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Simple and Blended Organic Fertilizers Improve Fertility of Degraded Nursery Soils for Production of Kolanut (*Cola acuminate*) Seedlings in Nigeria

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1. Introduction

Feeding the rapidly growing population in sub-Saharan Africa has become a major development concern to policy makers, agricultural experts and international agencies. Populations are increasing in the region where, ironically, the soils are fragile and highly weathered, with low cation exhcnage capacity and low inherent fertility.

Brader (1993) reported that intensive farming in the western world relies heavily on chemical fertilizers and pesticides. In contrast, traditional African farmers practice shifting cultivation of mixed crops which allow long fallows to restore fertility. However, this system is no longer feasible because of increasing population rate and limited land base.

The practice of using chemical fertilizers input for agricultural production has not been widely adopted by farmers in tropical Africa because they are expensive, scarce and destructs soil properties on continuous use (Moyin-Jesu, 2003, Moyin-Jesu and Ojeniyi, 2006, Moyin-Jesu, 2009). This is because NPK, Ammonium sulphate and urea when hydrolysed in the soil increased soil acidification through their nitrate phosphate and sulphate component that form strong acids (HNO $_3$,H_2SO_4 and H_2PO_4.

Moyin-Jesu (2007) reported that many agricultural wastes were available in tropical countries but only about 20% was returned to the soil for fertility maintenance because they are considered bulky and difficult to transport by poor resource farmers, most of them are either burnt on the field after harvest or eating up by termites. There is no much consciousnesses of using them as compost, green manure and farm yard manure.

Regrettably, soil organic matter is declining with cultivation and urgent research attention is needed to promote the use of organic fertilizers for sustainable crop production. Among the organic materials that could be used for crop production are wood ash, cocoa husk amended with goat, duck and turkey manures or sole application of manures. Their potential as organic amendments for raising kola nut seedlings in the nursery has not been tested previously. Kola belongs to the family Stericuliaceae and is noted for its use in religious and social activities throughout West Africa. Industrially, kola is used for preparation of drinks such as Coca Cola, Pepsi-Cola, dyeing purposes and production of pharmaceutical (Adegeye and Ayejuyo 1994).

Kolanut tree (*Cola accuminata*) is a slender tree, that can grow up to 12m high, but usually reaches 6-9 m. The branches are slender, crooked and markedly ascending, the foliage is often sparse and confirmed to the tips of the branches. The hermaphrodite flower may be up to 25cm across. The perianth segments usually joined for nearly half their length while the anthers are borne on a short, but distinct column.

The fruit consists of five follicles borne at right angles to the stalk or slightly bent downwards. The follicles are sessile and have a straight point or tip up to 20cm long. The surface is rough to the touch, russet or olive brown. There are up to 14 seeds in each follicle and the embryo may have three to five or more cotyledons which are pink, red or sometimes white in colour. The fruits mature in the period from April to June.

Kolanut (*Cola accuminata*) grows in an area with rainfall between 1200-1500mm and responds well to fertile soils with high organic matter. Well drained soils are suited for deep tap rooted tree. It is not a mycorrihzal plant. Kola trees are both grown in farms and plantations which are established by individual farmers (2-3 ha). In some government farms settlement, Kola plantations are about 50 – 100 ha but they have been abandoned because of oil boom in Nigeria.

The objective of writing this chapter is to investigate the effectiveness of several organic fertilizers (wood ash, cocoa husk amended with goat, duck and turkey manures, or manure alone) as a source of plant nutrients for kola seedlings in a nursery. Seedling growth, leaf nutrient concentration and soil parameters were evaluated in this study.

2. Materials and methods

The experiment took place at the Teaching and Research Farm Federal College of Agriculture in Akure (7^{o}N, 5^{o}10^{o}E) in the rainforest zone of Nigeria between August 2003 and May 2004 and was repeated between August 2004 and 2005 to validate the results.

