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Palm Kernel Cake and Sawdust Composts: Chemical Properties and Effects on Maize Growth in Acid Sands of Uyo, Nigeria

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ABSTRACT

A study was conducted to assess the chemical properties of palm kernel cake (PKC)/saw dust (SD) composts and its effects on maize (Zea mays) growth in Acid sands of Uyo, Nigeria. Six treatments with ratios of PKC/SD: A(1:4), B(1:1), C(2:1), D(4:1), E(8:1) and control (soil only), were applied to maize plant in a pot experiment and laid out in a completely randomized design with four replications. Results of chemical analysis of composts at four and eight weeks of compositing show that organic carbon and nutrients, calcium (Ca), magnesium (Mg), zinc (Zn), iron (Fe) and total nitrogen (N) levels were higher at eight weeks than at four weeks while potassium (K) and Cu levels were drastically reduced at the same period, indicating the need to determine optimum composting period in order to avoid nutrient losses. Ratio of composting also had effect on nutrient content of compost; the greater the amount of PKC the higher the level of nutrients except phosphorus (P) and Ca. Maize plant height and stem girth at six weeks after germination were significantly different ($P \leq 0.05$) and were found in the order of compost E > D > B > C > A > control for plant height and compost E > D > C > B > A > control for maize girth.

Keywords: Palm kernel cake, sawdust, chemical composition, acid sand soil, maize growth, Nigeria.

INTRODUCTION

The tropical soils are characterized by low pH, cation exchange capacity, organic matter, percent base saturation and low nutrient holding capacity [1], which are important criteria for retention, absorption and effective use of nutrients by crops. Under such prevailing soil conditions, addition of inorganic fertilizers are subject to nutrient losses even when they are properly incorporated into the soil. However, there are also problems in the acquisition of chemical fertilizers which are sometimes unavailable and unaffordable at critical periods [2]. When available, it contains in most cases a maximum of three major nutrients (N, P and K) out of the seventeen essential plant nutrients needed for normal growth and yield of crops. Parmer [3] stated that the restoration and rehabilitation of degraded soils to optimum productive level can be enhanced by using various off-farm sources of organic and agricultural wastes. Agboola and Omueti [1] also reported that organic materials enhance soil organic matter and help to maintain favourable biological and physical environments for root development and storage of plant nutrients.

In recent times, various methods have been used to convert organic wastes into quality organic fertilizers for crop production in various parts of the world. Two of such methods are composting (biological process through which organic materials are broken down by micro-organisms to humus end product called compost [4] and vermicomposting which involves the use of specialized worms such as *Eisenia fetida* (Tiger worm), *Eisenia Andrei* (Red tiger) and *Lumbriucus rubellus* (Dung worm) to decompose organic matter [5] to give castings. These products possess the ability to improve soil structure, increase water holding capacity and check erosion; add nitrogen and various micronutrients to the soil, slow the release of plant nutrients, provide an energy source for soil micro-organisms and enhance cation exchange capacity of low-fertility tropical soils.

Many composts have been prepared from poultry manure and sawdust; and sorted refuse and poultry manure alone [6], yard trimmings [7], solid domestic wastes [8], primary timber processing residues [9], food residual and sawdust [10] and municipal solid wastes [11]. Palm kernel cake, the by-product after extraction of oil, is normally used for the production of animal feeds. However, in most part of south eastern Nigeria the cake is sometimes used as fuel for cooking and some are found thrown away around homes (especially where the oil is extracted manually) and in oil mills. This necessitated this study which was to investigate the chemical properties of palm kernel cake/sawdust composts and their effects on the height and stem girth of maize.

MATERIALS AND METHODS

Environment of Study Area

The process of composting and testing of effects of composts on maize plant growth were carried out in Uyo which is located at latitudes 5.00′ and 5.10′N and longitudes 7.50′ and 8.00′E.

Climate of the Area

The climate of Uyo is typical of humid forest ecological zone, marked by excess of rainfall over evapotranspiration for more than six months of the year (April – October). The monsoon air mass blowing over the Atlantic ocean sweeps through this zone resulting in heavy annual rainfall of 2000 – 4000mm in the wet season. The rainfall has two peaks in July and September with a relatively moisture stressed period in August. The maritime tropical air mass is felt throughout the area in the dry months (November – March). The wind is dusty and dry, resulting in little humidity and less air cloud cover in some days. Annual mean relative humidity and mean monthly air temperature of 79% and 29°C are recorded for the area [12].

