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Integrated Nutrient Management; Option for Improvement on Soil Chemical Properties, Growth and Yield of Cocoyam (*Colocasia esculenta*)

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Authors' contributions

This work was carried out in collaboration between all authors. Author JCN designed the study, wrote the protocol and interpreted the data. Author JCN anchored the field study, gathered the initial data and performed preliminary data analysis. While authors CIK and POO managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

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ABSTRACT

The response of cocoyam *(Colocasia esuclenta* (L.) Schott) and soil chemical properties to different manure sources were studied under field conditions in 2014 and 2015 cropping season at Federal College of Agriculture, Ishiagu, Ebonyi State, a derived savanna zone of Southeastern Nigeria. Randomized complete block design (RCBD) was used to study these soil amendments. Ten(10) treatments; 10t/ha poultry dropping (PD), 200 kg/ha NPK 15:15:15 fertilizer (NPK), 5 t/ha rice husk ash (RHA), 10 t/ha rice husk dust (RHD), 5t/ha PD + 2.5 t/ha RHA, 5 t/ha PD + 5 t/ha RHD, 100 kg/ha NPK + 2.5 t/ha RHA, 100 kg/ha NPK + 5t/ha RHD, 66.67 kg/ha NPK + 3.33 t/ha RHD + 1.67 t/ha RHA and control, were used in the study which were replicated three times. Soil chemical properties evaluated were pH, organic carbon, exchangeable bases (K^+, Ca^{2+}, Mg^{2+} and Na^+) and

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exchangeable acidity. Others include CEC, total nitrogen, available phosphorus and base saturation while cocoyam yield was measured at harvest. The results showed that soil pH, soil organic carbon (SOC), cation exchange capacity (CEC), exchangeable acidity (EA), BS and available phosphorous were significantly affected by the application of the amendments, while total nitrogen shows non-significant effect. Cocoyam cormels and corms yield were significantly ($p < 0.05$) increased in all the soil amended plots than the control. Generally, the results implied that the integration of organic and inorganic amendments stand better chance of improving soil fertility indices and the crop yield than their sole forms in the study.

Keywords: Amendments; integrated nutrient; fertility indices; cocoyam corms and cormels.

1. INTRODUCTION

Cocoyam (*Colocasia esculenta*) is a major source of carbohydrates in Nigeria. The corms and cormels are eaten in the same way as yam *(Dioscorea spp)* and sweetpotato (*Ipomoea batatas*), boiled, fried, baked and roasted [1]. Cocoyam is the cheapest and most handy carbohydrate source of meals for diabetics, convalescents and most gastrointestinal disorder patients. It is also a good carbohydrate base for infant foods on account of their small-sized starch grains which are easily digested compared to those of yam, cassava *(Manihot spp)* or sweetpotato [2,3]. The crop initially referred to as a minor crop in the traditional intercropping system and often regarded as a "woman crop" has presently assumed significant economic importance due to the discovery of its nutritional qualities and industrial uses [4]. In spite of the crop's nutritional qualities and industrial uses, its yield is still very low in Nigeria (5143 kg/ha) compared with yields in Japan (13493 kg/ha) and China (13333 kg/ha) [5]. The very low yield may be attributed to poor production practices such as inappropriate use of fertilizers and other agrochemicals. In Nigeria, cocoyam production is still carried out by poor rural farmers who do not have access to or afford the cost of these agrochemicals. These resource poor farmers account for over 90% of Nigeria's agricultural output through the use of indigenous farming practices [6,7].

In the rain forest agro-ecology of Southeastern Nigeria, intensive cropping has become more common and the soil productivity improvement and fertility restoration is becoming less effective [8]. Bush fallow which had been an efficient, balanced and sustainable system for soil productivity and fertility restoration in the past is presently unsustainable due to high population pressure and other human activities which have resulted in reduced fallow period [9]. A major constraint to intensive production of cocoyam in this agro-ecology is the low level of inherent fertility of the acid soils [1]. The adoption of nutrient management practices that integrate organic, chemical and biological inputs into economically and environmentally sound production systems is an essential step towards sustaining high crop yields and preventing land degradation in the region. The implication is that with the usually high rainfall experienced in this zone, the application of inorganic fertilizers is accompanied by a high rate of leaching losses, increased nutrient imbalance, reduced infiltration and high bulk density [10].

The manure sources are associated with problems relating to unavailability, low quality depending on the type, transportation and handling problems, high C:N ratio, heavy metal pollution and slow nutrient release [11]. The single use of either organic or inorganic fertilizers in recent years has not really met the expected impact in boasting crop yield to cope with the geometric demand. This was the reason why integrated nutrient supply has been advocated by the Food and Agricultural Organization of the United Nation [12]. In view of this, the combined use of chemical fertilizers and organic manures (organomineral fertilizer) has been suggested [13]. Organomineral fertilizer combines the good attributes of inorganic and organic nutrients to enhance crop yield. Current studies on organomineral fertilizer have shown better yield performances than the single use of them and have proved to be a sound soil fertility management strategy in many countries of the world [12,14,15].

