Pertanika J. Trop. Agric. Sci. **32(1)**: 17 - 23 (2009) ISSN: 1511-3701

Evaluation of Sole and Amended Organic Fertilizers on Soil Fertility and Growth of Kola Seedlings (*Cola acuminate*)

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ABSTRACT

A healthy kola seedling in the nursery is very important for sustainable establishment and high yield of kolanuts in the fields. An investigation was carried out in Akure, in the rainforest zone of Nigeria, to determine the effectiveness of amended forms of wood ash and cocoa husk, turkey, goat and duck manures (sole) as sources of fertilizers, on the growth of kola (*Cola acuminate*) seedlings in the nursery. For this purpose, nine organic fertilizer treatments [duck manure, goat manure, turkey manure (sole), wood ash/duck manure mix, cocoa husk/duck manure mix, goat manure/wood ash mix, goat manure/cocoa husk mix, turkey manure/cocoa husk mix and turkey manure and wood ash mix] were applied at 8t/ha (40g per 10kg soil filled pots), replicated three times with NPK fertilizer and a control (no fertilizer), and arranged in a completely randomized design. The soil, plant and the organic residues were chemically analysed. The findings revealed that the use of organic residues significantly increased plant height, leaf area, stem girth, root length as well as leaf number of kolanut seedlings, soil and leaf N, P, K, Ca, Mg concentrations, soil pH and O.M contents ($p<0.05$), relative to the control treatments. The amended wood ash + duck increased the shoot weight, plant height, root length, leaf area, leaf number and stem girth of kolanut by 6%, 27%, 20%, 35%, 27% and 37% respectively, as compared to using the NPK fertilizer. In addition, it was also found to increase the same parameters by 84%, 80%, 72%, 78%, 56% and 82% respectively, as compared to the control treatment. As for the soil chemical composition, duck manure + wood ash were shown to increase the soil N, P, K, Ca, Mg, pH and O.M by 42%, 26%, 38%, 46%, 59%, 6% and 52% respectively, compared to the duck manure (sole). At the same time, it also increased soil K, Ca, Mg, pH and O.M by 51%, 97%, 93%, 29% and 90% respectively, as compared to using the NPK fertilizer. In particular, the treatment using duck manure + cocoa husk increased the leaf N, P, K, Ca and Mg of kolanut seedlings by 12%, 74%, 56%, 69% and 75%, respectively as compared to merely using duck manure (sole). It also increased the same leaf parameters by 42%, 54%, 92% and 84% respectively, as compared to the control treatment. In this study, the NPK fertilizer was found to decrease soil O.M but it increased soil N and P more than the organic residues. The amended duck manure + wood ash and duck manure + cocoa husk, applied at $8tha^{-1}$ (40g/10kg), were found to be the most effective in improving the performance of kolanut seedlings.

Keywords: *Cola acuminate*, organic fertilizers, kolanut seedlings

INTRODUCTION

Kola belongs to the family of stericuliaceae. The two main species of kola, namely cola nitida and cola acuminate, are of the most important commercial values in the markets. Kolanuts are featured prominently in the religious and social activities of West Africa. They are used particularly during marriages, child naming ceremonies and other cultural activities. Industrially, kola is used for the preparation of drinks such as Coca-cola and Pepsi cola, as well as dyeing purposes and the production of pharmaceuticals (Adeyeye and Ayejuyo, 1994).

Despite the above mentioned importance of kola, its optimum yield has not been attained because of the increasing decline in soil fertility and old age of kola trees in the field. Effort to increase the soil nutrient status, through the

Received: 20 June 2008
Accepted: 11 September 2008

use of chemical fertilizer by farmers, is rather limited due to high cost of fertilizer, and/or its poor availability to farmers locally. Thus, there is need to identify locally available organic fertilizers which can be used to improve the fertility of soils used in raising kola seedlings in the nursery, which takes usually about 8-12 months.

A literature review showed that using different levels of chromelana odorata on kola and coffee, with the exception of the previous research findings of Obatolu (1995). Apart from that, Oladokun (1990) worked on the effects of vegetative propagation on the growth and yield of kolanut, while Abulude (2004) worked on the determination of functional groups in the chemical composition of kola (*Cola acuminate*); nevertheless, there is a scarcity in the research and information on the use of wood ash, cocoa husk amended with goat, duck and turkey manures or the sole application of the manures for raising kola seedlings in the nursery.

