0.11
Exchangeable Ca (cmol kg^{-1})	1.53
Exchangeable Mg (cmol kg^{-1})	0.26

B. Chemical Properties of the Organic Amendments/ Organic Fertilizers Used in the Experiment

PM was richer in nutrient concentrations than CPA in respect of organic C (OC), N and P with lower C/N ratio of 7.3 while CPA had significantly higher ($p = 0.05$) K, Ca and Mg concentrations with higher C/N of 11.8 compared to PM (Table II). The prior processing of the organic amendments before application reduced their C/N ratio. The organic of C, N, P, K, Ca and Mg constituents of combinations of the materials are expected to improve the fertility of the experimental soil and cocoyam growth and yield. As the soil is also acidic, organic fertilizer materials especially CPA could help by reducing soil acidity [29].

C. Effect of CPA and PM on Soil Bulk Density, Total Porosity and Water Content

In the 3 years of cropping, application of CPA and PM gave relatively lower soil bulk density, higher total porosity and water content compared with the control (NSF), whereas application of NPK fertilizer did not influence soil bulk density, total porosity and water content (Table III). Sole application of PM and CPA alone gave similar values of soil bulk density, total porosity and water content that were not statistically different from each other. In general, the mixture of CPA with PM significantly reduced (p = 0.05) soil bulk density and increased total porosity and water content more than their sole applications (CPA; PM). NPK fertilizer and NSF (control) produced similar values of bulk density, total porosity and water content. The effects of complementary application of CPA+PM and their sole applications (CPA; PM) in reducing soil bulk density and increasing total porosity and water content was attributable to significant organic matter addition to the soil by the organic amendments, which provided stable aggregate conditions. Organic matter is known to stabilize soil structure, reduce bulk density, and enhance porosity and water infiltration and retention [10]. This study was similar with the findings of [30] that repeated application of organic residues to soil improves physicochemical properties of such soils.

Averaged over the 3 years, CPA+PM reduced soil bulk density, and increased total porosity and water content by 45, 35 and 54%, respectively, compared with NPK and NSF (control); whereas application of the sole form of PM reduced soil bulk density, and increased total porosity and water content by 31, 26 and 26%, respectively, compared with NPK and NSF (control).

TABLE II
CHEMICAL COMPOSITION OF SOIL AMENDMENTS/ORGANIC FERTILIZERS USED FOR GROWING COCOYAM

Soil amendment	Organic C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	C/N ratio
PM	22.5a	3.08a	1.40a	1.81b	0.82b	0.56b	7.3
CPA	14.52b	1.23b	0.52b	12.3a	3.2a	0.74a	11.8

Note: Values followed by the same alphabets on the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT). CPA = Cocoa pod ash; PM = Poultry manure.

TABLE III
EFFECT OF CPA AND PM ON SOIL PHYSICAL PROPERTIES (0-15 CM DEPTH) WHEN AVERAGED ACROSS FOUR SAMPLING PERIODS (2, 4, 6 AND 8 MONTHS AFTER PLANTING)

Treatment	Bulk density (Mg m^{-3})			Total porosity (%, v/v)			Water content (g kg^{-1})		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
NSF (Control)	1.36a	1.41a	1.46a	48.7c	46.8c	44.9c	92c	78c	83c
400 kg ha^{-1} NPK-15-15-15	1.36a	1.40a	1.45a	48.7c	47.2c	45.3c	95c	83c	81c
7.5 t ha^{-1} CPA	1.14b	1.07b	1.03b	57.0b	59.6b	61.1b	118b	101b	107b
7.5 t ha^{-1} PM	1.12b	1.05b	1.01b	57.7b	60.4b	61.9b	122b	105b	119b
3.5 t ha^{-1} CPA + 3.5 t ha^{-1} PM	1.03c	0.96c	0.91c	61.1a	63.8a	65.7a	133a	128a	138a

Note: Values followed by the same alphabets on the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT). NSF = Natural soil fertility; CPA = Cocoa pod ash; PM = Poultry manure.