Therefore, this study aimed at evaluating the effects of sole source and integrated forms of different manures on selected soil chemical properties, growth and yield of cocoyam.

2. MATERIALS AND METHODS

2.1 Location of the Study Site

The experiment was conducted in 2014 and 2015 cropping seasons at the Teaching and

Research Farm of Federal College of Agriculture Ishiagu. The area lies between latitude 5° 55´ N and 6° 00´ N and longitudes 7° 30´ E and 7° 35´ E in the Derived Savannah Zone of Southeastern Nigeria. The mean annual rainfall for the area is 1350 mm, which spreads from April to October with average annual air temperature being 29℃. The underlying geological material is Shale formation with sand intrusions locally classified as the 'Asu River' group. Generally, Ebonyi State lies mostly in an area of moderate relief (between 125 and 245 m above sea level), and between the Ebonyi (Aboine) River basin and the cross River plain. The soil is hydromorphic and belongs to the order Ultisol, and classified as Typic Haplustult [16]. The soils of the area are always prone to surface erosion, hence reduced surface organic matter.

2.2 Field Study

The experiment was a randomized complete block design (RCBD) with ten treatments including the control, replicated three times. The treatments were: 10 tons/ha of poultry dropping, 200 kg ha^{-1} of NPK fertilizer, 10 tons ha^{-1} of rice husk ash, 10 tons ha^{-1} of rice husk dust, 5 tons ha^{-1} of poultry + 5 tons ha^{-1} of rice husk ash, 5 tons ha^{-1} of poultry + 5 tons ha^{-1} of rice husk dust, 100 kg ha^{-1} of NPK + 5 tons ha^{-1} of rice husk ash, 100 kg ha^{-1} of NPK + 5 tons ha^{-1} of rice husk dust, 66.667 tons ha^{-1} of NPK + 3.33 tons ha^{-1} of rice husk ash + 3.33 tons ha^{-1} of rice husk dust and control (no fertilizer/treatment application). The nutrient compositions of the amendments were presented in Table 1.

The experimental site was cleared and tilled manually into seed beds with native hoe. The amendments were incorporated into the soil, two weeks before planting except NPK fertilizer that was applied two weeks after the crop sprouting, while the ash was applied three days before planting as it mineralizes faster than those other amendments used.

The test crop, cocoyam, *Colocasia esculent*a eddoes corm was sown in-situ at a spacing of 70 cm x 70 cm at the rate of one corm per hole. Two weeding operations were carried out manually with hoe and hand pulling at three and six weeks after planting.

Plant growth measurements were taken from four plants in each plot randomly selected, for the following parameters; plant height and plant number of leaves at 6, 8, 10, 12, 14 weeks after planting (WAP), weight of corms (tuber heads) and cormels (tuber head branches) at harvest.

2.3 Soil Sampling and Laboratory Analysis

A bulk (composite) auger sample was randomly collected within 0-20 cm soil depth before treatments application for initial soil characteristics. At harvest, another four sets of soil samples were collected from each of the plots to determine changes that occurred due to treatments application. The augered topsoil samples were air-dried and sieved with 2 mm sieve. Soil fractions sieved through a 2 mm mesh from individual samples were then analyzed using the following methods. Particle size distribution was measured by the hydrometer method as described by Gee and Bauder [17]. Soil pH was measured in a 1:2.5 (soil:0.1 M KCl) suspensions, while exchangeable acidity (EA) was measured using the method of McLean [18]. The soil organic carbon (OC) was determined by the Walkley and Black method described by Nelson and Sommers [19]. Total nitrogen was determined by semi-micro kjeldahl digestion method using sulphuric acid and $CuSO_4$ and Na_2SO_4 catalyst mixture [20]. Sodium (Na) and potassium (K) were determined from ammonium acetate leachate using the auto-electric flame photometer. Calcium (Ca) and magnesium (Mg) were determined using the complexometer titration method as described by Thomas [21]. Cation exchange capacity (CEC) was determined by the method described by Thomas [21]. The available phosphorous was determined by the Bray II method [22]. Base saturation was determined by calculation as the

Table 1. Properties of the organic amendments

Amendment	OC	N	K	Ca	Mg	P	C:N
	(%)						
PD	16.50	2.10	0.48	14.40	1.20	2.55	7.86
RHD	33.70	0.70	0.11	0.36	0.38	0.49	48.14
RHA	23.90	0.06	0.65	1.00	1.40	11.94	398.33

PD= poultry droppings; RH= rice husk dust; RHA= rice husk burnt ash; OC= organic carbon; N = nitrogen; K = potassium; Ca = calcium; Mg = magnesium; P = phosphorous; C: N = carbon to nitrogen ratio percentage ration of total exchangeable bases to effective cation exchange capacity, using the procedure outlined in Tropical Soil Biology and Fertility Manual [23].

