Journal of Agriculture and Ecology Research International

13(4): 1-11, 2017; Article no.JAERI.36000
ISSN: 2394-1073

Strengthening Cocoa Production through Site Specific Fertilizer Recommendation in Five Local Government Areas of Cross River State, Nigeria

O. S. Ibiremo[1*], C. I. Iloyanomon[2], A. A. Oloyede[2], J. O. Lawal[2] and I. Alhassan[1]

[1]Federal University, Gashua, Yobe State, Nigeria.
[2]Cocoa Research Institute of Nigeria, Ibadan, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Authors OSI and CII designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors AAO and JOL managed the literature searches and proofread the drafts while author IA performed the statistical analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2017/36000
Editor(s):
(1) Rusu Teodor, Professor, Department of Technical and Soil Sciences, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania.
(2) Daniele De Wrachien, Department of Agricultural and Environmental Sciences of the State University of Milan, Italy.
Reviewers:
(1) Arthur Tapi, Côte d'Ivoire.
(2) Çelenk Molva, Izmir Institute of Technology, Turkey.
(3) A. Orluchkwu Joseph, University of Port Harcourt, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/22241

Original Research Article

Received 7th August 2017
Accepted 30th November 2017
Published 11th December 2017

ABSTRACT

Ten cocoa farms with declining productivity in five Local Government Areas (LGAs) of Cross River State, Nigeria were selected for rehabilitation purpose through appropriate fertilizer recommendation based on soil test values. The LGAs were Akpamkpa, Ikom, Efung, Boki and Obudu of which Yaunde (Ikom), Agbokim waterfall (Etung) and Orimekpang (Boki) are high cocoa producing areas, while Begiaba (Obudu) and New Ndebiji (Akamkpa) are medium cocoa producing areas. Each farm was divided into four blocks with eight sampling points where soil samples were collected at depths of 0-15 cm, 15-30 cm and 30-45 cm. Similarly, leaf samples were taken from the tree under whose canopy the soil samples were taken. The soil and leaf samples were processed and analyzed for nutrient compositions in the laboratory using standard laboratory procedures. Results indicated that soils of New Ndebiji and Orimekpang in Akamkpa and Boki Local Government Areas respectively contained 0.65 and 0.71 gkg^{-1} soil total N. These values are below the critical value for cocoa

**Corresponding author: E-mail: femiibiremo@yahoo.com;*

production. Hence, Nitrogen fertilizer will be necessary for optimum production in the two farms. Similarly, Potassium and Phosphorus are deficient in all the cocoa farms evaluated in the five LGAs. Leaf samples for N, P and K almost follow the trend of soil results. However, soil pH organic carbon, base saturation, CEC all fell within the acceptable range for cocoa production. The fertilizer computation based on the nutrient compositions of the soils indicated that Begiaba (Obudu) farm will require 41 kg P_2O_5/ha, and 188 kg K_2O/ha with no Nitrogen fertilizer, New Ndebiji (Akampka) farm will need 23 kgN/ha, 27 kgP_2O_5 and 211 kg K_2O/ha, Agbokim-waterfall (Etung) 41 kg P_2O_5/ha and 188 kgK_2O/ha, Yaunde (Ikom) will require 94 kg P_2O_5/ha and 272 kg K_2O/ha while Orimepang (Boki) requires 18 kgN/ha, 23 kgP_2O_5 and 13 K_2O/ha. Soil pH had high negative and significant ($p < 0.01$) correlation with soil available P in the various locations of study while the cocoa leaf N significantly correlated with leaf K ($p < 0.01$). Non-acid forming fertilizers particularly organic based will be appropriate to achieve optimum productivity.

Keywords: Cocoa; soil fertility; Cross River State; productivity; fertilizer.

1. INTRODUCTION

The cocoa industry was the dominant foreign exchange earner for Nigeria from the sixties through the mid-seventies during which the national production was over 307,000 metric tonnes of beans. Cocoa is the foremost contributor (0.3%) to Gross domestic products (GDP) among other agricultural export [1] In 1970, Nigeria was the second highest producer of cocoa with production of 304,000MT of cocoa beans [2]. The discovery and exploration of petroleum oil resulted into a shift from agrarian economy to almost total dependence on petroleum. This led to decline in cocoa production and yield. The need to diversify the economy and prevent overdependence on petroleum has brought back attention to cocoa production. Nevertheless, cocoa still remains a major export crop with revenue of at least 190 million US dollars annually from cocoa beans alone, besides revenue from cocoa by-product like butter, cake, liquor and powder [3]. Cocoa is the highest foreign exchange earner after petroleum with a contribution of 38.54% to GDP [1].

On a global scale, cocoa is grown successfully on different kinds of soils [4]. Wessel [5], observed that unsuitable soil conditions, particularly those of a physical nature, may not be amenable to improvement and may impose a limitation on cocoa production regardless of the quality of the planting material used or the level of husbandry employed. This implies that planting of cocoa on unsuitable soils will among other things leads to low productivity and poor economic returns. Cocoa is a tap-rooted plant and requires deep well-drained soils, free from iron concretions, high in nutrient content and topsoil rich in organic matter [5].