D. *Effect of CPA and PM on Soil Chemical Properties*

Application of NPK fertilizer significantly increased (p = 0.05) soil total N, available P, exchangeable K, Ca and Mg compared with NSF (control), but significantly reduced soil pH after 3 years of cultivation compared with other treatments (Table IV). The decline in soil pH of plots treated with NPK in this study could be adduced to their rapid rates of release of nutrients, which are immediately used up by plants, leading to poor accumulation of exchangeable bases that neutralizes soil acidity. The mixture of CPA+PM and their sole forms (CPA; PM) significantly increased (p = 0.05) soil pH, OC, total N, available P, exchangeable K, Ca and Mg compared with NPK and NSF (control). The mixture of CPA+PM and their sole forms (CPA; PM) tended to increase soil pH, OC, total N, exchangeable K, Ca and Mg more than NPK. In general, the mixture of CPA+PM increased soil total N, available P, and exchangeable Ca and Mg concentrations more than their sole forms (CPA; PM). This is could be attributed to positive cumulative and synergistic relations between CPA and PM which further enhanced or fortified their nutrient supplying power. The combination of more than one organic manure in soil amendments had been found in most studies to enhance higher release of nutrients [31], [32] as observed in this study. This trend might have resulted from the higher concentration of OC, N and P in the PM and the higher K, Ca and Mg concentrations in the CPA used in the amendment (Table II). PM is found to have high concentration of nutrients especially OC, N and P, and in most soils amended with the PM, soil nutrient levels have been significantly enhanced [33] while cocoa pod products have been found to have high level of K [32]. The increase in soil pH observed under CPA alone or when mixed with PM compared with other treatments was attributable to its high K, Ca and Mg concentrations. This could be due to the liming effect of plant ash on soil [29] unlike NPK which could lead to soil acidity with repeated use. The increase in soil pH recorded for sole applications of CPA and PM compared with NPK could be attributed to the increased availability of organic matter and the release of some cations from the decayed organic amendments.

At the end of the 3 years of cultivation, CPA+PM increased soil pH, OC, total N, available P, exchangeable K, Ca and Mg by 33, 81, 173, 35, 150, 70 and 25%, respectively, compared with NPK. The treatment also increased soil pH, total N, available P, exchangeable K, Ca and Mg by 8, 36, 25, 88, 45 and 63%, respectively, compared with PM alone. However, PM alone increased soil OC by 29% compared with a mixture of CPA+PM. In the same vein, CPA+PM also increased soil OC, total N, available P, exchangeable K, Ca and Mg by 28, 88, 70, 25, 16 and 17%, respectively, compared with sole application of CPA. However, CPA alone increased soil exchangeable K by 9%, compared with a mixture of CPA+PM. NPK increased soil total N, available P, exchangeable K, Ca and Mg by 83, 72, 167, 14 and 33%, respectively, compared with NSF (control). PM alone increased soil pH, OC, total N, available P, exchangeable K, Ca and Mg by 22, 134, 100, 8, 33, 17 and 25%, respectively, compared with NPK.

TABLE IV
EFFECT OF CPA AND PM ON SOIL CHEMICAL PROPERTIES (0-15 CM DEPTH) AFTER CROP HARVEST IN 2014

Treatment	pH (water)	Organic C (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})
NSF (Control)	5.3d	0.77d	0.06e	6.8e	0.09e	1.21e	0.21e
400 kg ha^{-1} NPK-15-15-15	4.9e	0.79d	0.11d	11.7c	0.24d	1.38d	0.28d
7.5 t ha^{-1} CPA	7.1a	1.12c	0.16c	9.3d	0.48b	2.02b	0.41b
7.5 t ha^{-1} PM	6.0c	1.85a	0.22b	12.6b	0.32c	1.62c	0.35c
3.5 t ha^{-1} CPA + 3.5 t ha^{-1} PM	6.5b	1.43b	0.30a	15.8a	0.60a	2.35a	0.57a

Note: Values followed by the same alphabets on the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT). NSF = Natural soil fertility; CPA = Cocoa pod ash; PM = Poultry manure.

