Effects of Sole and Integrated Application of Cocoa Pod Ash and Poultry Manure on Soil Properties and Leaf Nutrient Composition and Performance of White Yam

T. M. Agbede, A. O. Adekiya

***Abstract*—**Field experiments were conducted during 2013, 2014 and 2015 cropping seasons at Rufus Giwa Polytechnic, Owo, Ondo State, 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 yam. Three soil amendments: CPA, PM (sole forms), CPA and PM (mixture), were applied at 20 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). The five treatments were arranged in a randomized complete block design with three replications. The test soil was slightly acidic, low in organic carbon (OC), N, P, K, Ca and Mg. Results showed that soil amendments significantly increased ($p = 0.05$) tuber weights and growth of yam, soil and leaf N, P, K, Ca and Mg, soil pH and OC concentrations compared with the NSF (control). The mixture of CPA+PM treatment increased tuber weights of yam by 36%, compared with inorganic fertilizer (NPK) and 19%, compared with PM alone. Sole PM increased tuber weight of yam by 15%, compared with NPK. Sole or mixed forms of soil amendments showed remarkable improvement in soil physical properties, nutrient availability, compared with NPK and the NSF (control). Integrated application of CPA at 10 t ha^{-1} + PM at 10 t ha^{-1} was the most effective treatment in improving soil physical properties, increasing nutrient availability and yam performance than sole application of any of the fertilizer materials.

***Keywords*—**Cocoa pod ash, leaf nutrient composition, poultry manure, soil properties, yam.

I. Introduction

YAM (Dioscorea *rotundata* Poir) belongs to the family Dioscoreaceae and it is an important staple food crop in West Africa. Nutritionally, yams are rich in carbohydrates and are valuable sources of certain vitamins; they also contain 1.9-3.9% protein [1]. Yam is second to cassava as the most important cultivated tropical tuber crop. It is widely grown in Nigeria; and because of its multipurpose uses, it occupies a principal place in farming systems of the humid tropical region. While Africa alone contributes 90% of the world production of yams, Nigeria accounts for over 70% of the world production [2], [3]. In West Africa, yams are processed into various food forms, which include pounded, boiled, roasted or grilled, fried, slices and balls, mashed, chips and flakes. Yam is also an indispensable part of the bride dowry among Yoruba and Ibo tribes in southern Nigeria [4].

In spite of the great economic importance of the crop, its potential yields to meet the global demand for the tuber yield has not been achieved because of the increasing decline in soil fertility levels and lack of soil management requirements for continuous yam cultivation. Yam, being a tuber crop has a high requirement for K [5], [6]. 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 [7], [8]. 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 tuber crop like yam. 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 [9]. 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 pod husks are burnt into ash as a method of ensuring proper sanitation and for the control black pod disease of cocoa. In [10], 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 [11], [12]. Research information on the sole and integrated use of CPA and PM for the production of yam is yet to receive research attention. Yams like any other root and tuber crops require a relatively rich soil, particularly in terms of organic matter and soil nutrients [13], in order to perform well. Therefore, continuous cultivation of crop like yam on the same soil lead to nutrient depletion, degradation of soil quality and consequent low yield. According to [14], for a target yield

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of 37.91 t ha^{-1}, yam removes 148.0, 41.2 and 199.2 kg ha^{-1} of N, P, K, 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 effects of no fertilizer, inorganic fertilizer, CPA and PM alone and their combination on soil properties, leaf nutrient composition and yield of yam 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 2013, 2014 and 2015 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^{o}C. The soil of the experimental site belongs to an Alfisol classified as Oxic Tropuldalf [15] or Luvisol [16] derived from quartzite, gneiss and schist [3]. 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 cocoyam (*Xanthosoma sagittifolium* Schott), 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 2013, 2014 and 2015 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) and mixtures of the two, (CPA with PM). Yam is a high nutrient requiring plant, and it benefits greatly from liberal use of organic and inorganic manures [8]. Therefore, organic manures were applied at 20 t ha^{-1}, based on recommendation for high nutrient requiring tuber crop like yam [17], [18], while inorganic fertilizer was applied at 400 kg ha^{-1}, based on field recommendation for yam production on a nutrient-depleted soil [14]. 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$05, 15 $K_2$0) at 400 kg ha^{-1}; (c) PM at 20 t ha^{-1}; (d) CPA at 20 t ha^{-1} and (e) CPA at 10 t ha^{-1} mixed with PM at 10 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 seedyam weighing about 0.4 kg of white yam (*Dioscorea rotundata* cv Gambari) was planted per hole on 2 April 2013, 5 April 2014 and 7 April 2015, 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 vine emergence, while the second dose was applied at 2 months later when tuber expansion, rapid stem and leaf development were in progress. Stakes were installed after sprouting. Weeding was done manually with a hoe at 3, 8, 12 and 16 weeks after planting in each experiment. The same treatment was applied to each plot for the three years.