Cross River state is one of the foremost cocoa producing states in Nigeria. The Cross River State Government in its bid to increase cocoa production has identified training farmers on rehabilitation of cocoa farms and good agricultural practices such as pruning, grafting, fertilizer application just to mention a few, as ways of boosting cocoa production in Cross River state. Site selection is crucial as this ensures identification of farms on which these practices will be carried out. Hence, the objective of this study was to evaluate the fertility status of some cocoa farms in the five local Government Areas (LGAs) of Cross River State, Nigeria for rehabilitation purpose through appropriate fertilizer recommendation based on soil test values.

2. MATERIALS AND METHODS

Cross River State, one of the fourteen cocoa producing states in Nigeria, located between Latitudes 5°.45^{1}N, 8°.30^{1}E and Longitudes 5°.75^1 and 8°.50^{1}E (Fig. 1). It is located on the southeastern coastal rainforest belt of Nigeria bordering with Cameroon. The Cross River landscape descends precipitously from the Oban-Obudu rugged foothills (1000-2000 m) of the Cameroun mountains on the east, into the Cross River plains (30 m) to the west, and down to the Bright of Bonny coastal plains to the south. The annual rainfall in the state ranges from 1300 to 3000 mm. The mean annual temperature is 30°C prevail over the state except on the Obudu plateau where the climate is sub-temperate with temperature range between 15-23°C. The vegetation ranges from mangrove swamps, through rainforest to derived savanna and montane parkland [6].