The annual rainfall is between 1100 and 1500mm while the average temperature is 24^{o}C. The Soil is sandy clay loam, skeletal, Kaolinitic, isohyperthermic oxic paleustalf (Alfisol) and belongs to Akure soil series. Soil survey staff (1999). The site had been continuously cropped to arable crops for more than 5 years.

2.1 Soil sampling and analysis before planting

Thirty core samples were collected with hand corer (3 cm diameter) from 0-15cm depth of the site, composited, air dried and sieved through a 2mm screen prior to analysis.

The soil pH (1:1 soil/water and 1:2 soil/0.01M $Cacl_2$) solution was determined using a glass calomel electrode system (Crockford and Nowell, 1956) while organic matter was determined by the wet oxidation chromic acid digestion (Walkley and Black, 1934).

The total nitrogen was determined by the microkjedahl method in which the distillate is titrated against the boric acid (AOAC, 1990) while available soil phosphorus was extracted by the Bray P_1 extractant and measured by the Murphy blue colouration and determined on a spectronic 20 at 882um (Murphy and Riley, 1962). Soil K, Ca, Mg and Na were extracted with 1M NH_4OAc, pH 7 solutions. The K, Ca and Na contents were determined with flame photometer while Mg was determined on atomic absorption spectrophotometer (Jackson, 1958). The mechanical analysis of the soil was done by the hydrometer method. (Barycous 1951) and the soil textural name was determined using textural triangle.

2.2 Determination of soil bulk density and porosity

The soil bulk density (mgm^{-3}) was determined by a core method (Ojeniyi, 1980). The soils samples taken were placed in an aluminium can, at 105°C for 48 hours, allowed to cool down and weighed. Thereafter, measured volume of water is put into an eureka can and the mass of the soil is placed inside nylon bag tied to a thread and is suspended by a tripod stand.

Gradually, it is immersed into the eureka can and displaces the water through upthrust displacement. The mass of the soil divided by the volume of displaced water gives the soil bulk density.

The soil porosity was calculated from the values of bulk density using the formulae $ep=\left[I-\frac{eb}{es}\right]\times100$ where eb = bulk density and soil particle density 2.75 mg m^{-3} for tropical soils.

2.3 Source and preparation of organic fertilizers

Cocoa husk and wood ash were obtained from cocoa plantation and cassava processing unit at Federal College of Agriculture, Akure respectively while the poultry; duck and turkey manures were obtained from their pens in the livestock unit of Federal College of Agric, Akure.

The organic materials were processed to allow decomposition. The woodash was sieved to remove pebbles, stones and unburnt shafts while the cocoa husk was partially composted for 6 weeks to reduce C/N ratio. The poultry, duck and turkey manures were air-dried to allow quick mineralization process.

2.4 Chemical analysis of the organic materials

Two grammes from each of the processed forms of the organic materials used, were analysed. The nitrogen content was determined by kjdaht method (Jackson, 1964) while the determination of other nutrients such as P,K, Ca, Mg was done using the wet digestion method based on 25-5-5 ml of $HN0_3$ – $H2SO_4$ – $HclO_4$ acids AOAC, 1990). The organic Carbon (%) was determined by wet oxidation method through chromic acid digestion. Walkley and Black, (1934).

2.5 Collection of kolanuts feeds for planting

Ripe fruits of kolanut were collected from the kola tree plantation in Federal College of Agric, Akure. The seeds were obtained after extraction of the fruits, its mucilage washed and air dried for 72 hours at room temperature to remove moisture.

2.6 Pre-nursery establishment of kolanut seedlings

Five seed boxes of (90 x 60 x 30cm) size each were filled with top soil and the mature seeds of kolanut were planted. A shed was erected for the pre-nursery to prevent the seeds from dessication and cultural practices such as weeding and watering twice a day were carried out. The planted kolanut seeds germinated after 21days and were transplanted to the nursery.