Geology, Soil and Land Use

Uyo is located on the undulating Northern coastal plain parent materials overlying the Tertiary coastal plain sands geological formation, usually referred to as ‘Acid sands’ [13, 14]. Although the lithology of the area is uniform, the soil characteristics however vary. The soils are well drained, moderately low to medium in moisture holding capacity, slightly to strongly acidic in reaction, low in organic matter content and in fertility status. The land use practice centres around the cultivation of arable crops such as maize, cassava, fluted pumpkin, upland rice, cocoyam, and melon in rotational and short bush fallow systems.

Experimental and Composting Process

Analysis of palm kernel cake (PKC) and sawdust (SD) revealed a carbon to nitrogen (C/N) ratio of 21:1 and 53:1, and these ratios were used for deciding the quantity of PKC and SD used in composting. Five compost ratios mixed were (PKC/SD); A(1:4) 40kg of PKC and 160kg of SD), B(1:1) 100kg of each PKC and SD, C (2:1) 133.2kg of PKC and 66.8kg of SD, D(4:1) 160kg of PKC and 40kg of SD and E (8:1) 177.6kg of PKC and 22.4kg of SD, using dry mass basis. These mixtures were kept in large polyethylene bags in an open space and the heaps were covered with black polyethylene. Turning of compost heaps and sprinkling of water were carried out at four days interval for the first 4 weeks and once a week for the next four weeks and once for the remaining two weeks. Compost temperatures were measured and recorded before each turning by placing a thermometer underneath the composting pile.

Pot Experiment

The composts produced were tested for the growth of *Zea mays* (the test crop). Exhausted loamy soil from the University of Uyo Commercial Farm was taken and 10kg placed in each polyethylene bag, 20 grams of compost was mixed with the soil in each bag before planting.

The bag were perforated for aeration. Five maize seeds were planted per bag and later thinned to two plants per bag two weeks after germination. Spacing of the bags was 1m x 1m. Six treatments were applied: control (o), A (1:4), B (1:1), C (2:1), D (4:1), E (8:1) and replicated four times. Weeding around and inside the bags was done manually. Plant height and stem girth were measured forth-nightly for six weeks.

Laboratory Studies

Composts samples were collected at four and eight weeks of composting for chemical analysis. The samples were ground using agate mortar and pestle and then sieved to obtain particles <2mm and stored in airtight container for the determination of some chemical properties of the compost. The properties were determined according to accepted methods [15]; for pH (pH meter with glass electrode), electrical conductivity (EC) (conductivity bridge), organic C (dichromate wet oxidation), total N (kjeldahl distillation), phosphorus (P) (ammonium fluoride), Ca, Mg, K (ammonium ethanoate extraction). Iron, Mn, Zn and Cu were measured on Atomic absorption spectrophotometer (model 939).

Statistical Analysis
Data collected were subjected to analysis of variance (ANOVA), and means that showed significant differences were separated using the Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Chemical Properties of Composts at Four Weeks of Composting
The chemical composition of various compost treatments at four weeks of composting is presented in Table 1a. The pH of compost was slightly acidic (6.2 – 6.8) in all the compost ratios while electrical conductivity values (total dissolved solids) ranged from 1.012dSm^{-1} in compost E to 1.681dSm^{-1} in compost A. Organic carbon and total nitrogen levels were high with values ranging from 231.8 in compost E to 357.2gkg^{-1} in compost B for organic carbon and 21.0 in compost B to 28.0gkg^{-1} in compost E for total N. Organic carbon content in composts A, C and D were not statistically different ($P \leq 0.05$) from each other. Similarly, organic carbon and total N levels in composts A and C were not statistically different ($P \leq 0.05$) from each other likewise composts D and E, in terms of total N. Phosphorus content in the compost was very high with values ranging from 2001.5 to 2461.3mgkg^{-1}. Phosphorus content in compost E was statistically different from P levels in other composts ratios while P concentrations in composts B, C and D were not different from each other statistically. The mobility of total N and P in the compost studied and in terms of abundance were in the order of E > D = A > C > B for total N and C > E > A > D = B for P.

Concentrations of Ca (1021:1-1384.0mgkg^{-1}) and Mg (547.0-561.8mgkg^{-1}) in the various composts at 4 weeks of composting were many times higher than its critical values (4 & 0.5gkg^{-1}) in the soils of southeastern Nigeria. Potassium content of the various compost ratios was extremely high with the highest concentration in composts E (11500mgkg^{-1}) and A (1100mgkg^{-1}), D (9000mgkg^{-1}) and C (6500mgkg^{-1}). Such high concentration may have come from palm kernel cake in the compost. The order of abundance of Ca, Mg and K in the compost were A > C > B > D > E, A > D = E = C ≥ B and A = C > D = B > E.