The objective of this study was to investigate the effectiveness of various types of organic residues as a source of plant nutrients on the growth, leaf and soil parameters of the kola seedlings in the nursery.

MATERIALS AND METHODS

The experiment was carried out at Akure (7°N, 5° 10° E) in the rainforest zone of Nigeria. The rainfall is between 1100 to 1500mm per annum and the temperature is 24°C.

Soil Sampling and Analysis

30 core soil samples were collected from 0-15cm depth on the site, and mixed thoroughly. The representative samples were taken to the laboratory, air-dried and sieved with 2mm sieve and ready for routine analysis.

The soil pH (1:1 soil/water) was read on the pH meter. Organic matter was determined using wet oxidation method through chromic acid digestion (Walkley and Black, 1934). Soil P was extracted by Bray P_1 extractant and the extract was developed into Murphy blue colouration and determined on a spectronic 20 (Bausch and Lomb Spectronic 20 the Bausch and Lomb France S.A., Boie Postate 3, F-78320 Les Mesnil Saint Denis, France) at 882um (Murphy and Riley, 1962). The soil K, Ca, Mg and Na were extracted with IM NH_4 $0A_c$ pH 7 and the contents of K, Ca and Na were read on the flame photometer (Jenway Clinical PFP7, Designed and manufactured by Jenway Ltd. Felsted Dunmow, Essex CM6 3LB, United Kingdom), while the Mg content was determined on the atomic absorption spectrophotometer (Novaspec II visible spectrophotometer; manufactured by Pharmacia Biotech (Biochron Ltd) Cambridge, England). Meanwhile, the % N was determined using the microkjedahl method (Jackson, 1964).

The Analysis of the Organic Residues Used for the Experiment

The manures from turkey, goat and duck were obtained from their pens at a nearby farm and were air-dried, while wood ash and cocoa husk were obtained from domestic source and cocoa plantation. The cocoa husk was ground using hammer mill for a better utilization by crops, while the wood ash was sieved with 2mm sieve to remove pebbles, wood and charcoals remains. The turkey, goat and duck manures were each stacked under a shade to allow quick mineralization and this was done to reduce the C/N ratio.

The % nitrogen was determined by weighing 2g of each organic material into a digester flask and 5ml of H_2S0_4 with selenium, and copper sulphate tablets were added. After 5ml of NaH was added, the distrillate was collected, and boric acid was added with an indicator before it was titrated with 0.1. M HC1.

Furthermore, two grams of each organic material was weighed into a clean dry tecator digestion tubes to determine the P, K, Ca and Mg contents. 25ml of $HN0_3$ was added down the neck of the flask and swirled to ensure that the organic material was thoroughly wetted. 5ml of $H_2 SO_4$ and 5ml of perchloric acid ($HC1O_4$) were added and the mixture was swirled again. This was then placed on the digestion block and heated carefully by ensuring that the samples did not froth. Digestion was continued until the samples were clear and acids were completely volatized.

The samples were allowed to cool and 10ml of distilled water was added; filtration into 100ml volumetric flask was done and the filtrate was left to cool before it was filled to the mark with distilled water.

As for phosphorus (P), 20ml of phosphor-vanado molybdate solution was added and allowed to stand for at least 2 hours. The colour absorbance was measured on spectronic

20 at 442um. Meanwhile, the % K, Ca and Na contents, an aliquot was measured into 100ml flask and diluted to mark. 1ml of the sample solution was taken, and the flame photometer was adjusted; this was followed by the aspiration of the diluted sample solution. The solution was read and later converted to mg/kg. The Mg content was determined using the atomic absorption spectrophotometer.

Experimental Hypotheses

Three hypotheses were tested using independent variable (X_1) and dependent variables as the Y_1 for kola seedlings. The independent variables (X_1) were defined as organic materials such as turkey manure, duck manure, goat manure, goat manure/cocoa husk mix, turkey manure/cocoa husk mix, wood ash/duck manure mix, cocoa husk/duck manure mix, wood ash/turkey manure mix and cocoa husk/turkey manure mix.

The dependent variables (Y_1) were defined as comprising plant height, leaf area, stem girth, tap root length, shoot weight and leaf number, soil and leaf N, P, K, Ca and Mg, soil pH and O.M.

