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Nutrient Release Pattern of Cocoa Pod Husk Based Composts in an Incubation Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author COK designed the study, wrote the protocol, and the first draft of the manuscript. Author AFA managed the literature searches, assisted in composting and collated the contribution of other authors, Author OEAO performed the statistical analysis and assisted in laboratory analysis, Author DOO collated all collected data and contributed to the manuscript write up and Author DTE-A monitored the research and contributed to it. All authors read and approved the final manuscript.

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ABSTRACT

In order to apply compost to fulfill the nutrient requirements of a crop, knowledge of the amount of nutrients mineralized following application is needed. The objective of this study was to compare the effect of different cocoa pod husk based composts on soil nutrient status as well as the pH. The experimental design was 4 x 2 x 5 factorial laid in a completely randomized design replicated three times. The factors were four compost types; Cocoa Pod Husk + Poultry Manure + Neem leaves (CPH + PM + NL), Cocoa Pod Husk + Poultry manure (CPH + PM), Cocoa Pod Husk + Neem leaves (CPH + NL) and No compost (Control), two soil types; Ibadan (Alfisol) and Ikenne (Ultisol) and five incubation periods; 2, 4, 6, 8 and 10 weeks. Each compost was applied separately at the rate of 10 tons ha^{-1}. Routine analysis of the soil before incubation indicated that the two soil types had low nutrient status. The composts significantly ($p<0.05$) influenced the soil nutrient status after incubation. Correlation of nutrient release with time by composts showed that there was no correlation between the time of incubation and nutrient release from all the composts except in the

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case of CPH + PM that had significant relationship with the release of N. The result showed that the N release from CPH+PM decreases with time of incubation. The pH of the soils treated with different composts was significantly increased compared with control.

Keywords: Cocoa pod husk; compost; nutrient status; incubation.

1. INTRODUCTION

The use of organic fertilizers had drastically declined following the introduction of inorganic fertilizers which has immensely affected most of the farmers in developing nations. Developing countries are endowed with a large production of organic residues that are not put into use. It is assumed that the average nutrient status of a soil would be improved when organic residues are applied into it. Efficient application of these organic residues would therefore alleviate the problem of declining land productivity in a soil with low nutrient status. Irrespective of the enormous organic residues potential in Nigeria, very small amount is utilized to increase soil fertility and crop productivity. The benefits derived from utilization of organic materials for improvement of soil fertility and crop production have been discussed by many authors [1,2,3,4,5].

Composting offers the most sensible and economic way to avoid wasting of useful natural resources creating environmental problems and at the same time, it produces a high quality and inexpensive soil amendment of desirable characteristics. Through composting, the undesirable features of waste materials (pathogens, odour, among others etc) can be changed to desirable ones. In general, finished compost is reduced in bulkiness bulk and highly regarded for its ability to improve soil fertility and plant growth. Compost supply macronutrient and micronutrients and their effect last longer than inorganic fertilizers because they are slow nutrient releasers [1,6].

There is an apparent lack of scientific basis for advising farmers on the appropriate quantity of compost and right time of application. This is highlighted because when composts are added to a soil, nutrient status of the soil would not be instantly improved, it takes some days after incubation. The use of compost as source of a particular nutrient requires the knowledge of the mineralization rate under field condition. Since mineralization is microbially driven, it is influenced by several factors, including temperature, soil moisture, soil properties, and compost characteristics [7]. Nitrogen (N) mineralization increases with increasing temperature under conditions found in agricultural soils [7]. Mineralization is greatest when soil moisture is almost at field capacity and declines with soil moisture. This study was carried out to investigate the nutrient release pattern of cocoa pod husk based compost on an Alfisol and Ultisol also to determine which of the composts is relatively optimal to improve the soil nutrient status within a given time frame.

2. MATERIALS AND METHODS

Soil samples (0-15 cm) were collected from the two locations (Ibadan and Ikenne), air-dried and sieved to pass through a 2 mm sieve. The soil particle size, pH (H_20),Organic carbon, total N, available phosphorus (P), potassium (K), Calcium (Ca), Magnessium (Mg) were determined.

Mechanical analysis was determined using the hydrometer method described by [8]. pH was determined in water 1:2 soil: water ratio. Total N was determined using the micro kjedhal procedure described by [9]. Organic carbon was determined by the method of [10].Available P was determined using Bray 1 method [11]. Exchangeable K, Ca, Mg and Na was determined by extraction with 1N ammonium acetate and the amount of K, Ca, Na in the filtrate was determined using flame photometer while Mg was determined using Atomic Absorption Spectrophotometer (AAS).