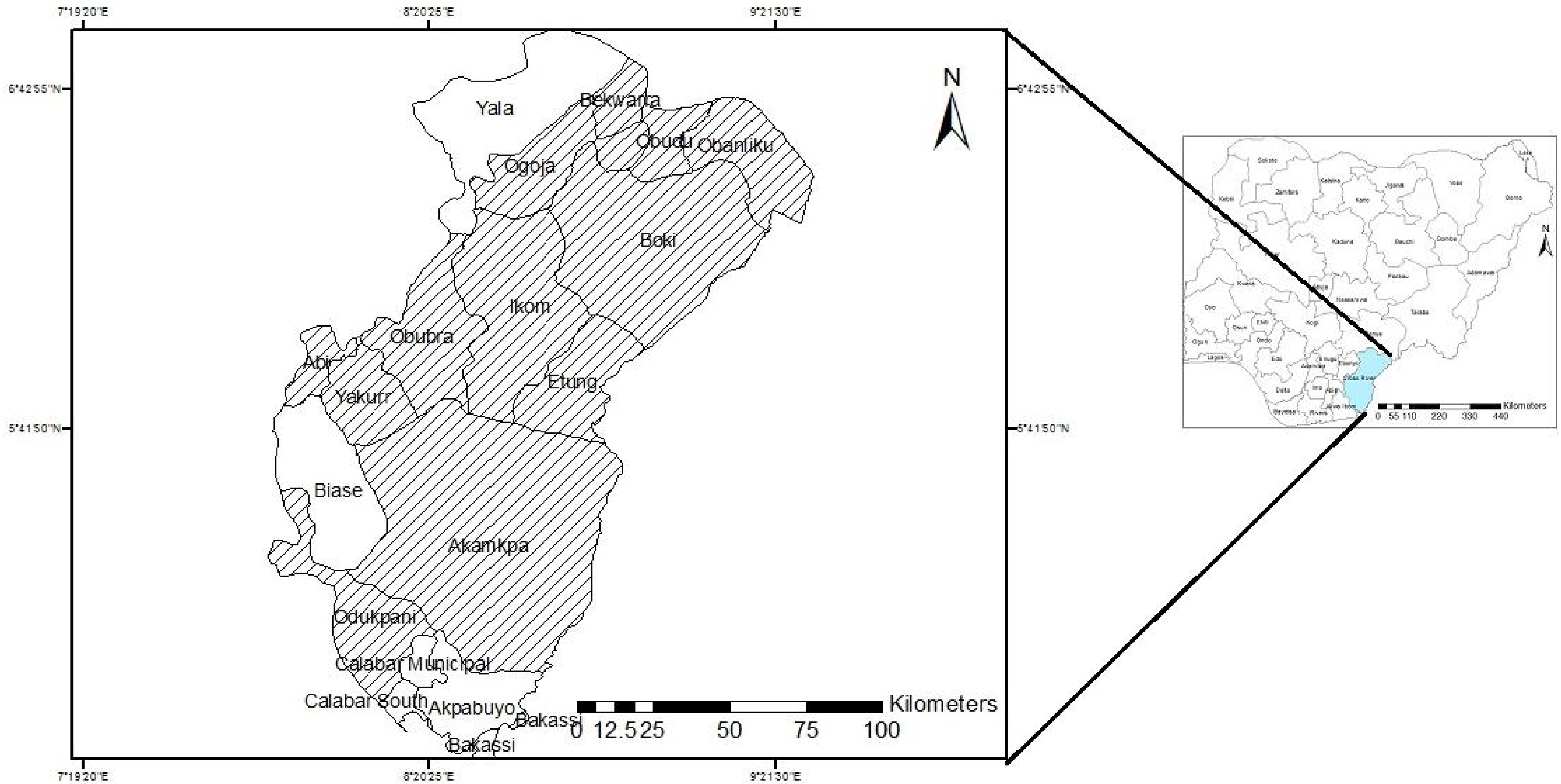

Fig. 1. Cocoa producing Local Government Areas of Cross River State, Nigeria

Cross River soils are predominantly five types. These are (i) the steep shallow yellowish and red gravelly soils on the Oban-Obudu, (ii) the deep lateritic fertile soils on the Cross River plain, (iii) the dark clayey basaltic soils on Ikom and (iv) the sandy heavily leached soils on the older coastal plain which are highly susceptible to gully erosion of the lower deltaic coastal plain that is usually floated during the rains. The state spans a total of 21,481 sq km which is equally divided into basement and sedimentary basins. The Oban-Obudu hills were formed from basement complex rocks (metamorphic and igneous rocks) [6].

2.1 Field Soil and Plant Sampling

Site selection was carried out in five local government areas of Ikom (Yaunde), Etung (Agbokim waterfall) and Boki (Orimekpang) which are high cocoa growing areas and Obudu (Begiaba) and Akankpa (New Ndebiji) which are medium cocoa growing areas (Fig. 1). The cocoa farms selected were over twenty years on the average but a few were below ten years old. In each local government, cocoa farms were visited for soil sampling. Each farm was divided into four blocks with eight sampling points and soil samples were collected at various depths of 0-15 cm, 15-30 cm and 30-45 cm at a distance of 20 m apart with the aid of soil auger. Soil samples at each of the sampling depths were bulked together to form composite samples. Similarly, leaf samples were taken from the tree under whose canopy the soil samples were taken. Soil samples were collected at a distance of 1 m from the base of cocoa tree trunk. The observations were selected in such a way that biased points like anthills and rocky spots were avoided and the soil samples collected were put in nylon bags and properly labeled. The sampled cocoa leaves were put in envelopes and labeled appropriately.

2.2 Laboratory Analysis

The soil samples were taken and the s soil samples collected were air-dried passed through 2 mm sieve and analyzed for particle size distribution was determined by Bouyoucos hydrometer method [7], pH was measured in 1:1 soil – water using the EDT BA 350 digital pH meter while the organic carbon was determined by the wet digestion dichromate acid oxidation method [8]. Total N was determined using the Kjeldahl digestion method and available P by Bray P1 method [9]. This involved the addition of 15 ml of 0.03 NHF and 25 ml of 14 ml of 0.5N HCl to 460 ml of water solution. Fourteen millilitres (14 mls) of the solution was added and shaken for 1 minute and filtered. Exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were extracted with 1N ammonium acetate (NH_4OAc) buffered at pH 7.0 exchangeable acidity was extracted with I N KCl and determined by titration with 0.05 N NaOH using phenolphthalein indicator [10] while the effective cation exchange capacity (ECEC) was by summation method and percent base saturation was calculated as:

% Base saturation =

$$\frac{\text{Exchangeable bases}}{\text{Total cation exchange capacity}} \times \frac{100}{1} \quad [11]$$

The leaf samples collected were washed with de-ionized water, oven dried, milled and analyzed for N, P, K, Ca, Mg, Na, Fe, Cu and Zn following the procedures as outlined by [11]. The fertilizer recommendations were based on the chemical properties of the top soil (0-30 cm) taking into consideration that both lateral and creeping roots are housed at this soil depth. Correlation analysis was carried out to determine the relationship among some soil nutrient compositions and cocoa leaf nutrient compositions at 1% level of significance.

3. RESULTS AND DISCUSSION

3.1 Obudu Local Government (Begiaba)

Sand fraction of Begiaba cocoa farm ranged from 588 – 608 gkg^{-1} with a mean value of 594.7 gkg^{-1}soil. Silt values were from 225.6 to 295.6 gkg^{-1} soil with a mean value of 255.6 gkg^{-1} soil, with silt quantity increasing with increasing soil depth. Silt content in the 0 – 30 cm top soil was 235.6 gkg^{-1}. Clay content ranged from 116.4 to 166.4 gkg^{-1} soil with a mean value of 149.7 gkg^{-1} (Table 1). Values of clay content at 0 – 15 cm and 15 – 30 cm were similar. Further increase in soil depth to 30 – 45 cm, witnessed decreased in clay content. The clay content in the soil is sufficient to retain water during the dry season. Silt and clay content was adequate for cocoa production as this falls within the recommended value to the silt and clay content of 350 – 500 gkg^{-1}. The textural class of the soil is sandy loam.

Soil pH of the area ranged from 5.41 - 5.55 with a mean value of 5.49. At the 0 – 30 cm soil depth mean pH was 5.47. The soil of this area is acidic but however falls within the pH ranged suitable for cocoa cultivation; hence there could be no deleterious effect on root development of cocoa. Organic carbon in the soil was 18.9 – 20.3 gkg^{-1}. This is adequate for cocoa production [12].

Total N content of 0 – 45 cm soil depth ranged from 0.84 – 1.54 gkg-^{1} with a mean value of 1.17 g/kg. Total N content decreased with increasing soil depth with the top 30 cm soil depth having a mean total nitrogen content of 1.34 gkg-^{1}. This is adequate for cocoa production, as this value is above the soil critical level of 0.9 gkg-^{1} according to [13] and [14]. However, organic fertilizer can be applied to sustain the nitrogen level of the soil.