Each null hypothesis (Ho=U) was tested to determine whether significant statistical relationship existed between each dependent and the observed independent variables.

The three hypotheses tested were as follows:

(i) There is no significant relationship between the organic materials and the plant height, leaf area, stem girth, root length and leaf number of the kolanut seedlings.
(ii) There is no significant relationship between the organic materials and soil N, P, K, Ca, Mg, pH and O.M composition after harvesting.
(iii) There is no significant relationship between the organic materials and leaf N, P, K, Ca and Mg of the kolanut seedlings.

Nursery Experiment

The site was cleared and the debris was removed for laying out polybags on the ground for the purpose of experiment. Each polybag was filled with 10kg soil (0-15cm depth) taken from the site.

The nine organic residue treatments included in the experiment were turkey manure, duck manure, goat manure, goat manure/cocoa husk mix, wood ash/goat manure mix, cocoa husk/duck manure mix, wood ash/duck manure mix, cocoa husk/turkey manure mix and wood ash/turkey manure mix. All these mixes consisted of equal weights (50%) of the two components. The treatments were applied at 8 t/ha (40g residues per 10kg soil).

There was an unamended control treatment (no fertilizer; no manure) and a fertilizer treatment (400kg/ha NPK 15-15-15 fertilizer at 2g per pot). All the treatments were replicated three times and arranged in a completely randomized design (CRD).

The residues were allowed to decay in the soil-filled polybags for one week by watering twice in a day. One pre-germinated kolanut seed was planted in each polybag and watered adequately. After two weeks of planting in the nursery, plant height, leaf area and stem girth of kolanut seedlings were measured using a ruler, graph method and calliper, while the leaf number was done by counts. These growth parameters were measured at every week interval, up to 24 weeks after planting.

Weeding of the site was started at 3 weeks after planting and repeated at 6, 9 and 15 weeks after planting. The kola seedlings were sprayed with karate (i.e. 25g lambda-cyhalotron per litre) at 10ml per 10L of water, every 2 weeks interval to control lead defoliating beetles. Initially, a shade structure was built above the seedlings and this was gradually removed, starting from 12 weeks to thicken the seedlings by receiving more sunlight.

At 10 weeks after planting in the nursery, some leaf samples were taken from the kola seedlings, dried and analysed for the N, P, K, Ca and Mg contents. At 24 weeks after planting (WAP), the seedlings were carefully uprooted, while the shoot weight and tap root length were also measured. The soil samples were taken from each polybag at 25 WAP, air dried and sieved for routine analysis of soil N, P, K, Ca and Mg, soil pH and O.M, as described in the earlier section.

Statistical Analysis

The data collected from the treatment effects of organic residues on the growth parameters, such as plant height, leaf area, stem girth, leaf number, shoot weight and tap root length, were analysed using the ANOVA F test technique and their means were separated and compared using the Duncan Multiple Range Test (DMRT) at 5% level.

RESULTS

Initial Soil Fertility Status

Both the physical and chemical properties of the soils used for rising of kola seedlings in the nursery are presented in Table 1. Using the established critical levels for the soils in South West Nigeria, the soils are acidic, and low in organic matter when compared with the critical level of 3% (Agboola and Corey, 1973). In addition, the total % nitrogen was found to be less than 0.15% N, which is considered as the optimum for crops (Sobulo and Osiname, 1981). The available P was less than 10mg/kg o, which is considered as adequate for the production of crop (Agboola, 1982).

TABLE 1
Soil chemical composition before planting kola seedlings

Soil parameters	Values
Soil pH (1:1) soil/water	5.35
Soil pH (0.01M) $CaCl_2$	5.10
Organic matter (%)	0.36
N%	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 (g/cm^3)	1.58

The exchangeable K values were very low and crop grown on the soils was expected to respond to K application, with 0.2mmol/kg soil being the critical level. The available Ca, Mg and Na were also found to be low, indicating the soils with poor fertility status. The soil was very sandy and low in clay. The soil bulk density was high (1.58 Mg/m) and would adversely affect the crop in terms of its growth. This soil belongs to the Akure series and is an Alfisol (USDA 7^{th} approximation).

The Analysis of the Organic Materials Used for the Experiment

Among the organic residues used, the manures taken from turkey and duck had the highest N, P and the lowest C/N ratios. In particular, the wood ash had the highest K, Ca and Mg concentrations, and this was followed by cocoa husk. The goat dung was indicated to be fairly high in N, P, K and Ca (Table 2).