E. Effect of CPA and PM on Leaf Nutrient Concentrations of Cocoyam

The mixture of CPA+PM and their sole forms (CPA; PM) had significant increases (p = 0.05) in leaf N, P, K, Ca and Mg concentrations of cocoyam compared with NPK and NSF (control) treatments (Table V). This could be attributed to their rich nutrient concentrations which increased the soil nutrients and subsequently improved nutrient uptake in the cocoyam plants. This observation agreed with [32] and [34], which reported that CPA and PM were good sources of N, P, K, Ca and Mg when applied to soils. Among all the treatments, leaf N, P, K, Ca and Mg concentrations decreases in the following order: CPA+PM > PM > CPA > NPK > NSF (control). The mixed treatment CPA+PM gave significantly higher (p = 0.05) leaf N, P, K, Ca and Mg concentrations when compared with their sole forms (CPA; PM) and NPK. The NPK significantly increased (p = 0.05) leaf N, P, K, Ca and Mg concentrations compared with NSF (control). This might be due to high soluble and plant-available nutrients, as well as the decomposition of organic matter and mineralization of its nutrients. The NSF (control) treatment gave the least values of leaf N, P, K, Ca and Mg concentrations (Table V). Nutrient concentrations in the leaves of cocoyam plants in the NSF (control) plots were below the critical levels of 3.2% N, 0.5% P, 2.3% K, 0.9% Ca and 1.3% Mg as reported by [16]. Thus, the leaves of the cocoyam plants exhibited symptoms deficiency in N (yellow colouration), P (purple colouration) and K (burnt leaf margin). The CPA+PM increased leaf N, P, K, Ca and Mg concentrations of cocoyam by 54, 66, 75, 206 and 62%, respectively, compared with NPK. The treatment also increased leaf N, P, K, Ca and Mg concentrations of cocoyam by 9, 17, 51, 64 and 27%, respectively, compared with sole application of PM. Similarly, sole application of CPA and PM alone significantly increased (p = 0.05) leaf N, P, K, Ca and Mg concentrations compared with NPK. The sole PM treatment increased leaf N, P, K, Ca and Mg by 41, 41, 15, 86 and 27%, respectively, compared with NPK treatment. The NPK treatment also increased leaf N, P, K, Ca and Mg by 40, 317, 16, 113 and 23%, respectively, compared with NSF (control).

TABLE V
EFFECT OF CPA AND PM ON LEAF NUTRIENT CONCENTRATIONS OF COCOYAM AT 168 DAYS AFTER PLANTING IN 2014 CROPPING SEASON

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
NSF (Control)	1.83e	0.23e	1.96e	0.24e	0.95e
400 kg ha^{-1} NPK-15-15-15	2.57d	0.58d	2.28d	0.51d	1.17d
7.5 t ha^{-1} CPA	3.26c	0.69c	2.44b	1.17b	1.66b
7.5 t ha^{-1} PM	3.62b	0.82b	2.63c	0.95c	1.49c
3.5 t ha^{-1} CPA + 3.5 t ha^{-1} PM	3.96a	0.96a	3.98a	1.56a	1.89a

Note: Values followed by the same alphabets on the same column are not significantly different at p = 0.05 according to Duncan's multiple range test (DMRT). NSF = Natural soil fertility; CPA = Cocoa pod ash; PM = Poultry manure.

F. Effect of CPA and PM on Growth and Yield Components of Cocoyam

Growth parameters such as plant height and leaf area of cocoyam increased significantly (p = 0.05) under organic amendment and NPK treatments compared with NSF (control) (Table VI). The organic amendment and NPK treatments had no significant effect on number of leaves in the first, second and third years of cropping. In general, the plant height and leaf area from plots with a mixture of CPA+PM were significantly higher (p = 0.05) than their sole applications (CPA; PM), and NPK. In the first year, the mixture of CPA+PM gave the highest values for plant height and leaf area, which were statistically different from other treatments. The PM alone gave higher plant height and leaf area than sole CPA and NPK. In the second and third years, the mixture of CPA+PM consistently gave highest values for plant height and leaf area, which were significantly greater (p = 0.05) than the other treatments. The sole PM followed by sole CPA gave values for plant height and leaf area that were significantly higher than NPK. The mean plant height for the NSF (control), NPK, CPA, PM and CPA+PM were 52.5, 58.6, 63.3, 72.4 and 83.4 cm, respectively, and the values for leaf area per plant were 1.54, 1.92, 2.11, 2.66 and 2.82 m^2, respectively.