Soil available phosphorous values across the various soil depths ranged from 0.53 – 1.60 mgkg-^{1} with a mean value of 0.97 gkg-^{1}. The top 30 cm soil depth had a mean phosphorous value of 1.07 mgkg-^{1} soil P. This is highly inadequate for cocoa production, as it is well below the critical value of 10 mg/kg required for cocoa production. This was corroborated by plant leaf P of 0.09% content which was low (Table 2), this is well below the 0.2% required for cocoa production [13]. Phosphorous is required for fruiting and enhancing bean quality. Deficiency of phosphorous therefore leads to lower cocoa bean quality and yield. There is therefore need for application of phosphorous fertilizer particularly non-acidifying phosphorous fertilizer such as Sokoto rock phosphate.

Exchangeable potassium soil value ranged from 0.08 – 0.1 cmol/kg soil across the various soil depths with a mean value of 0.09 cmolkg-^{1}. Potassium values at the 0 – 15 cm and 15 – 30 cm soil depth was similar, while potassium content decreased with increasing soil depth from 30-45 cm. Potassium was inadequate at all levels as it was well below the 0.3cmolkg-^{1} soil required for cocoa. Similarly leaf K content of 1.44% cocoa was also low (Table 2). This is below the 2.0% required for cocoa production. Calcium content in the soil was also low with a range of 0.25 – 0.77 cmolkg-^{1} soil with mean value of 0.38 cmolkg-^{1}soil. This is also well below the soil critical level of 5 cmol/kg soil required for cocoa. Similarly, leaf Ca content 0.18% was below 0.65% required by cocoa. This could explain the reason for the relatively low pH value of 5.47. Addition of fertilizer such as Sokoto rock phosphate would in addition to supplying phosphorous supply needed calcium to the soil.

Magnesium content of the soil is also low with values of 0.33 – 0.45 cmol/kg soil with a mean value of 0.41 cmolkg-^{1}soil. The top 30 cm soil had a mean magnesium content of 0.39 cmolkg-^{1}. Similarly, foliar Mg content was 0.46% which was below critical foliar level of 0.5% (Table 2). The magnesium in the soil is inadequate to meet the magnesium requirement of cocoa which has a soil critical level of 0.8 cmolkg-^{1} soil. This was reflected in the low Mg content of the cocoa leaf (0.46%) which was below the foliar critical level of 0.5%. The use of Sokoto rock phosphate fertilizer will also help to supply sufficient magnesium to the soil. Copper level in the soil ranged between 1.18 – 1.21 gkg-^{1}soil with a mean value of 1.19. CEC and base saturation were 0.76 cmolkg-^{1} soil and 78% respectively. These are within the acceptable level for cocoa cultivation [15]. The fertilizer calculation is based on the mean values of N, P and K at 0 – 30 cm soil depth. For N with mean value of 1.33 gkg-^{1} soil and the critical soil N value for cocoa is 0.9 mg/kg soil. The value obtained from the soil analysis is above this critical level. This implies that the soil in this farm location is not deficient in N. Hence, there is no need for N supplementation. The P mean value at 0-30 cm was 1.06 and the P critical level for cocoa is 10 ppm. The level of deficiency value is 8.935 ppm P kg-^{1} soil which was multiplied by 2 to get 17.87 kg Pha-^{1}which is equivalent to 41 kg P_2O_5ha-^{1}. The mean K value at 0-30 cm was 39.8 ppm which is equivalent to 0.10 cmolkg-^{1} soil and the critical value for cocoa soil is 0.3 cmolkg-^{1} soil, the deficiency of 0.20 cmolkg-^{1}soil was obtained and can be supplied by 187.7 kg $K_2$0ha-^{1} (Table 3).

3.2 Akamkpa Local Government (New Ndebiji)

At New Ndebiji cocoa farm location, the sand content of the soil ranged from 648 – 688 gkg-^{1} with a mean value of 674.3 gkg-^{1} sand and the with sand content decrease with increasing soil depth. Silt content was 65.6 gkg-^{1} across the various soil depths, while clay content ranged from 246.4 - 286.4 gkg-^{1} with a mean value of 214.17 gkg-^{1} clay (Table 1). The clay content in the soil is sufficient to retain water during the dry season with sandy clay loam soil texture. Soil pH increased with increasing soil depth. Mean soil pH across the top 30cm soil depth was 4.42. The soil pH is low, hence the soil is acidic according to Mossu (1992), this situation may cause main nutrient element such as phosphorus to become less usable by cocoa, whereas the trace elements, such as iron, manganese, copper and zinc, may sometimes reach toxic levels. Hence, the need for a fertilizer with liming effect.

The total N content of the soil ranged from 0.47 to 0.81 gkg-^{1} with a mean value of 0.59 gkg-^{1}. Nitrogen decreased with increasing soil depth.

Total N value is low for cocoa production as it is below the soil critical N value of 0.9 gkg^{-1} soil [16,17]. There is therefore need for application of a non-acidifying nitrogen fertilizer.