Twenty plants were randomly selected per plot for determination of vine length, number of leaves and leaf area at 5 months after planting (DAP) when the yam plant formed a full canopy. Vine length was determined by meter rule. Number of leaves was determined by counting the number of leaves on each yam plant and leaf area was measured using a graphical method (i.e. by placing the leaf on graph sheet for area determination). Tuber yield was determined at harvest (8 months after planting) by recording the weight of fresh tuber from twenty plants selected randomly from each plot using a top loading balance to determine their weights.

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

Two months after planting yam, 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 yam 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^{o}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 2013, 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 [19]. 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 were 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 yam.

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 Walkley 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 [20]. Phosphorus was measured colorimetrically by the molybdate blue method in an auto-analyser, K by flame photometry, and Ca and Mg by atomic absorption spectrophotometer.

In the 2015 cropping, representative leaf samples from the upper, middle and lower parts of the yam vines were randomly collected from ten plants per plot at 5 months after planting 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 ^{0}C 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 [20].

C. Statistical Analysis

Data collected for soil properties, leaf nutrient concentrations, growth parameters and yield 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 1.57 Mg m^{-3} and total porosity of 40.8% (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 values of between 6.0 and 7.0 considered as optimum for yam cultivation [21]. 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 [22]. Thus, indicating poor soil fertility. Hence, it is expected that application of organic fertilizer materials would enhance soil fertility and performance of yam.

TABLE I
SOIL PHYSICAL AND CHEMICAL PROPERTIES (0-15 CM DEPTH) OF THE EXPERIMENTAL SITE BEFORE EXPERIMENTATION IN 2013

Property	Value
Sand (g kg^{-1})	682
Silt (g kg^{-1})	151
Clay (g kg^{-1})	167
Textural class	Sandy loam
Bulk density (Mg m^{-3})	1.57
Total porosity (%, v/v)	40.8
pH (H_2O)	5.4
Organic C (%)	1.03
Total N (%)	0.10
Available P (mg kg^{-1})	8.9
Exchangeable K (cmol kg^{-1})	0.12
Exchangeable Ca (cmol kg^{-1})	1.33
Exchangeable Mg (cmol kg^{-1})	0.25

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

PM had significantly higher (p = 0.05) organic C (OC), N and P nutrient concentrations and 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 yam growth and yield. As the soil is also acidic, organic fertilizer materials especially CPA could help by reducing soil acidity [23].

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

In the 3 years of cropping, application of sole CPA or PM alone and integration of both 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, integrated application of CPA and 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 integrated application of CPA and 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 [8]. This study was similar with the findings of [24] 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, 32 and 38%, 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 26, 29 and 29%, respectively, compared with NPK and NSF (control).

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

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 (%)		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
NSF (Control)	1.38a	1.43a	1.48a	47.9c	46.0c	44.2c	9.8c	8.9c	8.4c
400 kg ha^{-1} NPK-15-15-15	1.38a	1.42a	1.47a	47.9c	46.4c	44.5c	10.1c	9.5c	8.5c
20 t ha^{-1} CPA	1.15b	1.08b	1.03b	56.6b	59.2b	61.1b	12.5b	11.3b	10.2b
20 t ha^{-1} PM	1.12b	1.06b	1.01b	57.7b	60.0b	61.9b	12.9b	11.8b	10.6b
10 t ha^{-1} CPA + 10 t ha^{-1} PM	1.01c	0.94c	0.92c	61.9a	64.5a	65.3a	14.2a	13.3a	12.3a

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 Sole and Integrated Application 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 integration 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 [25], [26] 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 [27] while cocoa pod products have been found to have high level of K [26]. 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 [23] unlike NPK which could lead to soil acidity with repeated use. The increase in soil pH recorded for sole applications of CPA and PM alone 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 35, 120, 133, 60, 211, 126 and 135%, respectively, compared with NPK. The treatment also increased soil pH, total N, available P, exchangeable K, Ca and Mg by 10, 36, 21, 149, 27 and 61%, respectively, compared with PM alone. However, PM alone increased soil OC by 18% 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 47, 84, 90, 38, 12 and 42%, respectively, compared with sole application of CPA. NPK increased soil total N, available P, exchangeable K, Ca and Mg by 88, 59, 180, 22 and 24%, respectively, compared with NSF (control). PM alone increased soil pH, OC, total N, available P, exchangeable K, Ca and Mg by 22, 161, 87, 33, 25, 78 and 46%, respectively, compared with NPK.