2.4 Data Analysis

Data analysis was performed using GENSTAT 3 7.2 Edition as described in GenStat, [24]. Treatment means were separated and compared using Least Significant Difference (LSD) and standard errors of differences of means, while all inferences were made at 5% level of probability.

3. RESULTS AND DISCUSSION

3.1 Organic Amendments Properties

Rice husk dust amendment had the highest percentage organic carbon, followed by rice husk ash, while poultry dropping recorded the least value. This means that rice husk dust has the potentials of enriching the soil more with organic carbon pools. The analysis also indicated that percentage nitrogen was higher in poultry dropping, while the least nitrogen percent was recorded in rice husk ash. The analysis (Table 1) showed that rice husk ash gave the highest values for percentage potassium and magnesium, while the highest percentage calcium was obtained from poultry dropping.

3.2 Initial Physical and Chemical Characteristics of the Studied Soil

The soil initial physical and chemical properties are in Table 2. Generally the soils were sandy loam with 12% clay, 19% silt and 69% sand. The pH value was 4.8, while the organic carbon and total nitrogen were; 7.3 g kg^{-1}, 1.10 g kg^{-1}, respectively. The exchangeable sodium and potassium were 0.089 and 0.050 cmol (+) kg^{-1}, respectively. Exchangeable calcium and magnesium values were 2.80 and 1.40 $cmolkg^{-1}$, while the cation exchange capacity, exchangeable acidity and available phosphorous were 10.20 $cmolkg^{-1}$, 3.6 $cmolkg^{-1}$ and 9.6 $mgkg^{-1}$, respectively.

3.3 Effects of Different Nutrient Sources on the Soil pH, Organic Carbon and Total Nitrogen

There was significant ($p < 0.05$) improvement on soil pH in the amended plots than in the control plot except the plots treated with NPK and NPK + RHD (Table 2). The 5 t/ha PD + 5 t/ha RHA treated plot (5.6) recorded the highest soil pH in the 2014 study. This was followed by plots amended with rice husk ash. In the 2015 study, the rice husk ash amended plots gave highest significant ($p < 0.05$) increase on the soil pH, followed by PD + RHA treated plots. The increase soil pH in rice husk ash (RHA) treated plots and its complementary form in the two years of study could be due to higher potassium (K), magnesium (Mg) and calcium (Ca) in the rice husk ash applied which then blended well to improve the pH higher than other treatments. The study generally indicated that organically amended plots and their integrated forms increase soil pH. NPK integration with organic amendments generally increases the soil pH more than its sole form. The results implied that integration of mineral fertilizer with organic fertilizer or two organic sources reduces the impact of acidity. . It will as well reduce the quantity of organic materials required for amending the soils and enhance nutrient release. This agrees with the report of Huang and Lin [25], and Zhang and Fung [26] who stated that combined application of organic and inorganic fertilizers has agronomic benefits including improvement on soil fertility and yield.

Table 2. Initial physical and chemical properties of the studied soil

Soil properties	Values
Clay (%)	12
Silt (%)	19
Fine sand (%)	58
Coarse sand (%)	11
Organic carbon (g kg^{-1})	7.3
Total nitrogen (g kg^{-1})	1.10
pH (H_2O)	4.8
Exchangeable bases ($cmolkg^{-1}$)	
Sodium (Na^+)	0.089
Potassium (K^+)	0.050
Calcium (Ca^{2+})	2.80
Magnesium (Mg^{2+})	1.40
Cation exchange capacity (CEC) $cmolkg^{-1}$	10.20
Exchangeable acidity (EA) $cmolkg^{-1}$	3.6
Available phosphorous (mg kg^{-1})	9.6

Soil organic carbon in 2014 revealed statistical ($P<0.05$) improvement from 6.80 g kg^{-1} to 9.73 g kg^{-1} values, with plots amended with rice husk dust increasing the organic carbon pool in the soil than other treatments including the control (Table 3). Generally, plots treated with rice husk dust significantly ($p< 0.05$) increasethe organic carbon pool in the soil than the other treatments. In 2015, there were little decline of soil organic carbon pools in plots amended with rice husk dust, poultry dropping and NPK + RHA (9.33, 8.13 and 7.50 g/kg), whereas plots treated with PD + RHA, PD + RHD, NPK + RHD and NPK + RHA + RHD (8.70, 9.50, 8.23 and 8.30 g/kg), had drastic improvement on the soil organic carbon pools. The reduced organic carbon pools in some of the amended plots in the 2015 study compared to the 2014 could be attributed to the observed surface runoff in some plots which could have reduced the amount of organic matter for decomposition in the affected plots. Plots treated with integrated nutrients increased the soil organic carbon pools higher than NPK and RHA amended plots. Generally, all the amended plots significantly ($p < 0.05$) increased the soil organic carbon (SOC) higher than the control.

There were no significant ($P<0.05$) differences among the treatments on the soil total nitrogen in 2014. The overall low magnitude in the enhancement of soil nitrogen by the amendments may suggest high level of top soil N volatilization [27].