Available phosphorous content of the soil was also low ranging from 1.60 – 8.27 $mgkg^{-1}$, within 0 – 15 cm soil depth having the highest P content and 15 – 30 cm soil depth having the lowest phosphorous content. The mean phosphorous value of the soil was 5.5 mg/kg with mean phosphorous content at the top 0 – 30 cm being 4.13 $mgkg^{-1}$. Phosphorous is inadequate at all levels as it is below the soil critical level of 10 $mgkg^{-1}$soil required for cocoa production. This is reflected in the low leaf P content of the cocoa leaf 0.1% (Table 2) which is below the 0.2% required for cocoa production. The low phosphorous content could also be associated with the low pH which makes phosphorous mostly unavailable. Phosphorous fertilizer with liming effect is therefore essential.

Potassium content of the soil ranged from 0.06 – 0.08 $cmolkg^{-1}$ soil with a mean value of 0.07 cmol/kg. This was below the critical level of 0.3 $cmolkg^{-1}$ soil required for cocoa. This is reflected in the low K content of the cocoa leaf 0.06% (Table 2) which is well below the foliar critical level of 2%. There is therefore need for application of potassium fertilizer. Calcium content in 0 – 45 cm soil depth ranged between 0.16 – 0.19 $cmolkg^{-1}$ with a mean value of 0.18 $cmolkg^{-1}$ this was also well below the soil critical level of 5 cmol/kg required for cocoa. Similar trend was observed in leaf Ca content of 0.06% which was well below the required 0.6% as this may account for the low soil pH of the soil. There is therefore need to add fertilizer such as Sokoto rock phosphate which will increase soil pH.

Magnesium content of the soil ranged from 0.21 – 4.2 $cmolkg^{-1}$ with a mean Mg content of 0.29 $cmolkg^{-1}$. Magnesium content decreased with increasing soil depth. Magnesium content was also below the 0.8 cmol/kg required by cocoa. Similar trend was observed in leaf Mg content of 0.42% which was below the required 0.5%. There is need to apply fertilizer which contains Magnesium which will increase Magnesium content of the soil. Copper content of the soil is low with a range of 1.64 – 1.67 gkg^{-1}. This was below soil toxic level for copper. Base saturation ranged between 79.69 – 95.56% with a mean value of 88.24%. This is sufficient for cocoa production. The following fertilizer recommendations were made based on the soil analytical results of the mean values at 0-30 cm as described above in which New Ndebiji (Akampka) farm will need 23 $kgNha^{-1}$, 27 kgP_2O_5 and 211 K_2Oha^{-1} (Table 3).

3.3 Etung Local Government (Agbokim Waterfall)

The mean sand, silt and clay fractions of the soil were 518, 261 and 216 gkg^{-1} soil respectively with a sandy loam texture at Agbokim waterfall (Table 1). The silt + clay content is adequate for good cocoa production particularly during the dry season [13]. Similarly, the mean organic carbon content was 22.20 gkg^{-1} soil. The soil pH of 4.78 is relatively low. This implies that acid-forming fertilizers are not encouraged to be applied in this soil. However, the level of total nitrogen was 1.33 g/kg soil at 0-30 cm soil depth which is above the critical level required for cocoa cultivation. Hence, there may be no need for N-fertilizer application as the level is more than sufficient for good cocoa production.

However, the level of available P was extremely low with a value of 3.55 mg P kg^{-1} soil. This was collaborated by the leaf P content of 0.08% which is below the foliar critical P level of 0.2% (Table 2). The low level of available P could be linked to low soil pH value. P is often the soil to be adequately supplied with P and be made available to cocoa, while the soil pH must be corrected for adequate P release to take place in the soil.

The soil exchangeable Potassium (K) was also low with a mean value of 0.03 cmol/kg soil, the leaf K content was 0.66%. This could be due to fixation and crop removal through the pods over the years. Hence, there is need for external addition to enable the soil meet the required amount of K for the cocoa plant. The mean values for Calcium (Ca) and Magnesium (Mg) were 0.98 and 0.44 $cmolkg^{-1}$soil respectively which are relatively low but the Ca/Mg ratio falls within the acceptable limit [18]. Hence, the soil remains productive as there is no evidence of nutrient imbalance in the soil system. The mean values of the soil micro nutrients were 0.88, 15.46, 0.78 and 1.84 $mgkg^{-1}$ soil for Manganese, Iron, Zinc and Copper respectively. The level of their concentration is suitable for cocoa production. The base saturation and CEC of the soil were 85% and 0.58 $cmolkg^{-1}$ soil respectively which falls within the required range for cocoa production in most producing regions in West Africa. The N value for 0.30 cm was 1.33 g Nkg^{-1} soil is above the critical level of 0.9 $gNkg^{-1}$

soil. This implies that the soil is not deficient in N which indicated that there is no need for N supplication. However maintenance amount through organic fertilizer could be employed. This farm location will require 41 kg P_2O_5ha-^{1} and 188 kg K_2Oha-^{1} respectively (Table 3) for sustainable cocoa production.