2.7 Nursery establishment of kolanut seedlings

The nursery site of 70 x 70m (490m^2) was cleared for laying out polybags and a shed was constructed to shade the site from direct evaporation and scorching of plants by the sun. The bulk soil randomly taken from the site (o-15cm) depth was sieved to remove stones and plant debris. Ten (10) kg of the sieved soil was weighed into a poly bag (30x17cm) size. (Manufacturer name is Nigeria Plastic Company, Ibadan, Polyethene type and 2cm in thickness).

Nine organic fertilizer treatments were used for the experiment namely; turkey manure, duck manure, goat manure, goat manure/cocoa husk mix, woodash/ duck manure mix, cocoa husk/turkey manure mix and woodash/turkey manure mix. All mixtures consisted of equal weight on a dry weight basis (50%) of the two components. The treatments were applied at 8t/ha (40g residues per 10kg soil). There was a control treatment (no fertilizer, no manure) and a fertilizer treatment (400kg/ha NPK 15-15-15 fertilizer at 2g per polybag). All the treatments were replicated three times and arranged in a completely randomized design (CRD).

The organic fertilizers and NPK fertilizer were incorporated into the soil filled poly bags using a hand trowel and allowed to decompose for one week by watering twice in a day. Then one pre-germinated kolanut seed from the pre-nursery was planted in each polybag and watered adequately in the morning and evening for the first 12weeks. The periods of the nursery experiments tallied with the commencement of dry season in previous year into the beginning of the rainy season in the following year., also, rains are not evenly distributed throughout the year. Hence, the need for supplementary watering to ensure steady growth of seedlings.

After two weeks, plant height, leaf area and stem girth of the seedlings were measured and these measurements continued every week till 24 weeks after planting.

Weeding of the site was done at 3,6,9 and 15 weeks after planting (WAP). The kola seedlings were sprayed with karate (active ingredient lambda cyhalotrin 720EC) at 10ml/10L of water 2 weeks intervals to control leaf defoliating beetles. At 12 weeks, part of the shed roof was removed to allow more sunlight to thicken the seedlings and permitted watering natural from incoming rainfall (4mm average per day during the study period).

At 10 weeks after planting, representative leaf samples from the top, middle and lower parts of the seedlings (excluding newly emerged leaves) per each treatment were randomly taken, packed into labeled envelopes and oven dried for 24 hours at 70^oC.

The dried leaf samples were ground and analysed. The nitrogen content was determined by kjedahl method (Jackson, 1964) while P,K, Ca and Mg contents were determined by wet digestion method using 25-5 - 5ml of $HN0_3$ – $H2SO_4$ and $HClO_4$ acids (AOAC, 1990).

At 24 weeks after planting, seedlings were carefully uprooted from the poly bag and separated into shoots and roots. The shoot weight (g dry mass) and tap root length were measured. Also, soil samples were taken from each polybag at 25 weeks after planting (WAP), air dried and sieved through a 2mm screen prior to soil analyses for total N and extractable N,P,K,Ca and Mg as well as soil pH (H_2O) and soil O.M (AOAC, 1990).

2.8 Statistical analysis

All the data collected on growth parameters, leaf nutrient concentrations and soil analysis after harvesting were evaluated with analysis of variance (ANOVA) and means separation using Duncan Multiple Range Test at P = 0.05 level.

3. Results

3.1 Initial soil analysis before planting the seedlings

The physical and chemical properties of the soils used for raising kola seedlings in the nursery are presented in Table 1.Based on the established critical levels for the soils in South West Nigeria, the soils are acidic and low in organic matter when compared with the 3% critical level (Agboola and Corey, 1973).

Soil parameters	Values
Soil pH (1:1) soil/water	5.35
Soil pH (0.01M Cacl2)	5.10
Organic matter (%)	0.36
Soil nitrogen	0.03
Available P (mg/kg)	5.36
Exchangeable K (mmol/kg)	0.09
Exchangeable Ca (mmol/kg)	0.08
Exchangeable Mg (mmol/kg)	0.13
Exchangeable Na (mmol/kg)	0.11
Soil bulk density (mgm-3)	1.58
Soil porosity (%)	40.80
Textural class	Sandy loam
USDA soil classification	Alfisol (Oxic tropodaulf)

Table 1. Soil chemical composition before planting kola seedlings.