The mixed form (CPA+PM) or sole (CPA; PM) of organic amendments/fertilizers, and NPK significantly increased ($p = 0.05$) corm and cormel weights of cocoyam in 2012, 2013 and 2014 cropping seasons compared with NSF (control) (Fig. 1). In 2012 cropping season, the sole PM treatment produced corm and cormel weights of cocoyam that were significantly higher ($p = 0.05$) than sole CPA and NPK treatments which produced similar corm and cormel weights of cocoyam (Fig. 1). The mixture of CPA+PM gave the highest corm and cormel weights of cocoyam and were significantly greater ($p = 0.05$) than other treatments. However, in 2013 and 2014 cropping seasons, the sole PM treatment followed by sole CPA treatment produced higher corm and comel weights of cocoyam, which were significantly higher ($p=0.05$) when compared to corm and comel weights of NPK. The better performance of PM and CPA in comparison with NPK after 3 years of cultivation could be attributed to their higher nutrient concentrations. For instance, PM had the highest OC, N and P, while CPA had the highest K, Ca and Mg. The remarkable performance of PM and CPA when compared with NPK could also be due to their buffering action against pH fluctuation and leaching, improved soil structure and water retention capacity. The relatively higher Ca, Mg and especially K are performance indicators for cocoyam. Abundant K supply has been reported to be an important nutrient in the production of cocoyam [21]. The mixture of CPA+PM gave significantly higher ($p = 0.05$) corm and cormel weights of cocoyam than their sole forms (CPA; PM), NPK and NSF (control). This could be attributed to the rise in nutrient levels in the amended soil. This is because their mixture with each other increased their nutrient supplying power, which increased the availability of soil nutrients and their subsequent uptake by plants. The better performance of the mixture of CPA+PM in comparison with other treatments could also be adduced to better improvement in soil physical properties (reduced soil bulk density, increased total porosity and water content). The lowest corm and cormel weights of cocoyam was produced by the NSF (control) and it was significantly lower ($p = 0.05$) than other treatments. This could be adduced to initial lower nutrient status of the soil and continuous cultivation without fertilization, thus indicating poor soil fertility. This finding highlighted the important of organic amendment use for the improvement of soil and crop productivity in the tropics.

TABLE VI
EFFECT OF CPA AND PM ON GROWTH PARAMETERS OF COCOYAM

Treatment	Plant height (cm)			Number of leaves per plant			Leaf area per plant (m^2)		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
NSF (Control)	54.4d	52.6e	50.4e	6.34ns	6.23ns	6.18ns	1.63d	1.54e	1.46e
400 kg ha^{-1} NPK-15-15-15	61.2c	58.4d	56.3d	7.56	7.24	7.20	2.01c	1.91d	1.88d
7.5 t ha^{-1} CPA	62.0c	63.3c	64.6c	7.55	8.04	8.22	2.03c	2.12c	2.17c
7.5 t ha^{-1} PM	71.5b	72.2b	73.5b	7.85	8.15	8.36	2.25b	2.34b	2.39b
3.5 t ha^{-1} CPA + 3.5 t ha^{-1} PM	82.3a	83.6a	84.3a	7.97	8.23	8.57	2.72a	2.83a	2.98a

Note: Values followed by the same alphabets on the same column are not significantly different at $p = 0.05$ according to Duncan's multiple range test (DMRT). NSF = Natural soil fertility; CPA = Cocoa pod ash; PM = Poultry manure; ns = Not significant.