TABLE IV
EFFECT OF CPA AND PM ON SOIL CHEMICAL PROPERTIES (0-15 CM DEPTH) AFTER CROP HARVEST IN 2015

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	0.81d	0.08e	7.3e	0.10e	1.08e	0.21e
400 kg ha^{-1} NPK-15-15-15	4.9e	0.84d	0.15d	11.6c	0.28d	1.32d	0.26d
20 t ha^{-1} CPA	7.1a	1.26c	0.19c	9.8d	0.63b	2.67b	0.43b
20 t ha^{-1} PM	6.0c	2.19a	0.28b	15.4b	0.35c	2.35c	0.38c
10 t ha^{-1} CPA + 10 t ha^{-1} PM	6.6b	1.85b	0.35a	18.6a	0.87a	2.98a	0.61a

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 Sole and Integrated Application of CPA and PM on Leaf Nutrient Concentrations of Yam

The integration 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 yam 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 yam plants. This observation agreed with [28] and [29], 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 yam plants in the NSF (control) plots were below the critical levels of < 2.9-4.0% N, 0.21-0.32% P, 2.2-2.8% K, 0.5-0.9% Ca and 0.10-0.14% Mg as reported by [30]. Thus, the leaves of the yam plants exhibited symptoms of deficiencies in N (yellow colouration), P (purple colouration) and K (burnt leaf margin). The integration of CPA+PM increased leaf N, P, K, Ca and Mg concentrations of yam by 51, 73, 70, 168 and 275%, respectively, compared with NPK. The treatment also increased leaf N, P, K, Ca and Mg concentrations of yam by 23, 15, 26, 34 and 67%, 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 23, 50, 34, 100 and 125%, respectively, compared with NPK treatment. The NPK treatment also increased leaf N, P, K, Ca and Mg by 26, 38, 33, 55 and 33%, respectively, compared with NSF (control).

TABLE V
EFFECT OF CPA AND PM ON LEAF NUTRIENT CONCENTRATIONS OF YAM AT 5 MONTHS AFTER PLANTING IN 2015 CROPPING SEASON

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
NSF (Control)	2.03e	0.16e	1.25e	0.22e	0.09e
400 kg ha^{-1} NPK-15-15-15	2.55d	0.22d	1.66d	0.34d	0.12d
20 t ha^{-1} CPA	2.87c	0.29c	1.94c	0.56c	0.33b
20 t ha^{-1} PM	3.13b	0.33b	2.23b	0.68b	0.27c
10 t ha^{-1} CPA + 10 t ha^{-1} PM	3.84a	0.38a	2.82a	0.91a	0.45a

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 Sole and Integrated Application of CPA and PM on Growth and Yield of Yam

In the first, second and third years of cropping, growth parameters such as vine length, number of leaves and leaf area of yam (Table VI) and tuber yield of yam (Fig. 1) increased significantly (p = 0.05) under organic amendment and NPK treatments compared with NSF (control). In general, the vine length, number of leaves and leaf area, and tuber yield of yam 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 vine length, number of leaves and leaf area, and tuber yield of yam which was statistically different from other treatments. NPK gave higher vine length, number of leaves and leaf area, and tuber yield of yam that was not statistically different from the PM alone. The growth and tuber yield produced by these treatments (NPK and PM alone) were significantly higher (p = 0.05) than the sole CPA. The NSF (control) treatment gave the lowest growth and tuber yield and was significantly lower (p = 0.05) than other treatments. In the second and third years, the mixture of CPA+PM consistently gave highest values for vine length, number of leaves and leaf area, and tuber yield of yam which were significantly greater (p = 0.05) than the other treatments. The sole PM produced significantly higher (p = 0.05) vine length, number of leaves and leaf area, and tuber yield of yam compared with NPK and sole CPA. The growth and tuber yield of yam produced by CPA in these two years were significantly higher (p = 0.05) than NPK, except in 2014, which produced similar growth and tuber yield with NPK. The lowest growth and tuber yield was also produced by NSF (control) treatment. The mean vine length for the NSF (control), NPK, CPA, PM and CPA+PM were 2.77, 3.28, 3.34, 3.63 and 4.22 m, respectively. The respective values for number of leaves per plant were 1907, 2374, 2400, 2614 and 2978, respectively, and the values for leaf area per plant were 1.38, 1.78, 1.86, 2.05 and 2.86 m^2, respectively.