3.4 Effects of Different Nutrient Sources on the Soil Exchangeable Acidity, Cation Exchange Capacity, and Available Phosphorous

The soil exchangeable acidity (EA) was generally lowered by the application of organic treatments in both years of study compared with the amount in the initial soil sample. The RHA treated plots statistically decreased the exchangeable acidity more compared with the other plots. This could be as a result of fertility improving attribute of ash material as a quick means of reducing acidity and increasing cations availability in the soils [28]. The highest exchangeable acidity (EA) values were obtained from the control and plots treated with mineral fertilizer (NPK). This agrees with the findings of Agboola [10], that the application of inorganic fertilizers is accompanied by a high rate of leaching losses and consequent upon this, increased nutrient imbalance, increased soil acidification, reduced infiltration and high bulk density. The results showed that plots amended with RHA and PD (1.53, 1.53 $cmolkg^{-1}$), gave the most significant ($p < 0.05$) reduction in the soil exchangeable acidity (EA) in 2015.

Significant ($P<0.05$) improvement on the cation exchange capacity (CEC) due to treatment applications was observed in 2014 and 2015. The highest significant ($P<0.05$) increase on cation exchange capacity was recorded for plot treated with PD+ RHD in 2014. This was followed by soil amended with PD + RHA, while the least was NPK + RHD treated plots. The mean values of CEC ranged from 11.0 cmo kg^{-1} l to 20.3 cmol (+) kg^{-1} in 2014. The highest significant ($p < 0.05$) increase in the cation exchange capacity was recorded for poultry dropping amended plots, while the control gave the least. The results showed that most of the integrated forms of the amendments performed significantly higher than its sole.

Table 3. Effect of integrated nutrient sources on the soil pH, organic carbon and total nitrogen

Soil amendments	2014			2015		
	Soil pH	SOC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)	Soil pH	SOC ($g\ kg^{-1}$)	TN ($g\ kg^{-1}$)
PD	5.27^{b}	8.30^{b}	1.13	5.53^{b}	8.13^{b}	7.85^{ab}
NPK	4.87^{c}	8.60^{b}	1.12	4.87^{c}	7.77^{b}	7.84^{ab}
RHA	5.50^{ab}	7.47^{cd}	1.13	6.17^{a}	7.53^{b}	7.94^{ab}
RHD	5.47^{ab}	9.73^{a}	1.21	5.20^{bc}	9.33^{a}	10.01^{a}
PD + RHA	5.60^{a}	7.50^{cd}	1.15	5.63^{ab}	8.70^{a}	7.11^{ab}
PD + RHD	5.23^{bc}	7.90^{bc}	1.18	5.70^{ab}	9.50^{a}	13.10^{a}
NPK + RHA	5.03^{bc}	7.87^{bc}	1.03	5.07^{bc}	7.50^{b}	5.49^{bc}
NPK + RHD	4.97^{c}	6.80^{d}	1.04	4.97^{c}	8.23^{b}	3.34^{c}
NPK + RHA + RHD	5.47^{ab}	6.80^{d}	1.14	5.10^{bc}	8.30^{b}	10.57^{a}
CT	4.87^{c}	6.63^{d}	1.02	4.47^{d}	6.73^{c}	1.77^{d}
Mean	5.20	7.76	1.12	5.27	8.17	7.50
$LSD_{0.05}$	0.311	0.8034	NS	0.6267	0.9015	3.472
	F- pr. = <.001	F-pr. = <.001	F- pr. = 0.430	F- pr.= 0.001	F- pr. = <.001	F- pr. = <.001
SED	0.15	0.04	0.01	0.30	0.43	1.65

PD = poultry droppings. NPK = nitrogen, phosphorous, potassium. RHA = rice husk ash. RHD = rice husk dust. CT = control. LSD = least significant difference. SED = standard errors of differences of means. SOC = soil organic carbon. TN = total nitrogen. NS = non-significant

In this regard, integration of the NPK fertilizer with other organic source(s) increased the CEC higher than the sole source of the NPK. This affirms Adediran et al. [29] report that whenever organic manure is applied alongside mineral fertilizer; the inorganic fertilizer aids the decomposition of the organic manure, hence, achieving earlier mineralization of the organic manure. Generally, all the treated plots performed significantly ($p < 0.05$) higher than the control in 2015.

The effect of integrated nutrients application on soil available phosphorous is presented in Table 4. Application of the soil amendments significantly ($p < 0.05$) increased available phosphorous compared to that of the control. The average values of available phosphorous in 2014 ranged from 8.68 to 19.85 mg kg^{-1}, with the highest and lowest values from rice husk dust (RHD) and the control, respectively. Generally, the increased available phosphorus in all the amended soils higher than the control plots could be attributed to increased pH of the study soils resulting from the amendments which must have release the fixed P at the soil exchange site. Plots treated with integration of PD + RHA and PD + RHD significantly ($p < 0.05$) increased the available phosphorous higher than sole NPK, RHA and RHD in 2015. This implies that combined application of poultry droppings with any other organic manure source might improve soil available phosphorous better than when applied in their sole forms. However, the huge amount of poultry manure required for field crop production and its handling problems limit its use. Studies [30] have also shown the superior effect of integrated nutrient supply over sole use of inorganic or organic source in terms of balanced nutrient supply, improved soil fertility and crop yield [31].