Three types of compost were prepared using cocoa pod husk (CPH), neem leaves (NL) and poultry manure (PM) as follows:

i. CPH+NL +PM (3:1:1)
ii. CPH+PM (3:1)
iii. CPH+NL (3:1)

The CPH, NL and PM materials were analyzed for nutrient content before composting. The CPH was chopped into smaller pieces before composting to reduce the particle size. The temperature of each pile was monitored daily for the first week and every other day for next four

weeks and weekly until the end of the composting with the use of soil thermometer. The mixtures were turned every fortnight and watered. The organic materials were composted for three months after which they were allowed to cure for two weeks, shredded and bagged for use. At maturity of the composts, samples were randomly taken from each compost type, milled, sieved through a 2 mm sieve and subjected to chemical analysis.

The experimental design used was a 4 x 2 x 5 factorial experiment in a completely randomized design (CRD). The factors are: Fertilizer types (CPH + NL + PM, CPH + PM, CPH + NL and No fertilizer i.e. Control), Soils (Ibadan and Ikenne) and Incubation periods (2, 4, 6, 8 and 10 weeks). 80 g of 2 mm sieved soil was weighed into each of the plastic cups (135 mls). Each compost was separately applied to the soil in the plastic cups at the rate of 10 tons ha^{-1} (i.e. 0.4 g compost per plastic cup). The experiment was replicated three times. Deionized water was applied to each of the cups. In all, 120 plastic cups were used for the experiment. A total number of 24 plastic cups were withdrawn at the end of each incubation period for chemical analysis.

The following analyses were carried out at the end of each of the incubation period. pH was determined in water (1:2 soils: water ratio). Mineralized total Nitrogen was determined by Kjedahl method, mineralized available P was extracted from the incubation samples using Bray P method and mineralized K was extracted with 1N ammonium acetate at neutral pH. Data was analyzed using analysis of variance (ANOVA) and the means were separated using least significant different (LSD). Correlations of nutrients released with time were carried out to determine significant relationship between the nutrients released by each treatment and time of incubation.

3. RESULTS

The pH of the soils were slightly acidic (5.9 and 6.2) while the textural class of both soils was sandy loam (Table 1). The total N of both soils were low (0.9 and 0.7g/kg) which was below the critical level of 1.5g kg^{-1} while the available P of the soils (4.42 and 3.43mg/kg) was below the critical level of 10-16mg/kg [12]. The K status of Ikenne soil was low (0.1 cmol/kg) which was also less than the critical level of 0.2 cmol / kg while the K status of Ibadan soil was higher than the critical level (0.4 cmol/kg) Also the Na, Ca and Mg contents of Ibadan soil was higher than Ikenne soil. The soils were generally low in organic carbon (9.4 and 7.2g/kg) respectively (Table 1).

The materials used for composting differ in nutrient composition. The N concentration in the materials is in the order of PM > NL > CPH (24.5, 21.6 and 11.8 g kg^{-1} respectively). Concentration of P was also in the order of PM > NL > CPH (21.5, 1.9 and 1.4g kg^{-1} respectively). Potassium concentration was in the order of CPH >NL>PM (36.7, 23.8 and 3.8 g kg^{-1}) respectively (Table 2).

Table 1. Physical and Chemical properties of Pre-incubation soil

Parameters	Ibadan	Ikenne
pH (H_2O)	6.20	5.59
Exchangeable bases (c mol kg^{-1})		
Ca^{2+}	3.20	1.60
Na^{+}	0.20	0.20
K^{+}	0.40	0.10
Mg^{2+}	0.70	0.40
Ex. acidity (H^{+})	0.02	0.08
ECEC(c mol kg^{1})	4.52	2.38
Organic carbon (g kg^{-1})	9.4	7.2
Total N (g kg^{-1})	0.90	0.70
Av. P (mg kg^{-1})	4.42	3.43
Silt (g kg^{-1})	104.8	124.8
Clay (g kg^{-1})	209.2	109.2
Sand (g kg^{-1})	686	776
Textural class	Sandy loam	Sandy loam

The N content of CPH which was low increased when composted with PM and NL. However, the compost that consist the three materials had the highest N content of 23.3 g kg^{-1}. Generally N in the compost ranged between 19.9 - 23.3 g kg^{-1}. P ranged from 6.5-11.7 while K ranged from 10.4–14.6 g kg^{-1} (Table 3). The N, P and K contents of the composts was higher than that recorded for the two soils.