The Effect of Organic Fertilizers on the Leaf Chemical Composition of the Kolanut Seedlings

The leaf analysis of the kola seedlings for different organic fertilizer sources is presented in Table 3. Based on the results, there were significant increases ($p<0.05$) detected in the leaf N, P, K, Ca and Mg contents as compared to the control.

The amended and sole forms of the organic residues increases the kola leaf K, Ca and Mg contents compared to the NPK fertilizer; however, the NPK was found to increase the leaf N and P more than the organic residues. Among the organic residues, duck manure and amended duck manure with wood ash and cocoa husk increased the kola leaf N, P, K, Ca and Mg as compared to the others.

The sole forms of the turkey manure, duck manure and goat manure had lowered the kola leaf nutrient contents than the amended forms with wood ash and cocoa husk.

The Effects of Organic Fertilizers on the Soil Chemical Properties after the Experiment on Raising Kola Seedlings

Both organic and inorganic fertilizers were found to increase the soil N, P, K, Ca and Mg significantly ($p<0.05$), relative to the control treatment. On the contrary, the NPK fertilizer decreased soil pH and O.M, as compared to the organic fertilizer treatments (Table 4).

The duck manure, cocoa husk and wood ash amended with duck manure gave the highest values of soil N, P, K, Ca, Mg pH and O.M, as compared to other residues. Meanwhile, the organic fertilizers gave the best values of soil Ca and Mg as compared to the NPK fertilizer.

The Effects of Organic Fertilizers on the Growth Parameters of the Kola Seedlings

The plant height, leaf number, stem girth, leaf area, shoot weight and tap root length of kola seedlings, for the different organic fertilizers, are as presented in Table 5. The organic fertilizers were found to increase the growth parameters of the kola seedlings significantly ($p<0.05$), relative to the control.

TABLE 2
Analysis of the organic materials used for the experiment on raising kola seedlings

Treatment	C/N ratio	N (%)	P mg/kg	K	Ca	Mg mg/kg	Fe	Zn	Cu
Cocoa husk	11.0	1.44	100	20.6	9.3	7.1	50.4	1.69	0.16
Wood ash	11.8	1.53	86	23.0	9.4	8.5	65.5	1.83	0.16
Goat manure	7.9	1.82	168	10.0	2.9	4.5	34.5	1.30	0.16
Duck manure	7.2	2.10	260	6.6	1.9	1.5	21.3	1.13	0.16
Turkey manure	7.10	3.86	346	7.9	2.1	1.8	9.1	1.16	0.14

TABLE 3
The leaf chemical composition of kola seedlings under different organic fertilizers

Treatment	N	P	K	Ca	Mg
			%		
Duck manure (sole)	1.90^{f}	0.32^{d}	1.63^{e}	0.78^{de}	0.33^{c}
Turkey manure (sole)	1.65^{c}	0.28^{c}	1.53^{d}	0.72^{d}	0.36^{d}
Goat manure (sole)	1.48^{b}	0.25^{b}	1.20^{c}	0.63^{c}	0.32^{b}
Goat manure + cocoa husk	1.78^{d}	0.36^{e}	2.10^{f}	1.56^{f}	0.72^{e}
Goat manure + wood ash	1.80^{f}	0.42^{g}	2.43^{g}	1.63^{g}	0.75^{f}
Duck manure + cocoa husk	2.16^{h}	0.43^{h}	3.70^{j}	2.55^{j}	1.26^{i}
Duck manure + wood ash	1.85^{fg}	0.53^{i}	3.90^{k}	2.76^{k}	1.35^{j}
Turkey manure + cocoa husk	1.80^{f}	0.42^{g}	3.20^{h}	2.50^{h}	1.20^{g}
Turkey manure + wood ash	1.79^{de}	0.41^{f}	3.50^{i}	2.52^{hi}	1.23^{h}
NPK 15-15-15	2.23^{i}	0.56^{ij}	0.93^{b}	0.4^{ab}	0.3^{a}
Control	1.25^{a}	0.2^{a}	0.30^{a}	0.2^{a}	0.2^{a}

Treatment means, within each group followed by the same letters, are not significantly different from each other, using DMRT at 5% level.