3.5 Effects of Integrated Nutrient Sources on the Growth Performance of Cocoyam (Plant Height and Number of Leaves) at Various Weeks after Planting (cm)

The effect of different integrated nutrient sources on the cocoyam plant height and number of leaves at different weeks after planting (WAP) is shown Table 5. The results showed that there were significant ($p < 0.05$) differences among the treatments on the plant height at 6, 8 10, 12, 14 WAP in 2014 and 2015. The results (Table 5) indicated that in 2014 at 6 WAP, the highest significant increase on the cocoyam plant height was obtained from plots treated with NPK+RHA+RHD (48.7 cm), followed by plots treated with PD+RHD and PD+RHA (47.5, 45.0 cm), respectively, while the least value (30.2 cm) was recorded from plots with no manure application. At 10, 12 and 14 WAP, NPK+RHA+RHD treated plots gave highest significant improvement on the plant height (Table 5) in 2014. This was followed by plots amended with poultry droppings, while the control recorded the least value within the period.

Table 4. Effect of integrated nutrient sources on the soil exchangeable acidity, cation exchange capacity, base saturation and available phosphorous

Soil amendments	2014			2015		
	EA ($cmolkg^{-1}$)	CEC ($cmolkg^{-1}$)	Avail. P (mg/kg)	EA ($cmolkg^{-1}$)	CEC ($cmolkg^{-1}$)	Avail. P (mg/kg)
PD	3.1^{d}	16.1^{a}	10.75^{b}	1.53^{d}	22.27^{a}	14.12^{a}
NPK	4.5^{b}	15.2^{b}	10.61^{b}	3.93^{a}	18.93^{b}	10.33^{c}
RHA	2.3^{f}	13.4^{c}	12.72^{b}	1.53^{d}	17.00^{c}	12.40^{b}
RHD	2.7^{e}	15.6^{a}	19.85^{a}	2.90^{c}	14.87^{d}	11.53^{b}
PD + RHA	2.8^{d}	17.7^{ab}	11.91^{b}	2.60^{c}	18.97^{b}	14.45^{a}
PD + RHD	3.1^{d}	20.3^{a}	11.00^{b}	3.80^{b}	19.37^{b}	14.60^{a}
NPK + RHA	3.5^{c}	15.7^{a}	10.33^{b}	3.80^{b}	19.97^{b}	9.86^{c}
NPK + RHD	3.4^{c}	11.0^{d}	11.56^{b}	4.37^{a}	21.03^{a}	10.20^{c}
NPK + RHA + RHD	3.5^{c}	13.7^{c}	9.54^{c}	3.80^{b}	20.60^{a}	10.71^{c}
CT	5.3^{a}	12.3^{d}	8.68^{c}	4.60^{a}	12.53^{e}	7.49^{d}
Mean	3.5	15.1	11.70	3.29	18.55	11.57
$LSD_{0.05}$	0.3908	4.879	2.615	0.7680	2.151	1.292
	F- pr. = <.001	F- pr. = 0.035	F- pr. = <.001	F- pr. = <.001	F- pr. = <.001	F- pr. = <.001
SED	0.19	2.32	1.24	0.37	1.02	0.62

PD = poultry droppings. NPK = nitrogen, phosphorous, potassium. RHA = rice husk ash. RHD = rice husk dust. CT = control. LSD = least significant difference. SED = standard errors of differences of means. EA = exchangeable acidity. CEC = cation exchange capacity. BS = base saturation. Avail. P = available phosphorous

It was generally observed that in 2014 plots treated with combinations of the nutrient sources performed significantly better than their sole application. There was an increasing trend on the plant height as the weeks progresses, but reached the growth peak at the 12th week after planting. The plant growth performance was observed to decrease rapidly at the 14th week after planting. The same growth trend was observed in 2015 on the cocoyam height performance.

Table 6 shows the mean number of cocoyam plant leaves at various weeks after planting (WAP) in the two years of study. The cocoyam number of leaves was not significantly increased at the 6th and 8th week after planting, but was significantly improved at the 10th, 12th and 14th WAP in the 1st year of the study. It was obtained that at 6 WAP, PD+RHD treated plots gave the highest increase on the number of leaves, followed by plots amended with PD+RHA, while the control plots gave the least values. The values varied from 5.17 to 13.25. However, it was observed that at 8 WAP, the highest number of leaves was obtained from plots treated with poultry droppings in the first year. In week 10 after planting, the highest significant ($p < 0.05$) increase on the number of leaves (29.50) was recorded in plots amended with NPK+RHD. The values varied from 12.33 to 29.50 in the first year. The results (Table 6) gave that at 12 WAP, the integration of NPK + RHA + RHD gave the highest (33.42) significant ($p < 0.05$) increase on the number of leaves. This was followed by NPK and PD + RHA amended plots (31.17, 30.17), respectively, while the least value was recorded by the control. It was also observed that at 14 WAP plots treated with NPK (25.41) gave the highest value, followed by PD+RHA (23.16) treated plots while the least values were obtained from control plot. The range values obtained at the 14th WAP implied that the cocoyam number of leaves started decreasing after the 12th week after planting. Table 6 showed that in the 2nd year of the study, the plant number of leaves were