The rate of total N-release was in the order of CPH + PM + NL > CPH + PM > CPH + NL > Control (Fig. 1). However at 4 weeks after incubation (WAI), CPH + NL released more N into the soil more than the other composts and the control. At 6 WAI, CPH+PM released more N compared to the control and the other composts. At 8 WAI, N mineralization in the soil treated with CPH + PM + NL was significantly higher than CPH + PM, CPH + NL and the control treatment. However at 10 WAI, the total N mineralized by the composts was not significantly different amongst the fertilizer types.

Table 2. Chemical analysis of organic materials before composting

Nutrient(g / kg)	Cocoa pod husk	Poultry manure	Neem leaf
Org.C	231.3	117	122.5
N	14.9	24.5	21.6
P	1.7	20.5	2.3
K	37.6	3.9	23.8
Ca	3.4	11.7	1.6
Mg	1.9	5.4	2.5
Fe	69.0	26.7	65.2
Mn	31.2	13.8	32.1
Cu	29.7	1.1	25.0
Zn	25.3	10.8	45.7

Table 3. Nutrient content of matured compost

Nutrient	Compost		
(g kg^{-1})	CPH + PM + NL	CPH + PM	CPH + NL
N	23.3	20.6	19.9
P	11.7	8.2	6.5
K	14.6	12.8	10.4

Legend: CPH + PM + NL=Cocoa pod husk Poultry manure + Neem leaf,CPH + PM=Cocoa pod + Poultry manure, CPH + NL= Cocoa pod husk + Neem leaf.

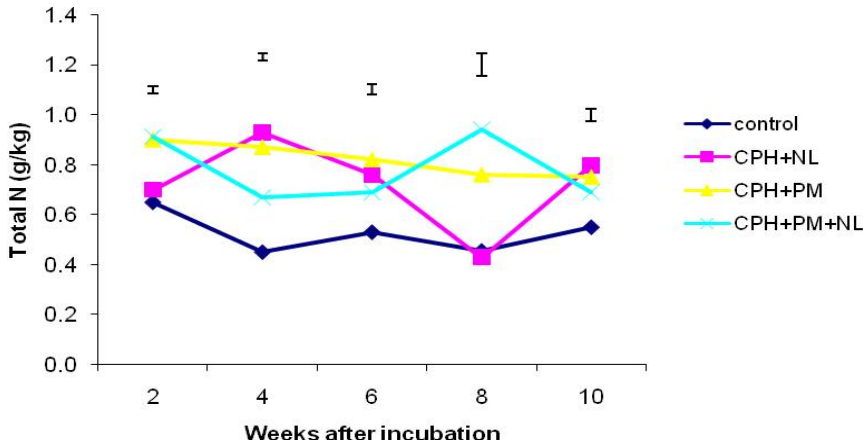

Fig. 1. N- Release pattern of different composts across weeks of incubation

Legend:CPH+PM+NL=Cocoa pod husk Poultry manure+Neem leaf, CPH+PM=Cocoa pod+Poultry manure, CPH+NL=Cocoa pod husk+Neem leaf

At 2 WAI, CPH + PM + NL released P which was significantly higher than the control and other composts. The P-release was in the order of CPH + PM + NL > CPH + PM > CPH + NL > Control (Fig. 2). The P-released from 4 to 10 WAI followed the same trend. The organic materials released significantly higher amount of P relative to the control in all the 10 weeks of incubation. All the organic materials release higher amount of K relative to the control at 2, 4 and 6 WAI. At 8 WAI, except for CPH + PM + NL all other treatments add similar values of K released with mean differences that were not significant and CPH + PM released more K than CPH + NL and the control which released almost the same amount of K (Fig. 3). t 8 WAI, CPH + PM + NL released K which was significantly higher than from other treatments.