TABLE 4
The soil chemical composition of kola seedlings under different organic fertilizers

Treatment	N (%)	P mg/kg	K	Ca mg/kg	Mg	Soil pH	O.M %
Duck manure (sole)	0.19^{d}	19.36^{d}	0.83^{e}	0.50^{e}	0.24^{f}	6.80^{e}	1.16^{e}
Turkey manure (sole)	0.18^{c}	17.26^{c}	0.74^{d}	0.48^{d}	0.22^{e}	6.40^{c}	0.98^{da}
Goat manure (sole)	0.15^{b}	15.60^{b}	0.52^{b}	0.36^{b}	0.16^{c}	6.20^{b}	0.70^{c}
Goat manure + cocoa husk	0.20^{e}	19.10^{d}	0.63^{c}	0.42^{c}	0.18^{d}	6.60^{d}	0.99^{d}
Goat manure + wood ash	0.22^{g}	0.94^{f}	0.94^{f}	0.46^{c}	0.22^{e}	6.90^{ef}	1.20^{f}
Duck manure + cocoa husk	0.23^{h}	24.4^{g}	1.24^{i}	0.96^{hi}	0.56^{hi}	7.10^{g}	2.10^{hi}
Duck manure + wood ash	0.33^{j}	26.3^{h}	1.34^{j}	0.92^{h}	0.58^{j}	7.20^{gh}	2.40^{j}
Turkey manure + cocoa husk	0.21^{f}	22.10^{f}	1.05^{fg}	0.85^{fg}	0.52^{g}	7.00^{f}	1.85^{g}
Turkey manure + wood ash	0.27^{i}	23.0^{f}	1.19^{h}	0.81^{f}	0.55^{h}	7.00^{f}	1.96^{h}
NPK 15-15-15	0.36	27.60^{i}	0.66^{c}	0.03^{a}	0.04^{ab}	5.10^{a}	0.25^{a}
Control	0.02^{a}	3.40^{a}	0.04^{a}	0.02^{a}	0.02^{a}	5.10^{a}	0.25^{a}

Treatment means, within each group followed by the same letters, are not significantly different from each other using DMRT at 5% level.

TABLE 5
The growth parameters of kola seedlings under different organic fertilizers treatments between 2 and 24 weeks of planting (WAP)

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

Treatment means, within each group followed by the same letters, are not significantly different from each other, using DMRT at 5% level.

Among the organic fertilizers, the duck manure (sole), wood ash/duck manure mix and cocoa husk/duck manure mix gave the highest values of plant height as compared to the others. The amended organic fertilizers were found to increase the plant height, leaf area, leaf number, stem girth, tap root length and shoot weight of the kola seedlings much more than the NPK fertilizer.

The amended residues resulted in superior growth compared to the sole forms. The NPK fertilizer, however, increased the growth parameters more than the sole forms of duck, goat and turkey manures.

DISCUSSION

The poor growth of the kola seedlings, in the nursery under the control treatment, was consistent with the low nutrient status of soil K, Ca, Mg, Na, O.M and pH; this fact is supported by Agboola (1982) who had identified poor soil fertility as the main factor in reduced crop yields. The increase in the soil and leaf N, P, K, Ca, Mg soil pH and O.M of the kola seedlings, under the organic fertilizer treatments, was consistent with their chemical composition (Table 3). 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 yield of crops.

The increase in the soil pH, through the use of organic fertilizers as compared to the NPK fertilizer, could be responsible for a better growth rate of the kola seedlings because it would favour nutrient release; this view is supported by Raymond (1990) who reported the importance of neutral soil pH in effective nutrient release. In addition, Tisdale and Nelson (1996) also reported that N is important in vegetative growth, protein synthesis and root formation of crops. The best growth performance recorded for the kola seedlings, under the duck manure and turkey manure (sole), wood ash and cocoa husk amended with duck manure, and turkey manure as compared to the others, could be due to the superiority of their nutrients and the low C/N ratio. This is supported by Folorunso (1990) who reported the importance of plant residues (cocoa husk and wood ash) in increasing crop yields.

CONCLUSIONS AND RECOMMENDATIONS

The current study proved that the duck manure and turkey manure (sole) and their amended forms with cocoa husk and wood ash increased the soil, leaf and growth performance of the kola seedlings in the nursery. For this reason, farmers are encouraged to adopt their use at 8 t ha^{-1} for the nursery and field production of kola seedlings.

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