The total % nitrogen was found to be less than 0.15%N, which is considered as the optimum for crops by Sobulo and Osiname (1981). The available soil P was less than $10mg/kg^{-1}$ that is considered as adequate for crop production in this region (Agboola, 1982).

Soil exchangeable bases (K, Ca, Mg and Na) had concentrations lower than the 0.20 $mmol/kg^{-1}$ critical level recommended by Folorunso *et al* (1995). The soil was very sandy and low in clay. The soil bulk density was high (1.58 mg m^{-3}) and would adversely affect root penetration and growth.

3.2 Chemical composition of the organic materials used for the experiment

Among the organic residues used, the turkey and duck manure had the highest N, P and lowest C/N ratios. In-addition, wood ash had the highest K, Ca and Mg concentration which was followed by cocoa husk. Goat dung was indicated to be fairly high in N, P, K and Ca. (Table 2).

Treatments	CN Ratio	N (%)	P (mg/kg)	K (%)	Ca (%)	Mg (%)	Fe (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
Cocoa husk	11.0	1.44	100	2.10	0.93	0.71	50.4	1.69	0.16
Wood ash	11.8	1.53	86	2.30	0.94	0.85	65.5	1.83	0.66
Goat manure	7.9	1.82	168	1.00	0.29	0.45	34.5	1.30	0.16
Duck manure	7.2	2.10	260	0.65	0.19	0.15	21.3	1.13	0.16
Turkey manure	7.1	3.86	346	0.79	0.21	0.18	29.7	1.16	0.14

Table 2. Analysis of the organic fertilizers used for the experiment on raising kola seedlings.

The quantity of nutrients (total kg/nutrients) supplied by each of the organic fertilizers for raising kola seedlings is presented in Table 3. More nutrients were supplied by the manure (turkey, duck manure and goat manures), wood ash and cocoa husk than the NPK 15-15-15 and control treatments.

Fertilizers	N	P	K	Ca	Mg
	→	Total kg/nutrient	←		
Cocoa husk	144	104	155.9	93.4	71.0
Wood ash	153	90	230.2	94.0	85.2
Goat manure	248	135	49.9	14.5	22.5
Duck manure	286	168	62.3	14.0	19.0
Turkey manure	434	186	48.6	16.0	20.50
NPK 15-15-15	240	240	240	0.2	0.1

+++ - Application of NPK 15-15-15 at 400kg/ha.
++ - Application of manures at 8t/ha.
+ - Application of wood ash and cocoa husk at 4t/ha.

Table 3. Total amount of nutrients supplied kg/nutrient by each of the organic fertilizers used for raising kola seedlings.

The quantities of nutrients supplied by the organic fertilizers were adequate for sustaining growth of kola seedlings in the nursery and later, when seedlings were moved to the field as reflected in the chemical composition of the seedlings and soil chemical composition after this 24 weeks experiment. (Tables 5 and 6)

3.3 The growth parameters of kola seedlings under simple and blended organic fertilizers

There were significant increases ($P<0.05$) in the plant height, leaf number, leaf area, stem girth, shoot weight and tap root length of kola seedlings under different simple and blended organic fertilizers compared to the control treatment (Table 4).