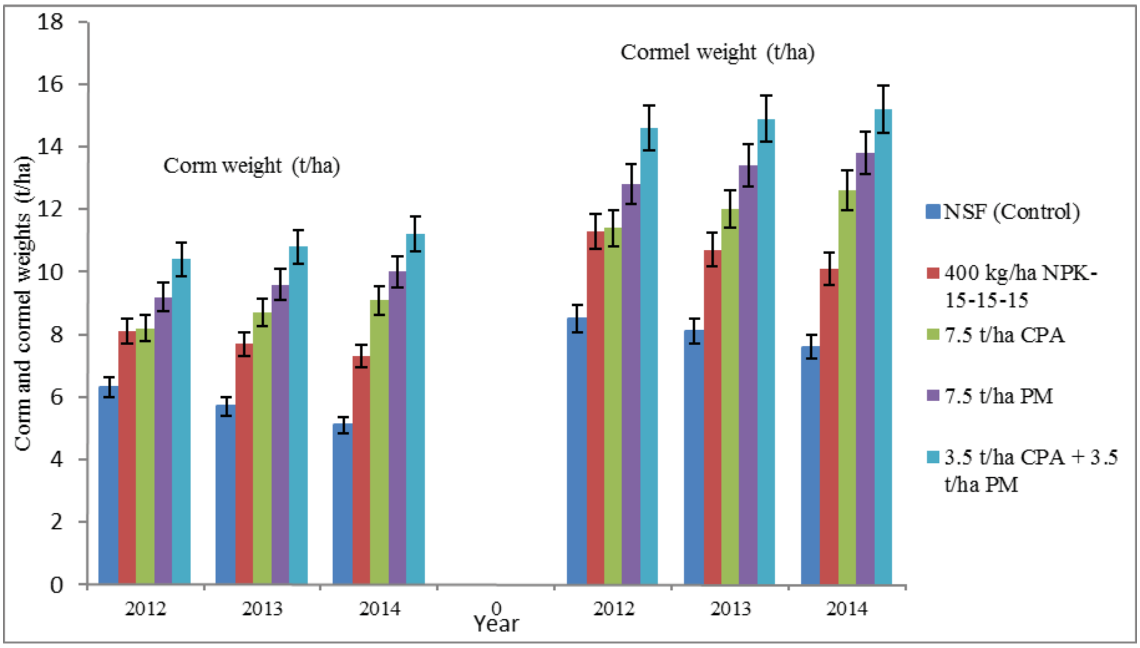

Fig. 1 Effect of CPA and PM on corm and cormel weights of cocoyam. Vertical bars show standard errors of paired comparisons

The plant height, leaf area, corm and cormel yields of cocoyam in the organic amendment regime treatments increased overtime, whereas that under NPK or NSF (control) regime treatment decreased (Table VI and Fig. 1). The increase in plant height, leaf area, corm and cormel yields of cocoyam over-times in the organic amendment regime treatments could be attributed to their high residual effects on soil properties and were able to sustain three successive cropping of cocoyam in this study. Whereas the decrease in plant height, leaf area, corm and cormel yields of cocoyam over-times in the NPK regime treatment was related to the fact that nutrients from NPK are quickly released into soil which may not benefit subsequent cocoyam crops and its continuous application degrades soil properties.

Averaged over the 3 years, CPA+PM increased corm and cormel weights of cocoyam by 13 and 12%, respectively, relative to PM alone (Fig. 1). Relative to the NPK, CPA+PM increased corm and cormel weights of cocoyam by 40 and 39%, respectively. This treatment CPA+PM also increased corm and cormel weights of cocoyam by 24 and 24%, respectively, compared with CPA alone. The NPK treatment increased corm and cormel weights of cocoyam by 35 and 32%, respectively, compared with the NSF (control), whereas PM alone increased corm and cormel weights of cocoyam by 25 and 24%, respectively, compared with NPK.

IV. Conclusions

The sole forms of CPA and PM applied at 7.5 t ha^{-1} each and a mixture of CPA+PM applied at 3.5 t ha^{-1} each increased plant height and leaf area, corm and cormel yields of cocoyam and reduced soil bulk density, and increased total porosity, water content, soil and leaf N, P, K, Ca and Mg, soil pH and OC compared with the NSF (control). NPK did not improve soil physical properties, but did increase soil and leaf N, P, K, Ca and Mg concentrations, plant height and leaf area, corm and cormel yields of cocoyam compared with the NSF (control). Maximum plant height and leaf area, corm and cormel yields of cocoyam was obtained with a mixture of 3.5 t ha^{-1} CPA + 3.5 t ha^{-1} PM due to its higher N, P, K, Ca, Mg, total porosity, water content and lower bulk density compared with other treatments and therefore recommended for cocoyam production on an Alfisol of the humid tropics for enhancing soil fertility conditions and cocoyam productivity. This recommendation agreed with the fact that the use of inorganic fertilizers in crop production has not been sustainable due to its high cost and scarcity, and also degrade soil properties when use continuously. These organic amendments (CPA and PM) are very cheap, readily available and sustainable, and also have beneficial secondary effects on soil properties and are more environmentally friendly.