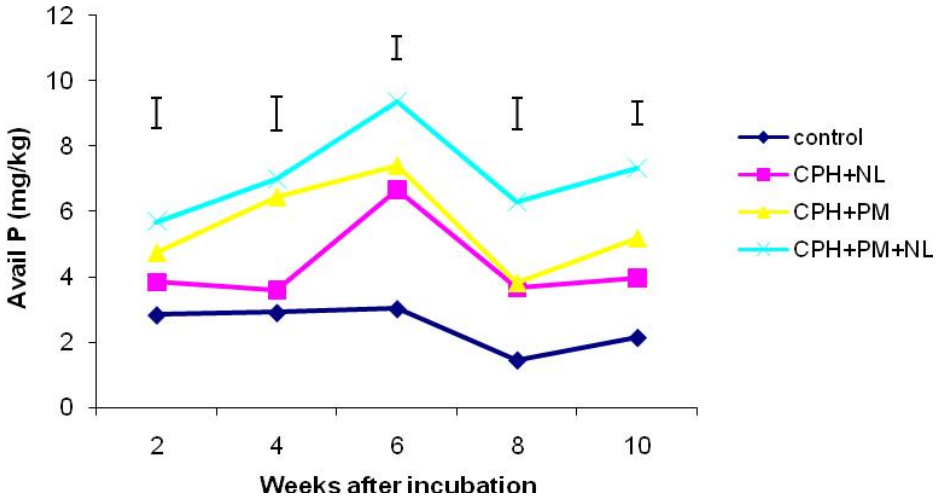

Fig. 2. P- Release pattern of different composts across the weeks of incubation
Legend: CPH+PM+NL=Cocoa pod husk Poultry manure+Neem leaf, CPH+PM=Cocoa pod+Poultry manure, CPH+NL=Cocoa pod husk+Neem leaf

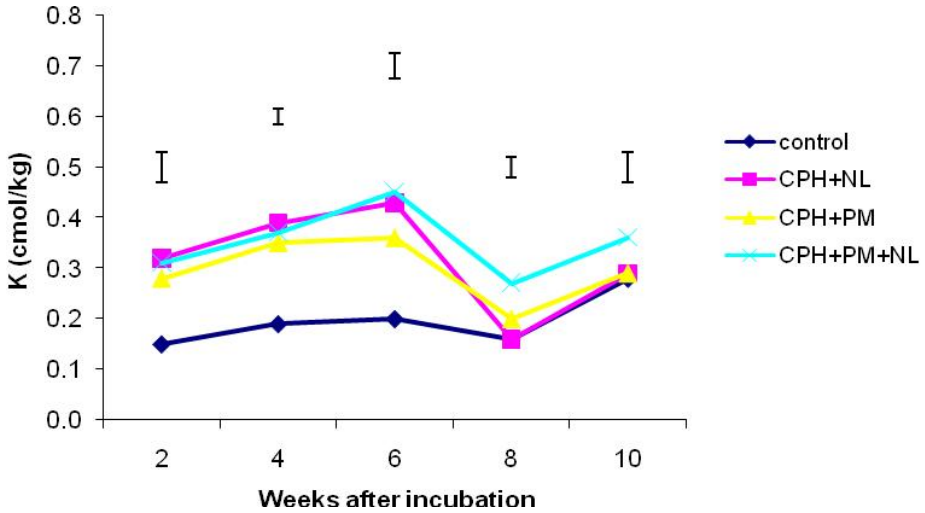

Fig. 3. K- Release pattern of different composts across weeks of incubation
Legend: CPH+PM+NL=Cocoa pod husk Poultry manure+Neem leaf,CPH+PM=Cocoa pod+Poultry manure, CPH+NL=Cocoa pod husk+Neem leaf

Correlation of nutrient release with time by composts under laboratory incubation showed that there was no correlation between the time of incubation and the amount of nutrient released from all the fertilizer types' composts except in the case of CPH + PM that had significant relationship with the N released of N. The result showed that the N-release from CPH+PM gradually decreased from 0.9 – 0.7 g Kg^{-1} decreases with time of incubation (Table 2).

3.1 pH Changes

pH of the soils treated with different composts were significantly increased compared with control as from 2 WAI (Fig. 4). At 6 WAI, pH of soils treated with CPH + PM + NL significantly decreased compared to other composts while at At 8 WAI, soils treated with CPH + PM + NL, CPH + PM and CPH + NL gave pH values which were comparable with each other but significantly higher than the control but the values were higher for CPH + PM than other treatments at. At 6 WAI, the pH of soil treated with CPH+PM+NL decreased compared to other composts. At 10 WAI, CPH + PM raised the pH of the soil higher than CPH + PM + NL, CPH + NL and the control.