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 yam. Abundant K supply has been reported to be an important nutrient in the production of yam [21]. The mixture of CPA+PM gave significantly higher ($p = 0.05$) vine length, number of leaves and leaf area, and tuber yield of yam 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 vine length, number of leaves and leaf area, and tuber yield of yam 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 SOLE AND INTEGRATED APPLICATION OF CPA AND PM ON GROWTH PARAMETERS OF YAM

Treatment	Vine length (m)			Number of leaves per plant			Leaf area per plant (m^2)		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
NSF (Control)	2.86d	2.79d	2.66e	1931d	1908d	1882e	1.53d	1.34d	1.26e
400 kg ha^{-1} NPK-15-15-15	3.48b	3.28c	3.07d	2594b	2335c	2194d	1.92b	1.79c	1.62d
20 t ha^{-1} CPA	3.12c	3.34c	3.55c	2367c	2401c	2433c	1.71c	1.86c	2.02c
20 t ha^{-1} PM	3.39b	3.62b	3.88b	2588b	2621b	2632b	1.89b	2.04b	2.21b
10 t ha^{-1} CPA + 10 t ha^{-1} PM	4.16a	4.21a	4.29a	2955a	2986a	2994a	2.77a	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.

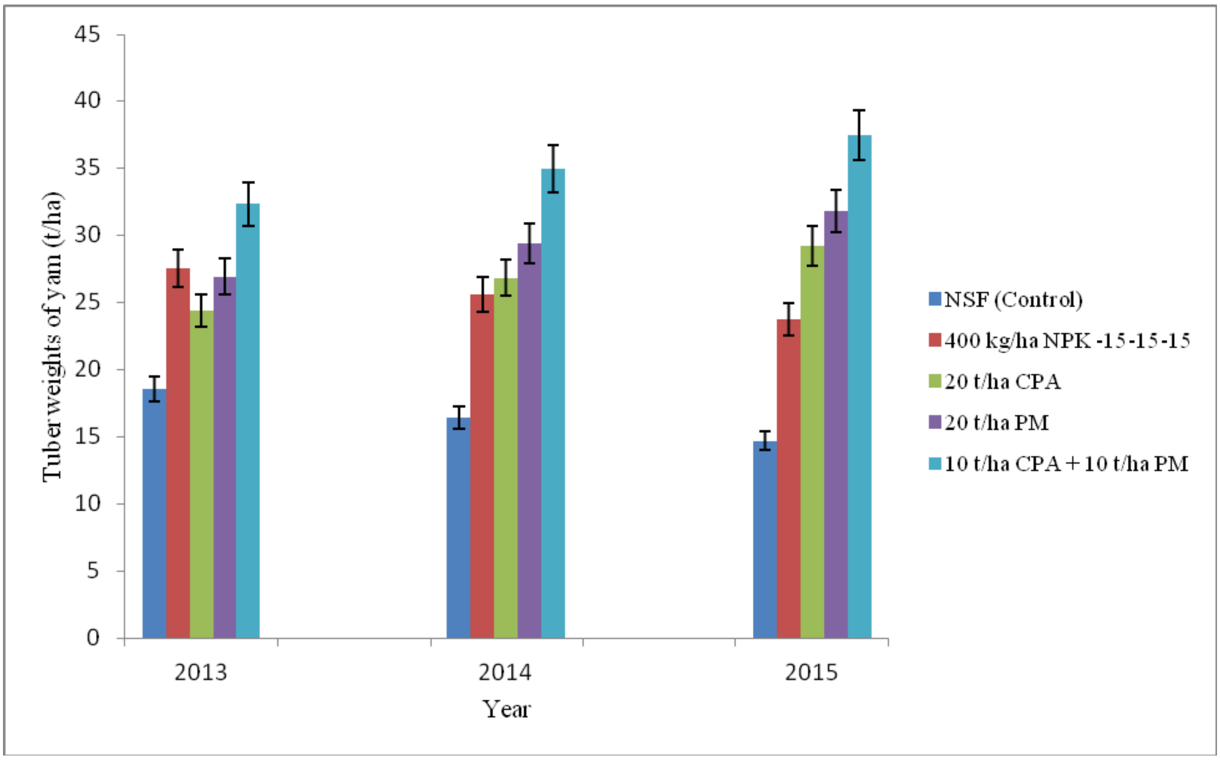

Fig. 1 Effect of sole and integrated application of CPA and PM on tuber weights of yam. Vertical bars show standard errors of paired comparisons

The vine length, number of leaves and leaf area, and tuber yield of yam 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 vine length, number of leaves and leaf area, and tuber yield of yam 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 yam in this study. Whereas the decrease in vine length, number of leaves and leaf area, and tuber yield of yam 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 yam crops and its continuous application degrades soil properties.