Treatments	Shoot Weight (g)	Plant height (cm)	Tap root length (cm)	Leaf area (cm^2)	Leaf number	Stem girth (cm)
Duck manure (sole)	180.2f	18.2f	8.5c	26.8d	5.0d	0.83d
Turkey manure (sole)	140.1c	15.8c	7.3b	24.5c	4.0b	0.76c
Goat manure (sole)	130.0b	13.4b	7.0b	22.6b	4.0b	0.50b
Goat manure + Cocoa husk	163.2d	17.3e	10.4d	27.6de	4.4bc	0.92e
Goat manure + Wood ash	175.3e	16.2cd	11.0de	28.2f	5.1de	0.96ef
Duck manure + Cocoa husk	193.2i	28.4j	13.3h	32.4i	7.6h	1.16h
Duck manure + Wood ash	201.4j	31.6k	14.8i	42.3j	8.2i	1.46i
Turkey manure + Cocoa husk	185.1g	26.1h	12.0g	30.5g	7.0g	1.00f
Turkey manure + Wood husk	190.0h	27.2hi	13.8f	31.1h	7.4gh	1.10fg
NPK 15-15-15	188.2h	23.2g	11.8g	27.5de	6.0f	0.92e
Control	32.10a	6.3a	4.1a	9.3a	3.6a	0.26a

Treatment means within each column followed by the same letters are not significantly different, using DMRT at $P<0.05$.

Table 4. The growth parameters of kola seedlings with simple and blended forms of organic fertilizers treatments between 2 and 24 weeks after planting.

Among the organic fertilizers, the simple forms of duck manure, wood ash blended with duck manure and cocoa husk blended with duck manure had the highest values of plant height for kola seedlings compared to others.

The blended forms of the organic fertilizers were found to increase significantly ($P<0.05$) the plant height leaf area, leaf number, stem girt, tap root length and shoot weight of kola seedlings compared to the NPK 15-15-15 fertilizer. For instance, the wood ash blended with duck manure increased the shoot weight, plant height, root length, leaf area, leaf number and stem girth of kola seedlings by 6%, 27%, 20%, 35%, 27% and 37% respectively compared to using NPK 15-15-15 fertilizer.

Generally, all the growth parameters of kola seedlings under the blended forms of the organic fertilizers were higher in value than those under the simple forms. For-instance, wood ash blended with duck manure increased the plant height, leaf area, tap root length, leaf number and stem girth by 42%, 37%, 43%, 39% and 43% respectively compared to the simple form of duck manure.

Furthermore, NPK 15-15-15 fertilizer increased the growth parameters of kola seedlings more than the simple forms of duck, goat and turkey manures.

3.4 Leaf chemical composition of kola seedlings with simple and blended organic fertilizers

The leaf analysis of the kola seedlings receiving different organic fertilizer sources are shown in Table 5. There were significant (P<0.05) increases in the leaf N, P, K, Ca and Mg concentrations of seedlings receiving organic fertilizers than the control treatment. The simple and blended forms of the organic fertilizers increased the kola seedling leaf K, Ca and Mg compared to the NPK fertilizer. For-instance, turkey manure + wood ash increased kola leaf K, Ca and Mg concentrations by 73.4%, 84% and 76% respectively, compared to the NPK 15-15-15 treatment. However, the NPK 15-15-15 treatments increased the leaf N and P concentrations more than the organic fertilizers.

Treatments	N	P	K	Ca	Mg
	%				
Duck manure (sole)	1.90f	0.32d	1.63e	0.78de	0.33c
Turkey manure (sole)	1.65c	0.28c	1.53d	0.72d	0.36d
Goat manure (sole)	1.48b	0.25b	1.20c	0.6 3c	0.32b
Goat manure + Cocoa husk	1.78d	0.36e	2.10f	1.56f	0.72e
Goat manure + Wood ash	1.80f	0.42g	2.43g	1.63g	0.75f
Duck manure + Cocoa husk	2.16h	0.43h	3.70j	2.55j	1.26i
Duck manure + Wood ash	1.85fg	0.53i	3.90k	2.76k	1.35g
Turkey manure+ Cocoa husk	1.80f	0.42g	3.20h	2.50h	1.20g
Turkey manure + Wood ash	1.79de	0.41f	3.50i	2.5hi	1.23h
NPK 15-15-15	2.23i	0.56ij	0.93b	0.40ab	0.3
Control	1.25a	0.20a	0.30a	0.2a	0.2a

Treatment means within each column followed by the same letters are not significantly different, using DMRT at P <0.05.