References

[1] D.F. Uwah, A.U. Udoh and G.A. Iwo, "Effect of organic and mineral fertilizers on the growth and yield of cocoyam (*Colocasia esculenta* (L.) Schott)", International Journal of Agricultural Sciences, 3(1):33-38, 2011.

[2] A.O. Adekiya, T.M. Agbede and S.O. Ojeniyi, "The Effect of three years of tillage and poultry manure application on soil and plant nutrient composition, growth and yield of cocoyam", Experimental Agriculture, pp. 1-11, 2015. doi: 10.1017/S0014479715000253.

[3] B.A. Ndon, N.H. Ndulaka and N.U. Ndaeyo, "Stabilization of yield parameters and some nutrients components in cocoyam cultivars with time in Uyo, southeastern Nigeria", Global Journal of Agricultural Science, 2(2):74-78, 2003.

[4] I C. Onwueme and T.D. Sinha, "Field Crop Production in Tropical Africa, CTA Ede". The Netherlands, pp. 1-480, 1991.

[5] D. Som, "Handbook of Horticulture, Indian Council of Agricultural Research", New Delhi, pp. 507-508, 2007.

[6] J.O. Erhabor and W. A. Molindo, "Assessing nutrient potentials of a soil continuously cropped with *Xanthosoma sagittifolia* (L) in Onisere, Ondo State, Nigeria", Agricultural Journal 5(4):269-272, 2010.

[7] G.O. Obigbesan, A. A. Agboola and A.A.A. Fayemi, "Effect of potassium on tuber yield and nutrient uptake of yam", In: J. Cock, R. MacIntyre and M. Graham (Eds.). Proceedings of the 4th Symposium of the International Society for Tropical Root Crops, CIAT, Cali, Colombia, 1-7 August 1976, pp. 104-107, 1976.

[8] G.O. Obigbesan, "In: Potassium Workshop", Oct. 1980, IITA, Ibadan, Nigeria, 1980.

[9] S.O. Ojeniyi, "Effect of goat manure on soil nutrient and okra yield in a rainforest area of Nigeria", Applied Tropical Agriculture, 5:20-23, 2000.

[10] T.M. Agbede, A.O. Adekiya and J.S. Ogeh, "Effects of organic fertilizers on yam productivity and some soil properties of a nutrient-depleted tropical Alfisol", Archives of Agronomy and Soil Science, 59(4-6):803-822, 2013.

[11] O.A. Egunjobi, "On the possible utilization of discarded cocoa (*Theobroma cacao* L.) pod husks as fertilizer and nematicides", Proceedings of the 5th International Cocoa Research Conference, CRIN, Ibadan, Sept. 1-9, 1975, pp. 541-547, 1976.

[12] H.K. Adu-Daapah, J. Cobbinah and E.O. Asare, "Effect of cocoa pod ash on the growth of maize", Journal of Agricultural Science, 122:31-33, 1994.

[13] D.I. Akanni and S.O. Ojeniyi, "Effect of different levels of poultry manure on soil physical properties, nutrient status, growth and yield of tomato (Lycopersicon esculentum)", Research Journal of Agronomy, 1:1-4, 2007.

[14] L.S. Ayeni and M.T. Adetunji, "Integrated application of poultry manure and mineral fertilizer on soil chemical properties, nutrient uptake, yield and growth components of maize", Nature and Science, 8(1):60-67, 2010.

[15] B. Osundare, "Effect of fertilizer types and varying population on the performance of cocoyam", Moor Journal of Agricultural Research, 5(1-2):7-12, 2004.

[16] J. Vicente-Chandler, H. Irizarry and S. Silva, "Nutrient uptake by taniers as related to stage of growth and effect of age on yields of the Morada variety", Journal of Agriculture of University of Puerto Rico, 66(1):1-10, 1982.

[17] Soil Survey Staff, "Keys to soil taxonomy", 11th Edition. Agriculture Handbook, No. 436. United States Department of Agriculture and Natural Resources Conservation Service, Washington DC, 2010.