Table 5. Effect of integrated nutrient sources on the plant height at various weeks after planting (WAP) (cm)

Soil amendments	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
		2014			
PD	46.6^{a}	77.6^{a}	90.1^{a}	98.9^{a}	90.6^{a}
NPK	37.8^{b}	57.4^{a}	82.7^{a}	94.3^{a}	81.9^{a}
RHA	33.8^{c}	49.5^{b}	60.6^{b}	68.8^{b}	61.1^{b}
RHD	37.2^{b}	64.7^{a}	77.9^{a}	89.0^{a}	80.3^{a}
PD + RHA	47.0^{a}	70.8^{a}	79.1^{a}	89.4^{a}	79.9^{a}
PD + RHD	47.5^{a}	58.6^{a}	83.8^{a}	100.2^{a}	88.2^{a}
NPK + RHA	37.8^{b}	54.2	75.8^{a}	86.1^{a}	73.2^{b}
NPK + RHD	40.3^{a}	65.8^{a}	80.7^{a}	94.3^{a}	82.0^{a}
NPK + RHA + RHD	48.7^{a}	62.3^{a}	91.2^{a}	105.3^{a}	95.3^{a}
CT	30.2^{d}	39.7^{c}	51.3^{c}	49.3^{c}	42.7^{c}
Mean	40.7	60.1	77.3	87.6	77.5
$LSD_{0.05}$	10.14	20.46	19.44	20.90	18.41
	F- pr. 0.011	F- pr. 0.049	F- pr. 0.010	F- pr. <.001	F- pr. <.001
SED	4.83	9.74	9.25	9.95	8.76
		2015			
PD	47.7^{a}	74.4^{a}	88.4^{a}	100.9^{a}	90.7^{a}
NPK	38.7^{b}	49.7^{b}	73.6^{b}	92.7^{a}	82.3^{b}
RHA	49.6^{a}	50.5^{b}	64.9^{c}	72.0^{b}	67.8^{c}
RHD	37.9^{b}	63.5^{a}	78.4^{b}	90.2^{a}	80.0^{b}
PD + RHA	51.9^{a}	75.4^{a}	80.7^{a}	90.6^{a}	85.7^{a}
PD + RHD	50.6^{a}	74.0^{a}	87.2^{a}	96.7^{a}	85.2^{a}
NPK + RHA	43.1^{a}	51.6^{b}	70.2^{c}	87.1^{a}	75.6^{b}
NPK + RHD	38.5^{b}	59.7^{b}	75.8^{b}	85.3^{a}	85.7^{a}
NPK + RHA + RHD	46.1^{a}	66.9^{a}	92.9^{a}	100.3^{a}	94.5^{a}
CT	29.7^{c}	39.1^{c}	48.2^{d}	49.1^{c}	42.3^{d}
Mean	43.4	60.5	76.0	86.5	79.0
$LSD_{0.05}$	12.17	13.98	13.70	16.56	11.59
	F- pr. = 0.023	F- pr. =<.001	F- pr. = <.001	F- pr. = <.001	F- pr. = <.001
SED	5.79	6.65	6.52	7.88	5.52

PD = poultry droppings. NPK = nitrogen, phosphorous, potassium. RHA = rice husk ash. RHD = rice husk dust. CT = control. LSD = least significant difference. SED = standard errors of differences of means. WAP = weeks after planting significantly ($p < 0.05$) increased at 6, 8, 10, 12 and 14 weeks after planting as against the results obtained in the first year. It was obtained that at 6 and 10 WAP, the PD + RHD amended plots gave the higher number of leaves. At the 8th week, plots amended with PD + RHA gave the highest significant improvement on number of leaves of the cocoyam. The results (Table 6) also revealed that most of the integrated forms of the nutrient sources performed significantly better than their sole sources in their effect on the cocoyam number of leaves within the two years of study. It was generally observed that all amended plots significantly ($p < 0.05$) increased the plant number of leaves higher relative to the control within the period of study.