Table 5. The leaf chemical composition of kola seedlings under different simple and blended organic fertilizers.

Among the organic fertilizers, duck manure and blended duck manure with wood ash and cocoa husk increased the kola seedlings leaf N, P, K, Ca and Mg concentrations when compared to other organic fertilizers. In-addition, the simple forms of the turkey manure, duck manure and goat manure had lower values of kola leaf nutrients than the blended forms with wood ash and cocoa husk. Duck manure + cocoa husk increase the Kolanut leaf concentration of N by 12%, P by 74%, K by 56%, Ca by 69%, and Mg by 75% compared to the duck manure compared to duck manure.

The leaf K, Ca, Mg contents of kola leaf in both simple and blended forms of organic fertilizer treatments were far higher than 1.19% K, 0.8% Ca and 0.25% Mg critical levels reported by Jones and Eck (1973) while the leaf N and P contents were also higher than 1.5% N and 0.22% P critical levels recommended by Adepetu *et al* (1979).

However, the leaf N, P, K, Ca and Mg contents in the control treatments (no fertilizer applied) were far below the different critical levels mentioned above. Leaves of seedlings in the control treatment showed deficiency symptoms of N and Mg (loss of chlorophyll and yellow leaf colouration), P (purple colouration), K (burnt leaf margin and Ca (stunted root growth). Ojeniyi (1984).

3.5 Soil chemical composition after the experiment on kola seedlings under different simple and blended organic fertilizers

Both simple and blended organic fertilizers and NPK 15-15-15 increased significantly ($P<0.05$) the soil N, P, K, Ca and Mg compared to the control treatment (Table 6). However, NPK fertilizer decreased soil pH and O.M relative to the simple and blended organic fertilizer treatments.

Treatments	N	P	K	Ca	Mg	Soil pH	O.M
	(%)	(mg/kg)	mmol/kg				%
Duck manure (sole)	0.19d	19.36d	0.83e	0.50e	0.24f	6.50e	1.16e
Turkey manure (sole)	0.18c	17.26c	0.74d	0.48d	0.22e	6.40c	0.98c
Goat manure (sole)	0.15b	15.60b	0.52b	0.36b	0.16c	6.20b	0.70b
Goat manure + Cocoa husk	0.20e	19.10d	0.63ef	0.42c	0.18d	6.60d	0.99cd
Goat manure + Wood ash	0.22g	20.94f	0.94f	0.46c	0.22e	6.90ef	1.20f
Duck manure + Cocoa husk	0.23h	24.4g	1.24i	0.96hi	0.56hi	7.10g	2.10hi
Duck manure + Wood ash	0.33j	26.3h	1.34j	0.92h	0.58j	7.20gh	2.40j
Turkey manure + Cocoa husk	0.21f	22.10f	1.05fh	0.85fg	0.52g	7.00f	1.85g
Turkey manure +Wood ash	0.27i	23.0f	1.19h	0.81f	0.55h	7.00f	1.96h
NPK 15-15-15	0.36k	27.60i	0.66c	0.03a	0.04ab	5.10a	0.25a
Control	0.02a	3.40a	0.04a	0.02a	0.02a	5.10a	0.25a

Treatment means within each column followed by the same letters are not significantly different, using DMRT at $P<0.05$.

Table 6. The soil chemical composition of kola seedlings with simple and blended forms of organic fertilizers.

The cocoa husk and wood ash blended with duck manure treatments gave the highest values of soil N, P, K, Ca, Mg, pH and O.M by 36%, 16%, 22%, 8%, 10%, 3% and 23% respectively, compared to turkey blended with cocoa husk.

In - addition, the simple and blended organic fertilizers had higher values of soil Ca and Mg relative to the NPK 15-15-15 fertilizer treatment. Also, the blended forms of organic fertilizers increased the soil N, P, K, Ca, Mg, pH and O.M compared to their simple forms.