3.4 Ikom Local Government (Yaunde)

The sand, silt and clay fractions of the soil at (Yaunde) were 588, 246 and 166 gkg-^{1} soil respectively at 0-30 cm depth with sandy loam texture. The soil is sandy loam. The clay level is sufficient to retain water during the dry season. The organic carbon fraction was 17 gkg-^{1} soil, which is moderate due to litter fall within the plantation through which nutrients are recycled on annual basis. The pH is low with a mean value of 4.93 suggesting that some nutrients will not be available for plant use, particularly phosphorus and basic macro nutrients.

The total N at 0-30 cm was 1.33 gkg-^{1} soil which is similar to what was obtained at Agbokim waterfall area. There is no need for N-fertilizer application. However, the available P has an average value of 3.04 mgkg-^{1} soil which is considered very low. This is reflected in the low P content 0.06% of the cocoa leaf (Table 2) which is well below the foliar critical level of 0.2% required for cocoa [13]. This implies that there is need for P-fertilizer application to supply adequate P in the soil for plant use.

In the same vein, the exchangeable Potassium (K) was very low (0.0075 cmolkg-^{1} soil) and there will be need for addition through fertilizer application. This value is very low compared to the critical level required for cocoa which is 0.3 cmolKkg-^{1} soil. Similar trend was observed in leaf K content of 0.43% which was well below the foliar critical K of 2.0% required by cocoa. The reason for this is similar to the one stated earlier for Etung area. The mean value of basic cations of Calcium and Magnesium were 0.24 and 0.50 cmol/kg soil respectively. Similarly, mean leaf Ca and Mg were 0.33% and 0.93% respectively (Table 2). The values are low for good cocoa cultivation and the use of Sokoto rock phosphate (SRP) as P source will adequately cater for the low values of Mg and Ca expressed.

The micronutrients in the soil had the mean values of 0.55, 14.81, 0.04 and 1.93 mgkg-^{1} soil for Manganese, Iron, Zinc and Copper respectively. The level of their concentration may not be toxic to cocoa due to the organic matter in the soil. The base saturation and CEC of the soil were 88% and 0.29 cmolkg-^{1} soil respectively. The values were within the acceptable level for cocoa cultivation [16]. However, the Yaunde (Ikom) soils would require 94 kg P_2O_5ha-^{1} and 272 kg K_2Oha-^{1} respectively for optimum cocoa productivity (Table 3).

3.5 Boki Local Government (Orimekpang)

The mean sand, silt and clay fractions were 688, 96 and 216 gkg-^{1} soil at 0-30 cm depth respectively with sandy loam texture. The silt + clay content will retain sufficient water that will sustain cocoa particularly during the dry season. The organic carbon was 12.6 gkg-^{1} soil which can be considered moderate. However, the pH value of 4.50 is relatively low for good cocoa production. This may predispose the soil to fixation of vital soil nutrients particularly the basic cations. Liming may be necessary complement the organic matter in the soil to correct the low pH value of the soil.

The total N in the soil was 0.71 gkg-^{1} soil at 0-30 cm which is below the critical N value for cocoa this suggest the need for N-fertilizer application. Similarly, the available P and exchangeable K had the mean values of 4.87 mgkg-^{1} soil and 0.04 cmolkg-^{1} soil respectively. Both are critically deficient because they fall below the critical values of 10 mg/kg soil and 0.3 cmol/kg soil respectively [19,14]. Similar trend was observed in leaf P and K content of 0.02% and 1.08% respectively (Table 2), these values were below the foliar critical levels required for cocoa. External addition of P and K-fertilizers will be very necessary to meet the soil requirement for good cocoa cultivation at Orimekpang.

Soil Ca and Mg were low with mean values of 0.14 cmolkg-^{1} soil and 0.43 cmol/kg soil respectively. Foliar Ca and Mg content were low with values of 0.15% and 0.47% respectively. The micro-nutrients across the soil depths averaged 13.09, 15.23, 0.01 and 1.88 mgkg-^{1} soil for Mn, Fe, Zn and Cu respectively. The base saturation and the CEC of the soil were 70% and 0.29 cmol/kg soil respectively. The values are suitable for cocoa production [20]. The mean N at 0-30 cm was 0.71 gkg-^{1} soil which was below the critical value by 0.19 g/kg soil is equivalent to 190 ppm. This value is multiplied by 2 to obtain 380kg Nha-^{1}. In Orimepang (Boki), 380 kgNha-^{1}, 23 kgP_2O_5 and 13 K_2Oha-^{1} will be required for optimum productivity in the farm location (Table 3).