3.6 Effects of Different Manure Sources on the Cocoyam Yield Weight (t/ha)

The effect of soil amendment on the weight of cormels and corm (yield) after harvest in the two years of study indicated that the amendments significantly ($p<0.05$) increased the yield (Table 7). In 2014, plots treated with NPK+ RHD (5t/ha+5t/ha) gave the highest yield weight of cormels (8.55 t/ha), while NPK+RHD treated plots gave the highest corms yield weight (7.00 t/ha) among the treated plots in the same 2014 cropping season. The results implied that the integration of mineral fertilizer with organic manure sources might significantly increase the yield of the corms and cormels higher than their sole forms. These results are in agreement with Adeniyan and Ojeniyi [32] and Osundare [33], that the superior effect of integrated nutrient supply as opposed to application of inorganic fertilizer or organic source alone is essential for good growth and yield of cocoyam. In 2015, the yield weights of cormels decreased, while the corms yield weights appreciated significantly higher. The highest significant corms' yield weight was recorded in plots treated with the integration of PD + RHD.

Table 6. Effect of integrated nutrient sources on the plant number of leaves at various weeks after planting (WAP)

Soil amendments	6 WAP	8 WAP	10 WAP	12 WAP	14 WAP
			2014		
PD	11.58	20.33	24.17^{a}	28.25^{a}	23.51^{c}
NPK	10.33	13.17	21.83^{a}	31.17^{a}	25.41^{a}
RHA	7.58	10.08	17.25^{b}	22.00^{b}	16.40^{i}
RHD	9.50	12.17	19.92^{b}	25.25^{a}	20.33^{f}
PD + RHA	12.75	15.67	22.50^{a}	30.17^{a}	23.16^{d}
PD + RHD	13.25	11.00	29.50^{a}	25.33^{a}	20.45^{g}
NPK + RHA	8.67	9.00	20.08^{b}	25.00^{b}	19.17^{h}
NPK + RHD	8.92	12.75	19.17^{b}	26.67^{a}	21.52^{e}
NPK + RHA + RHD	9.15	14.67	23.50^{a}	33.42^{a}	24.13^{b}
CT	5.17	7.37	12.33^{c}	10.71^{c}	9.48^{j}
Mean	9.69	12.62	21.02	25.80	20.36
LSD $_{0.05}$	NS	NS	7.718	8.346	0.03235
	F- pr. = 0.397	F- pr. = 0.207	F- pr. = 0.021	F- pr. = 0.002	F- pr. = <.001
SED	3.24	5.39	3.67	3.97	
			2015		
PD	10.50^{b}	22.20^{a}	26.97^{a}	28.13^{a}	21.70^{b}
NPK	9.57^{c}	14.60^{b}	21.13^{b}	24.20^{a}	23.33^{a}
RHA	7.80^{c}	12.73^{b}	16.90^{c}	20.03^{b}	17.27^{c}
RHD	10.33^{b}	16.40^{b}	22.23^{b}	27.07^{a}	21.50^{b}
PD + RHA	13.50^{a}	25.07^{a}	23.70	24.83^{a}	22.27^{a}
PD + RHD	14.37^{a}	21.50^{a}	28.33^{a}	28.30^{a}	21.77^{b}
NPK + RHA	10.40^{b}	12.73^{b}	19.87^{c}	22.50^{a}	20.73^{b}
NPK + RHD	9.63^{c}	13.03^{b}	18.97^{c}	24.97^{a}	21.97^{a}
NPK + RHA + RHD	10.63^{b}	18.27^{a}	27.07^{a}	28.23^{a}	24.67^{a}
CT	5.30^{d}	6.97^{c}	11.47^{d}	11.70^{c}	11.27^{d}
Mean	10.20	16.35	21.66	24.00	20.65
LSD $_{0.05}$	3.702	7.529	6.081	6.425	2.991
	F- pr. = 0.004	F- pr. = 0.003	F- pr. = <.001	F- pr. = 0.001	F- pr. = <.001
SED	1.76	3.58	2.89	3.06	1.42

PD = poultry droppings. NPK = nitrogen, phosphorous, potassium. RHA = rice husk ash. RHD = rice husk dust. CT = control. LSD = least significant difference. SED = standard errors of differences of means. WAP = weeks after planting. NS = non-significant

3.7 Relationship between Cocoyam Plant Height and Number of Leaves

The regressions of the number of leaves on plant height showed positive and higher linear relationship, with R^2 values for the two years higher than 0.90 (Figs. 1a and 1b). The relationship was strongest in 2015 than in 2014. The R^2 is the coefficient of determination and describes the amount of the total variation that is accounted for by the independent variables in the model.