The ratio of compost has significant effect on macronutrient contents in prepared compost. For example, in compost E (8:1) with the highest ratio of PKC to SD, the concentration of total N, P, Ca and K were highest. Compost A was highest in Ca and K; compost B, in organic carbon and Mg while composts C and D had Ca for compost C and total N for compost D as highest nutrient levels, respectively (Table 1a).

The carbon to nitrogen ratio (C/N), the degree of decay of organic residues, in the compost ranged from 8 in compost E (8:1) to 17 in compost B (1:1). These ratios are below 20, indicating N contents of greater than about 2.5% (25gkg^{-1}) according to Stevenson and Cole [16] and this may lead to increase in mineral N levels through net mineralization.

Table 1a: Chemical Composition of the Different Compost Treatments at 4 weeks of Composting

Compost treatment	pH	EC (dS/m)	Org. C (gkg^{-1})	Total N (gkg^{-1})	P	Ca	Mg	K	C/N
					←	mgkg^{-1}		→	
A (1:4)	6.7b	1.681a	283.2b	26.6b	2001.5c	138	3d	11000ab	11bc
B (1:1)	6.7b	1.102c	357.2a	21.0c	2158b	1021.1c	561.8a	10500b	17a
C (2:1)	6.8a	1.226b	286.0b	25.9b	2357.1b	1376.0a	559.9b	6500c	11b
D (4:1)	6.5c	1.015c	275.5b	27.0a	2184.4b	1299.9b	547.0d	9000b	10c
E (8:1)	6.2d	1.012c	231.8c	28.0a	2461.3a	1376.0a	554.8c	11500a	8d

EC- electrical conductivity, org.c – organic carbon, Total N-total nitrogen, C/N – carbon to nitrogen ratio
Figures followed by the same letter in the same column are not significantly different ($P \leq 0.05$)

Table 1b: Chemical Composition of the Different Compost Treatments at 8 weeks of Composting

Compost treatment	pH	EC (dS/m)	Org. C (gkg^{-1})	Total N (gkg^{-1})	P	Ca	Mg	K	C/N
					←	mgkg^{-1}		→	
A (1:4)	7.1b	1.740c	334.0b	29.1b	2203.0c	1812a	1154a	1435a	11bc
B (1:1)	6.8c	1.348d	398.2a	22.0d	2201.0d	1432c	1034c	1335b	18a
C (2:1)	6.1d	1.890b	326.6c	28.0c	2441.2a	1580b	1057bc	1403a	12b
D (4:1)	7.4a	1.990a	346.6b	29.6ab	2211.0d	1360d	1088b	1365b	12b
E (8:1)	6.9bc	1.998a	284.4d	30.0a	2331.9b	1002e	1068b	1811c	9c

EC- electrical conductivity, org.c – organic carbon, Total N-total nitrogen, C/N – carbon to nitrogen ratio
Figures followed by the same letter in the same column are not significantly different ($P \leq 0.05$)

Chemical Properties of Compost at Eight Weeks of Composting

Some properties of various compost ratios at eight weeks of composting are presented in Table 1b. The pH of compost ranged from 6.1 in compost C to 7.4 in compost D, indicating slightly acid reaction in compost C, B, and E and slightly alkaline reaction in composts A and D; respectively. Electrical conductivity values were high with values ranging from 1.348dSm^{-1} in compost B to 1.998dSm^{-1} in compost E, indicating that the total soluble salts released increased as the period of composting increases. Similar observation was made with percentage increases for organic C (11-26%), total N (5-10%), Ca (5-40%) and Mg (89-> 138%) (Table 2). This observation agrees with the report of Brady and Weil [17] that finished compost is generally more concentrated in nutrients than the initial combination of raw materials used. However, K level was observed to drastically reduce in the 8th week of composting in all the compost ratios, with percent reduction ranging from 5-87%. This reduction may have resulted from temporary K fixation by organic matter.

The pH level in compost C decreased by > 10% though the reaction still remained slightly acidic while the reaction of composts A and D became slightly alkaline. The complete mineralization of organic residue increased water soluble salts resulted in 4 – 97% increase in electrical conductivity of compost. P level had a slight increase from 1 in compost D to 10% in compost A while in compost E, P content decreased by > 5% probably due to microbial immobilization into their cells or decomposition products of organic matter such as humic matter [18]. The low to moderate increase in total N content from the 4th to 8th week of composting could have resulted from the chemical reaction of ammonia with organic matter and favoured by the near alkaline reaction of the cured compost. The C/N ratio of cured compost (8th week of composting) ranged from 9 – 18 and did not differ from that of the 4th week (8-17) of composting.