Table 1. Physical and chemical characteristics of soil of cocoa farms in five cocoa growing LGA of Cross River State

Location	Soil depth	Soil physical characteristics				Soil Chemical characteristics													
		Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Organiccarbon (g/kg)	pH	Total N (g/kg)	Avail. P (mg/kg)	Exch. K^+ cmol/kg	Exch. Ca^{2+} cmol/kg	Exch. Mg^{2+} cmol/kg	Mn^{2+} (mg/kg)	Fe^{3+} (mg/kg)	Zn^{2+} (mg/kg)	Cu^{2+} (mg/kg)	H^+	Al^{3+}	CEC cmol/kg	BS%
Obudu:	0-15	608.0	225.6	166.4	24.1	5.52	1.54	0.53	0.10	0.25	0.33	11.27	14.75	0.06	1.18	0.034	0.00	0.71	95.78
Begiaba	15-30	588.0	245.6	166.4	18.9	5.55	1.13	1.60	0.10	0.33	0.45	12.80	14.90	0.06	1.18	0.024	0.00	0.90	97.78
	30-45	588.0	295.6	116.4	17.8	5.41	0.84	0.80	0.08	0.77	0.45	7.31	15.11	0.005	1.21	0.160	0.00	1.46	89.04
	Mean	594.7	255.6	149.7	20.3	5.49	1.17	0.97	0.09	0.38	0.41	10.46	14.75	0.042	1.19			1.02	94.20
AkpampaNew	0-15	688.0	656.0	246.4	11.4	4.30	0.81	6.67	0.08	0.18	0.42	6.61	15.12	0.045	1.67	0.080	0.00	0.76	89.47
Ndebiji	15-30	688.0	656.0	246.4	10.6	4.39	0.48	1.60	0.07	0.19	0.25	4.33	15.36	ND	1.64	0.128	0.01	0.64	79.69
	30-45	648.0	656.0	286.4	8.2	4.45	0.47	8.27	0.06	0.16	0.21	2.78	15.42	0.005	1.72	0.024	0.00	0.45	95.56
	Mean	674.7	656.0	149.7	10.1	4.38	0.59	5.51	0.07	0.18	0.29	4.57	15.30		1.68				
Etung:	0-15	548.0	265.6	186.4	33.8	4.77	1.63	5.20	0.03	0.92	0.44	1.25	15.61	1.50	1.85	0.036	0.00	0.50	92.0
Agbokim	15-30	488.0	255.6	246.4	10.6	4.79	1.04	1.87	0.03	1.04	0.45	0.52	15.31	0.06	1.83	0.146	0.04	0.66	77.27
waterfall	30-45	408.0	285.6	306.4	13.9	4.63	0.97	2.40	0.03	0.64	0.44	0.42	15.09	0.075	1.85	0.044	0.00	0.38	89.47
	Mean	481.3	268.9	246.4	19.4	4.73	1.21	3.16	0.03	0.87	0.44	0.73	15.33	0.55	1.84			0.51	86.25
Ikom: Yaunde	0-15	528.0	305.6	166.4	19.6	5.15	1.65	1.96	0.005	0.29	0.44	0.04	14.90	0.045	2.01	0.022	0.00	0.27	95.59
	15-30	648.0	185.6	166.4	14.3	4.72	1.01	4.13	0.01	0.19	0.56	1.06	14.72	0.045	1.85	0.060	0.01	0.31	80.65
	30-45	468.0	285.6	246.4	12.6	4.77	0.73	4.13	0.01	0.10	0.56	2.29	14.94	0.04	1.77	0.034	0.00	0.38	88
	Mean	548.0	258.9	193.0	15	4.88	1.10	3.40	0.009	0.19	0.52	1.13	14.85	0.04	1.88			0.28	88.08
Boki:	0-15	688.0	856.0	226.4	12.6	4.32	0.66	6.67	0.02	0.12	0.49	10.54	15.07	0.04	1.96	0.166	0.03	0.38	55.26
Orimekpang	15-30	688.0	105.6	206.4	12.6	4.69	0.76	3.07	0.008	0.08	0.41	15.64	15.20	0.005	1.81	0.034	0.00	0.20	85.0
	30-45	648.0	105.6	246.4	10.2	4.52	0.72	3.53	0.009	0.23	0.39	6.22	15.26	0.105	1.85	0.072	0.00	0.28	75.0
	Mean	674.7	989.0	226.4	11.8	4.51	0.71	4.42	0.01	0.14	0.43	10.81	15.17		1.87			0.29	71.75

Table 2. Cocoa leaf nutrient concentration (kg ha^{-1}) in the selected farms of five local government area of Cross River State

Location	N	P	K	Ca	Mg	Na	Mn	Fe	Cu	Zn
Ikom	7.50	0.60	4.30	3.30	9.30	5.30	0.08	0.02	0.05	0.09
Boki	11.6	0.20	10.80	1.50	4.70	13.00	0.03	0.02	0.02	0.06
Obudu	13.10	0.90	14.40	1.80	4.60	17.80	0.03	0.02	0.01	0.06
Etung	8.80	0.80	6.60	1.70	7.40	7.50	0.07	0.02	0.03	0.06
Akampka	12.40	1.00	15.10	0.08	4.20	16.60	0.07	0.02	0.01	0.01

Table 3. Fertilizer recommendation/application rates for the farm locations assessed