Averaged over the 3 years, CPA+PM increased tuber weight of yam by 19%, relative to PM alone (Fig. 1). Relative to the NPK, CPA+PM increased tuber weights of yam by 36%. This treatment CPA+PM also increased tuber weight of yam by 30%, compared with CPA alone. The NPK treatment increased tuber weight of yam by 65%, compared with the NSF (control), whereas PM alone increased tuber weight of yam by 15%, compared with NPK.

IV. CONCLUSIONS

The integrated application of CPA at 10 t ha^{-1} and PM applied at 10 t ha^{-1} increased vine length, number of leaves and leaf area, and tuber yield of yam and reduced soil bulk density, and increased total porosity, water content, soil and leaf nutrient concentrations of yam for the three years of study than the sole application of CPA, PM alone and single NPK. NPK did not improve soil physical properties, but did increase soil and leaf N, P, K, Ca and Mg concentrations, vine length, number of leaves and leaf area, and tuber yield of yam compared with the NSF (control). This study shows that integrated application of CPA and PM was more effective in improving soil physical properties, increasing nutrient availability and yam performance than sole application of any of the fertilizer materials, and therefore recommended for yam production on an Alfisol of the humid tropics for soil fertility maintenance and performance of yam crop. 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. Combined organic wastes can be used as nutrient source for yam in the absence of inorganic fertilizer.

REFERENCES

[1] S.K. Hahn, D.S.O. Osiru, M.O. Akoroda and J.A. Otoo, “Yam production and its future prospects”. Outlook Agriculture, 16(3):105-110, 1987.
[2] C.A. Okoh, “The effect of mulching on soil physico-chemical properties and the yield of white yam”, Tropical Journal of Root Tuber Crops, 4(2):24-31, 2004.
[3] 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.
[4] G.C. Orkwor, R. Asiedu and I.J. Ekanayake, “Food Yams: Advances in Research. International Institute of Tropical Agriculture (IITA), Ibadan, National Root Crops Research Institute, Umudike, Nigeria, 249 p, 1998.
[5] 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.
[6] G.O. Obigbesan, “In: Potassium Workshop”, Oct. 1980, IITA, Ibadan, Nigeria, 1980.
[7] 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.
[8] 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.
[9] 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.
[10] 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.
[11] 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.
[12] 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.
[13] L. Degras, “The yam: a tropical root crop. London: Macmillan/ The Technical Centre for Agricultural and Rural Cooperation, 1993.
[14] G.O. Obigbesan and A.A Agboola, “Uptake and distribution of nutrients by yams (*Dioscorea* spp) in western Nigeria”, Experimental Agriculture, 14:349-355, 1978.
[15] 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.
[16] FAO, “World reference base of soil resources”, World Soil Resources Report 84. Foods and Agriculture Organisation of the United Nations, Rome, 1998.
[17] T.M. Agbede and A.O. Adekiya, “Effects of poultry manure on soil fertility, growth and yield of white yam and yellow yam”. University of Khartoum Journal of Agricultural Sciences, 20(3):286-303, 2012.
[18] E.U, Onweremadu, I.I Ibeawuchi and C.I. Duruigbo, “Land evaluation and productivity of organically-fertilized crop mixtures in a degraded soil”, Nature and Science, 6(1):34-42, 2008.
[19] M. Pansu and J. Gautheyrou, “Handbook of Soil Analysis”. Mineralogical, Organic and Inorganic Methods. Springer-Verlag, Berlin Heidelberg, New York, 995pp, 2006.
[20] W. Horwitz, Editor, “Official Methods of Analysis of the Association of Official Analytical Chemists International”. 16th Edition. AOAC International, Gaithersburg, MD; 1298pp, 1997.
[21] H. Shiwachi, C.C. Okonkwo and R. Asiedu, “Nutrient deficiency symptoms in yams (*Dioscorea* spp)”, Tropical Science, 44:155-162, 2004.
[22] 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.
[23] 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.
[24] 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.
[25] 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.

[26] 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.
[27] 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.
[28] E.O. Adeleye and L.S. Ayeni, "Effect of cocoa pod ash and poultry manure combinations on soil and plant nutrient contents and performance of maize – Screenhouse Experiment", Researcher, 2(12):51-56, 2010.
[29] 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.
[30] J.N. O'Sullivan, "Yam nutrition: Nutrient disorders and soil fertility management", Australian Centre for International Agricultural Research (ACIAR) Monograph No. 144, Canberra, 112 pp, 2010.