The soil N, P, K, Ca, Mg, pH and O.M values after the experiment were far higher than 0.15% N, P (10mg/kg), K, Ca and Mg (0.2mmol/kg) and 3% recommended by Sobulo and Osiname (1981), Agboola and Corey (1973) and Folorunso *et al* (1995) as critical soil fertility levels for sustainable crop growth in the field.

The soil K/Ca, K/Mg and P/Mg ratios were 22:1, 17:1 and 690:1 under NPK 15-15-15 fertilizer compared to soil K/Ca (1:1), soil K/Mg (2:1) and P/Mg (43:1) ratios under turkey manure blended with cocoa husk signifying the presence of nutrient imbalance in the NPK fertilized soil.

4. Discussion

The lowest values of Kola seedling growth parameters (plant height, leaf area, stem girth, leaf number, shoot weight and tap root length), leaf nutrient concentration and soil chemical parameters were found in the control treatment consistent with the initial low nutrient status of the soil before application of the organic fertilizers.

Therefore, the kolanut seedlings were having deficiency symptoms of yellow, purple colourations and the marginal burn of leaves consistent with N, P, K and Mg deficiencies. This observation agreed with Adepetu *et al* (1979), who reported an approximate 55% drop in soil O.M over seven years of continuously cultivating an Iwo soil association in the green house and under field conditions. Hence, this finding corroborates the importance of fertilizer use to enhance crop productivity in the tropics.

The effectiveness of blended forms of wood ash and cocoa husk with duck, turkey and goat manures in improving the growth, soil and leaf chemical composition of kolanut seedlings can be attributed to enhancement of their degradation rate by the manures with lower C/N ratio.

Furthermore, the blending of the organic fertilizers before application to soil also enhanced their decomposition and rate of nutrient release to the soil. Woodash is expected to be a good source of cations and cocoahusk could retain soil moisture also the composting of cocoahusk would reduce its immobilization of N and P. This observation might be responsible for the exceptional difference in the performance of wood ash and cocoa husk blended with manures compared to the work of Adebayo and Olayinka (1984) which used the unprocessed forms of sawdust, wood ash and cocoa husk blended with turkey and poultry manures to grow maize.

The better performance of duck manure blended with cocoa husk and wood ash treatments in increasing the plant height, leaf area, stem girth, leaf number, tap root length and shoot weight compared to the NPK 15-15-15 fertilizer could be traced to their rich nutrient contents (N, P, K, Ca and Mg) which increased the soil nutrients and consequently improved nutrient and water uptake in the plants. This is consistent with the leaf nutrition, based on N, P, K, Ca and Mg concentrations in foliage

The application of NPK 15-15-15 fertilizer at 400kg/ha led to high soil K/Ca, K/Mg and P/Mg ratios, which could have produced imbalances and limited uptake of P, K, Ca and Mg. Results point to lower concentration of leaf K, Ca and Mg with NPK fertilizer than the organic fertilizers.

Unbalanced fertilization with the NPK fertilizer treatment could be responsible for the lower values of soil K, Ca, Mg, concentrations, compared to the wood ash and cocoa husk blended with manures,. Lower soil pH and O.M content in the NPK fertilized poly bags, compared to the wood ash and cocoa husk blended with manures points to soil acidification and O.M loss. These findings are supported by Agboola (1982) who reported that arbitrary use of inorganic fertilizers resulted in signs of toxicities, poor yield responses and deterioration of some soil properties.

The contribution of the organic fertilizers used, in increasing the growth parameters of kolanut, leaf N, P, K, Ca and Mg concentrations, soil nutrients pH and O.M was also consistent with their chemical composition and the total nutrients/kg applied to the soil. The view is also corroborated by Swift and Anderson (1993) who reported that organic manures supplied nutrients which NPK fertilizer could not supply to the crops. This showed the potentials of organic fertilizers in increasing the crop yields.