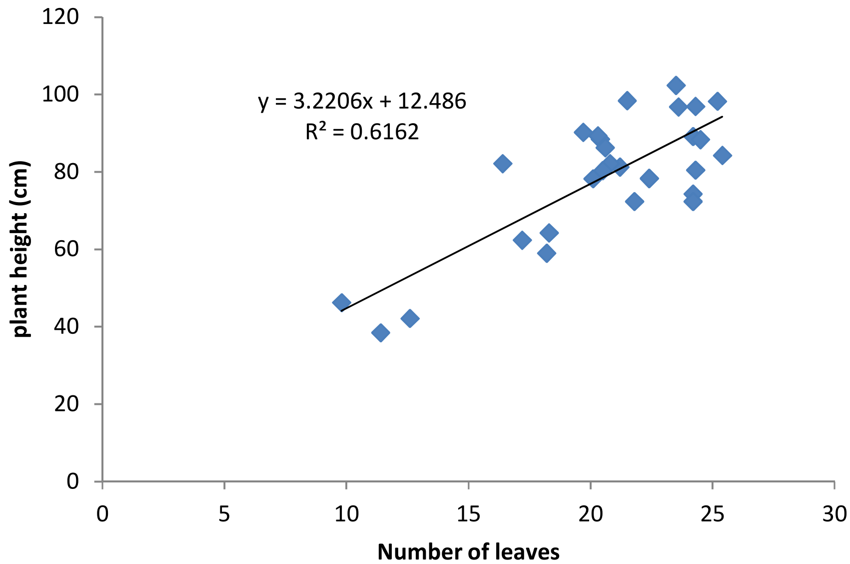

Fig. 1a. Relationship between plant height and number of leaves of cocoyam in 2014

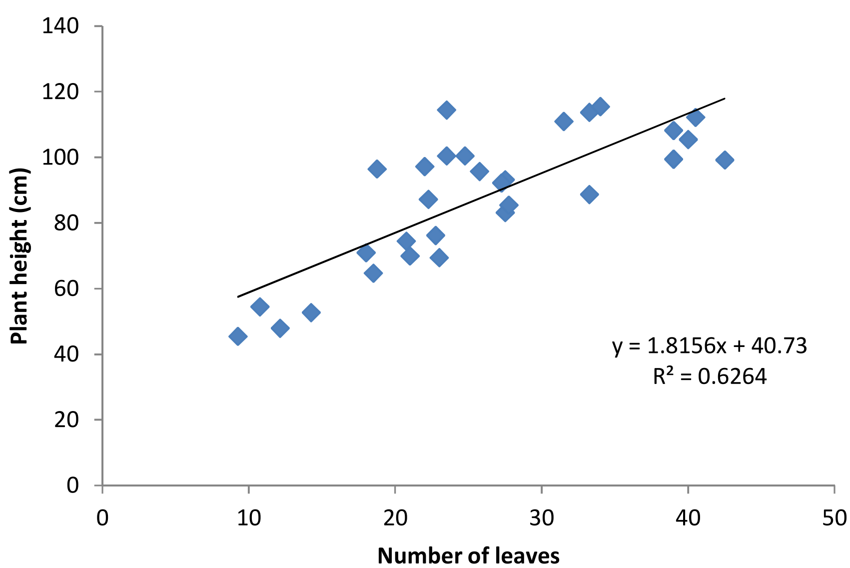

Fig. 1b. Relationship between plant height and number of leaves of cocoyam in 2015

Table 7. Effect of integrated nutrient sources on the weight of corms and cormels of the cocoyam at harvest (ton/ha)

Soil amendments	2014		2015	
	Cormels (ton/ha)	Corms (ton/ha)	Cormels (ton/ha)	Corms (ton/ha)
PD	8.35^{a}	5.22^{b}	6.74^{a}	11.06^{a}
NPK	7.95^{a}	5.69^{a}	5.55^{b}	9.82^{b}
RHA	5.41^{b}	4.06^{c}	6.35^{a}	10.28^{a}
RHD	6.76^{a}	5.25^{b}	6.33^{a}	9.80^{b}
PD + RHA	7.28^{a}	5.02^{b}	8.83^{a}	10.22^{a}
PD + RHD	6.64^{b}	5.33^{b}	8.50^{a}	12.89^{a}
NPK + RHA	7.40^{a}	7.00^{a}	8.37^{a}	10.87^{a}
NPK + RHD	8.55^{a}	5.77^{a}	6.11^{a}	8.61^{bc}
NPK + RHA + RHD	6.76^{a}	5.93^{a}	5.28^{b}	10.35^{a}
CT	3.75^{c}	$3.35^{c\,d}$	3.19^{c}	5.96^{c}
Mean	6.88	5.26	6.53	9.99
$LSD_{0.05}$	1.927	1.635	2.938	3.184
	F- pr. = 0.002	F- pr. = 0.014	F- pr. = 0.022	F pr. = 0.031
SED	0.92	0.78	1.40	1.52

PD = poultry droppings. NPK = nitrogen, phosphorous, potassium. RHA = rice husk ash. RHD = rice husk dust. CT = control. LSD = least significant difference. SED = standard errors of differences of means

4. CONCLUSION

The result from the study showed that soil chemical properties were significantly improved by the application of organic l and inorganic fertilizers. It is therefore, concluded that organo-mineral fertilizer application enhance growth and yield of cocoyam (*Colocasia esculenta*). It was also noted that integration of poultry dropping and rice husk ash can be a quick restoration of degraded soil and cocoyam crop yield in Southeastern Nigeria. The strong and positive association between leaf number and plant height indicates that both traits can be used as a selection index for each other.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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