Table 2: Percentage Change in Some Plant Nutrients as Affected by Period of Composting

Compost treatment	Nutrient							
	pH	EC	Org. C	TN	P	Ca	Mg	K
A (1:4)	6	4	18	9	10	31	109	-87
B (1:1)	1	22	11	5	2	40	138	-87
C (2:1)	-10	54	13	8	4	15	9	-78
D (4:1)	14	96	26	10	1	5	9	-5
E (8:1)	11	97	23	7	-5	-27	93	-84

EC- electrical conductivity, org.c – organic carbon, TN-total nitrogen, C/N – carbon to nitrogen ratio

Micronutrient Contents of Various Compost Ratios at 4th and 8th Weeks of Composting

Compost C had the highest Mn concentration at the 4th week of composting (323.2mgkg^{-1}) and its value was statistically different (P≤0.05) from all other compost ratios (Table 3a). Mn content in composts B, D and E were not statistically different from each other while compost A had the least value of Mn. The concentration of Zn ranged from 10.8mgkg^{-1} in compost A to 19.5mgkg^{-1} in compost C while Fe content was very high and ranged from 615.6mgkg^{-1} in compost E to 837mgkg^{-1} in compost D. Meanwhile the content of Fe in compost B did not differ from that of compost C but differed from those of composts A and C statistically (P≤ 0.05). Copper concentration was high too (20.6 – 36.8mgkg^{-1}).

Table 3b shows the contents of Mn, Zn, Fe and Cu in various compost ratios at the 8th week of composting. Mn content in composts A, D and E increased by over 68, 55 and 42%, respectively, while a decrease of over 11 and 6% Mn content was recorded for composts B and C (Table 3c). Zn and Fe concentrations increased considerably from > 60 – 120% for Zn and > 100 – 240% for Fe (Tables 3b and 3c). The content of Cu was low at the 8th week of composting, with values ranging from 1.93 – 3.70mgkg^{-1}; that is > 88 – 94% reduction in value. Reports in literatures indicate that organic acids, polysaccharides and fulvic acids can attract cations (Cu^{2+}) from edges of mineral structures and chelate or bind them in a stable organomineral complexes [17], which could probably be responsible for the low Cu content in cured composts.

Table 3a: Micronutrient Content of Various Compost Ratios at 4 weeks of Composting

Compost treatment	Mn	Zn	Fe	Cu
	←	mgkg^{-1}		→
A (1:4)	184.5c	10.87d	783.0b	20.6d
B (1:1)	226.5b	13.11b	675.0c	29.4b
C (2:1)	323.2a	19.50a	669.6c	36.8a
D (4:1)	220.0b	12.62c	837.0a	26.2c
E (8:1)	262.2b	13.00b	615.6d	25.2c

Figures followed by the same letter in the same column are not significantly different (P≤0.05)

Table 3b: Micronutrient Content of Various Compost Ratios at 8 weeks of Composting

Compost treatment	Mn	Zn	Fe	Cu
	mgkg^{-1}			
A (1:4)	311.3b	20.45c	1630.0c	3.70a
B (1:1)	200.0d	21.08c	2295.0a	1.93c
C (2:1)	301.4c	36.83a	1995.0a	2.12b
D (4:1)	341.5b	21.04c	1820.0b	3.00a
E (8:1)	373.5a	28.60b	1235.0d	2.62b

Figures followed by the same letter in the same column are not significantly different (P≤0.05)

Effects of Compost on Maize Growth

Application of various compost treatments on maize plant (six weeks after germination) showed that compost E was most effective with plant height significantly higher (P≤0.05) than those treated with composts A, B, C and D, giving the effect in the following order of composts E > D > B > C > A > control. Similar observation was also made for stem girth.

Table 3c: Percentage change in Micronutrient Content as Affected by Period of composting

Compost treatment	Mn	Zn	Fe	Cu
A (1:4)	69	88	108	-82
B (1:1)	-12	61	240	-93
C (2:1)	-7	89	197	-94
D (4:1)	55	67	117	-89
E (8:1)	42	120	101	-90

Figures followed by the same letter in the same column are not significantly different (P≤0.05)

CONCLUSION

Cured compost contains substantial amounts of plant macro-nutrients such as total N, available P, Ca, Mg and K, and also enriched with micro-nutrients (Mn, Zn, Fe, Cu), indicating that when added to soil of low inherent fertility, will have restorative effect such as increase in soil organic matter, conservation of soil and water and reduce the need for inorganic fertilizers. Concentrations of all the essential plant nutrients in the composts were higher than their critical levels in soils of southeastern Nigeria, making it possible to save a large quantity of inorganic fertilizer. Farmers should be encouraged to use composts with moderate addition of inorganic fertilizer for starter effect to make the soil more productive.

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