DISCUSSION

Incubation study was conducted to investigate the nutrient release pattern of the different compost; cocoa pod husk + poultry manure + neem leaf (CPH + PM + NL), cocoa pod husk + poultry manure (CPH + NL) and cocoa pod husk + neem leaf (CPH + NL) for 10 weeks. The result of studying various composts was very useful in understanding the nutrient release behavior of the organic materials used in composting. Decrease in total N recorded in some of the soils under compost treatments could have been as a result of microbial fixation activities [13] and volatilization of N in form of NH_3 as reported by [14].

Table 2. Correlation of nutrients released with time of incubation by compost under laboratory condition

Treatment	N	P	K
Control	.105	-.675	.724
CPH+NL	-.435	.042	.537
CPH+PM	-.984**	-.197	.378
CPH+PM+NL	-.207	.294	-.009

*** Significant (p=0.01), Time is 2, 4, 6, 8, and 10 weeks after incubation*

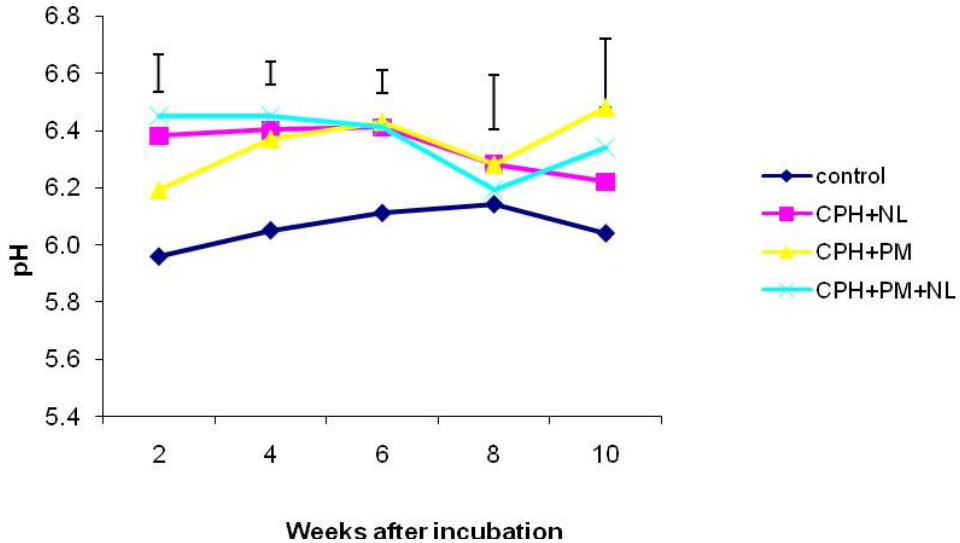

Fig. 4. pH of the soils as influenced by the organic materials during incubation

Legend: CPH+PM+NL=Cocoa pod husk Poultry manure+Neem leaf, CPH+PM=Cocoa pod+Poultry manure, CPH+NL=Cocoa pod husk+Neem leaf

The persistent increase in N in CPH + PM + NL and CPH + PM might be as a result of mineralization. The continuous increase in soil P by compost throughout the incubation period showed that much of the P added in the agro wastes remain in a pool that is readily available for plant uptake and that mineralization has not stopped at 70 days of incubation. The high K content release recorded in composts over control suggests that CPH, PM and NL used in composting are high in K. The sharp increase in K at 10 WAI in CPH + PM + NL treated soil may be due to greater decomposition that must have taken place. The higher soil pH of the amended soil than the control treatment at each period of pH determination was probably due to the supply of basic cations into the system by the mineralization of the organic materials. This trend was corroborated by [15] and [16] reported similar trend. Analysis of CPH by [17] and [16] showed that it contained Ca, K, P and Mg. The increase in the pH of soils treated with compost suggests that CPH will be useful in correcting soil acidity Among the compost treated soils, the release of nutrients did not correlate with time of incubation except in the case of N-release from CPH+PM which decreases with time of incubation.

CONCLUSION

The laboratory incubation conducted indicated that cocoa pod husk based composts significantly increased the N, P, K and pH of the two soils compared to the control .However, CPH + PM + NL performed significantly better than the other composts.

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