[18] FAO, "World reference base of soil resources", World Soil Resources Report 84. Foods and Agriculture Organisation of the United Nations, Rome, 1998.

[19] T.M. Agbede, "Effect of tillage on soil properties and yam yield on an Alfisol of southwestern Nigeria", Soil Tillage Research, 86(1):1-8, 2006.

[20] A.O. Adekiya, S.O. Ojeniyi and T.M. Agbede, "Poultry manure effects on soil properties, leaf nutrient status, growth and yield of cocoyam in a tropical Alfisol", Nigerian Journal of Soil Science, 22(2):30-39, 2012.

[21] S.O. Ojeniyi, O.A. Amusan and A.O. Adekiya, "Effect of poultry manure on soil physical properties, nutrient uptake and yield of cocoyam (*Xanthosoma sagittifolium*) in southwest Nigeria", American-Eurasian Journal of Agricultural and Environmental Science, 13(1):121-125, 2013.

[22] A. Agueguia, "Non-destructive estimation of leaf area in cocoyam (*Xanthosoma sagittifolium* (L.) Schott)", Journal of Agronomy and Soil Science, 171(2):138-141, 1993.

[23] M. Pansu and J. Gautheyrou, "Handbook of Soil Analysis". Mineralogical, Organic and Inorganic Methods. Springer-Verlag, Berlin Heidelberg, New York, 995pp, 2006.

[24] W. Horwitz, Editor, "Official Methods of Analysis of the Association of Official Analytical Chemists International". 16th Edition. AOAC International, Gaithersburg, MD; 1298pp, 1997.

[25] N.R. Hulugalle, R. Lal and O.A. Opara-Nadi, "Effect of tillage system and mulch on soil properties and growth of yam (*Dioscorea rotundata*)

and cocoyam (*Xanthosoma sagittifolium*) on an Ultisol", Journal of Root Crops, 11(1-2):9-22, 1985.

[26] T.M. Agbede, "Nutrient availability and cocoyam yield under different tillage practices", Soil Tillage Research, 99(1):49-56, 2008.

[27] S. Kabeerathumma, B. Mohankumar and P.G. Nair, "Nutrient uptake and their utilization by yams, aroids and coleus", Technical Bulletin Series 10, Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India, 1987.

[28] E.A. Akinrinde and G.O. Obigbesan, "Evaluation of the fertility status of selected soils for crop production in five ecological zones of Nigeria", In: O. Babalola (Ed.). Proceedings of the 26th Annual Conference of Soil Science Society of Nigeria; 2000 Oct 30 – Nov 3; Ibadan, pp. 279-288, 2000.

[29] M.I. Onwuka, V.E. Osedeke, and N.A. Okolo, "Amelioration of soil acidity using cocoa husk ash for maize production in Umudike area of southeast Nigeria", Tropical and Subtropical Agroecosystems, 7:41-45, 2007.

[30] J.S.C. Mbagwu and A. Piccolo, "Changes in soil aggregate stability induced by amendment with humic substances", African Journal of Biotechnology, 5:1058-1061, 1989.

[31] E.I. Moyin-Jesu, "Evaluation of different organic fertilizers on the soil, leaf chemical composition and growth performances of coffee seedlings (*Coffee arabica* L.)", African Journal of Science and Technology (AJST)), Science and Engineering Series, 9(2):105-112, 2008.

[32] L.S. Ayeni, M.T. Adetunji, S.O. Ojeniyi, B.S. Ewulo and A.J. Adeyemo, "Comparative and cumulative effect of cocoa pod husk ash and poultry manure on soil and nutrient contents and maize yield", American-Eurasian Journal of Sustainable Agriculture, 2(1):92-97, 2008.

[33] K. Agyarko and E.K. Asiedu, "Cocoa pod husk and poultry manure on soil nutrients and cucumber growth", Advances in Environmental Biology, 6(11):2870-2874, 2012.

[34] S.O. Ojeniyi, M.A. Awodun and S.A. Odedina, "Effect of animal manure amended spent grain and cocoa husk on nutrient status, growth and yield of tomato", Middle-East Journal of Scientific Research, 2(1):33-36, 2007.