Furthermore, the exceptional performances of he blended cocoa husk and wood ash with duck, turkey, and goat manures over the simple forms of the manures was due to the fact that duck, turkey and goat manures have high nutrient concentrations and low C/N ratios and their combination with the cocoa husk and wood ash fortified their nutrient supplying power.

This observation explained the superiority in the growth parameters, leaf and soil chemical composition of kolanut seedlings in the wood ash blended with duck manure and turkey manure compared to their simple form of application.

This was in line with Moyin-Jesu (2007) and Moyin-Jesu (2008) who reported nutrient superiority of organically blended fertilizers over their sole forms in coffee seedlings and okra.

The increase in soil pH under duck manure blended with wood ash and cocoa husk compared to other treatments was traced to the high K, Ca and Mg contents of wood ash and cocoa husk and could be effective as liming materials as well as enhancing effective release of nutrients (Gordon, 1998). Unlike the NPK 15-15-15 fertilizer which acidify the soil if used continuously.

Obatolu (1995) reported that oil palm bunch ash, wood ash and cocoa husk improved soil K, Ca and Mg concentrations and corrected acidity in an Alfisol grown to coffee and maize. Therefore, the exceptional increase in soil pH in duck manure blended with wood ash over that turkey manure blended with wood ash could be responsible for better growth performance and soil nutrients due to the importance of soil pH in effective nutrient release.

The balanced nutrient supplying power of the manures blended with wood ash cocoa husk coupled with the simple forms of the manures contributed to the healthy kolanut seedlings in the nursery and for proper establishment on the field when they are transplanted.

4.1 Conclusions and recommendations

The research indicates that the duck manure and turkey manure (simple forms) and their blended forms with cocoa husk and wood ash applied at 8t/ha (40g/polybag) increased the soil nutrient supply, pH and O.M, leaf nutrition and a number of plant parameters (plant height, stem girth, leaf number, leaf area, tap root length and shoot weight) of kolanut seedlings.

Duck manure blended with wood ash and cocoa husk (8t/ha) was the most effective fertilizer materials and is recommended to improve the nutrient availability and ensure sustainable nursery and field production of kolanut seedlings on a commercial basis.

This recommendation agreed with the fact that inorganic fertilizers are becoming very expensive to purchase by the small holder farmers of kolanut. These organic fertilizer materials appear to have beneficial secondary effects on soil properties and could be more favourable to the environment.

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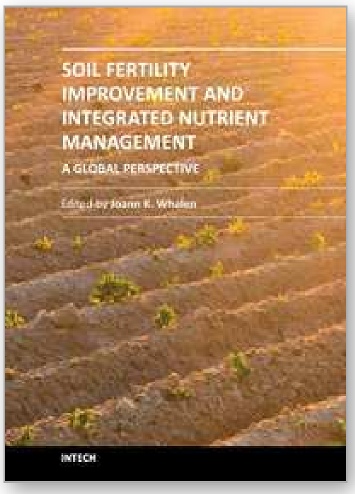

Soil Fertility Improvement and Integrated Nutrient Management - A Global Perspective
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Soil Fertility Improvement and Integrated Nutrient Management: A Global Perspective presents 15 invited chapters written by leading soil fertility experts. The book is organized around three themes. The first theme is Soil Mapping and Soil Fertility Testing, describing spatial heterogeneity in soil nutrients within natural and managed ecosystems, as well as up-to-date soil testing methods and information on how soil fertility indicators respond to agricultural practices. The second theme, Organic and Inorganic Amendments for Soil Fertility Improvement, describes fertilizing materials that provide important amounts of essential nutrients for plants.The third theme, Integrated Nutrient Management Planning: Case Studies From Central Europe, South America, and Africa, highlights the principles of integrated nutrient management. Additionally, it gives case studies explaining how this approach has been implemented successfully across large geographic regions, and at local scales, to improve the productivity of staple crops and forages.