Location	N	P	K	Remarks
Obudu: Begiaba	- Organic fertilizer may be applied	41 kg P_2O_5ha-^{1} =120 g of SRP/tree	188 kg K_2Oha-^{1}=300 g of MOP/tree	Fertilizer required only for elements of P and K
Akampka: New Ndebiji	- 23 kg Nha-^{1}= 48 g of Urea /tree	27 kg P_2O_5ha-^{1} =78 g of SRP/tree	211 kg K_2Oha-^{1}=338 g of MOP/tree	Fertilizer required for N, P and K
Etung: Agbokim-water fall	- Organic fertilizer may be applied	41 kg P_2O_5ha-^{1} =120 g of SRP/tree	188 kg K_2Oha-^{1}=300 g of MOP/tree	Fertilizer required only for elements of P and K
Ikom: Yaunde	- Organic fertilizer may be applied	94 kg P_2O_5ha-^{1} =90 g of SRP/tree	272 kg K_2O/ha-^{1}=440 g of MOP/tree	Fertilizer required only for elements of P and K
Boki: Orimepang	18 kg Nha-^{1}= 39 g of Urea/tree	23 kg P_2O_5ha-^{1} =68 g of SRP/tree	13 kg K_2Oha-^{1}=21 g of MOP/tree	Fertilizer required for N, P and K

SRP- Sokoto Rock phosphate, MOP- Muriate of potash

Table 4. Relationship among soil nutrients and cocoa leaf nutrient compositions

	pH	Soil N	Soil P	Soil K	Base Saturation	Nl	Pl
pH							
N	0.743						
P	-.972**	-0.832					
K	0.460	0.006	-0.356				
BS	0.644	0.530	-0.550	0.683			
Nl	0.134	-0.462	-0.053	0.739	0.030		
Pl	0.260	0.186	-0.181	0.783	0.862	0.219	
Kl	0.054	-0.519	0.050	0.801	0.132	.977**	0.374

***. Correlation is significant at the 0.01 level (2-tailed), Nl= leaf N, Pl= leaf P, Kl= leaf K*

3.6 Relationship among Soil Nutrients and Cocoa Leaf Nutrient Compositions

Relationship among soil nutrients and cocoa leaf nutrients indicated that there was a high positive correlation between soil pH and total soil N (Table 4). Similarly, the correlation between soil pH and base saturation was high. However, the soil pH had high negative correlation with soil available P. This implies that increasing soil acidity will lead to fixation of available P as previously reported by Isirimah [11]. Soil total N negatively correlated with soil available P, cocoa leaf N and K. The soil available P negatively correlated with soil available K, base saturation, cocoa leaf N and P in the various locations of study. The soil exchangeable K was positively correlated with base saturation, cocoa leaf N, P and K. Base saturation positively correlated with cocoa leaf P and K. Similarly, cocoa leaf N significantly correlated with leaf K ($p<0.01$) in the various locations of study.

4. CONCLUSION

In the five Local Government Areas evaluated, nitrogen was deficient in the cocoa farms at New Ndebiji and Orimekpang in Akampa and Boki Local Government Areas of the State. Hence, nitrogen fertilizer is therefore needed for optimum production. Moderate use of Urea with organic fertilizers is recommended as reflected above will be appropriate. Phosphorus was deficient in all the cocoa farms evaluated. Phosphorus fertilizer is needed to enhance productivity and Sokoto rock phosphate is recommended because of its CaO and MgO content. This will help to manage pH of the soil. Potassium was also deficient in all the cocoa farms evaluated. Potassium fertilizer is also required to enhance productivity. The low pH of the soils in the five LGs is a factor to be managed with non-acid forming fertilizers particularly organic based ones.

ACKNOWLEDGEMENTS

The authors wish to appreciate the technical assistance of the following staff of Soils and Plant nutrition Section of Cocoa Research Institute of Nigeria, Ibadan in persons of Ojewale O.J, Adebayo J.O, and Falusi E.L. We are equally grateful to the Management of Cocoa Research Institute of Nigeria for granting us the permission to travel to Cross River State for the work. The Authors appreciate Cross River State Commercial Agricultural Development Project (CADP) for providing the fund for this study.

DISCLAIMER

Some part of this manuscript was previously presented and published in the following conference.

Conference name: Regional Cocoa Symposium next Generation of Cocoa Research for West and Central Africa.
Date: 8-10th November 2016
Location: International Institute of Tropical Agriculture, Ibadan.
Web Link of the proceeding:
http://www.worldcocoafoundation.org/wp-content/uploads/files_mf/1478631672ProgramandBookofAbstractsRegionalSymposiumIbadan.pdf

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. N.E.P.C. National Export Promotions Council Annual Report. FAOSTAT; 2011. Available:www.faostat.fao.org/site/567
2. Akinwale O. Prospects and challenges in local production of cocoa as raw materials in Nigeria. Cocoa Mirror. 2006;1:9-11.
3. Smyth AJ. The selection of soils for cocoa, soils. Bulletin No 5, Rome, FAO; 1966.
4. Opeke LK. Tropical tree crops spectrum books Ltd. Pub. Woye and Sons Nigeria Ltd Ilorin. 2005;327.
5. Wessel M. Fertilizer requirements of cocoa (*Theobroma cacao* L) ion South-western Communication 61, London: Department of Agriculture and Natural Resources, Royal Trop Institute; 1971.
6. Cross River State Physical Setting. Available:www.online Nigeria.com/Cross River-State (Accessed online on 10th October 2017)
7. Bouyoucous GJ. Hydrometer methods improved for making particle size analysis of soils. Agronomy Journal. 1951;54:465.
8. Olsen SR, Sommers LE. Phosphorus. In: Page, A.L. et al (eds.), Ibid. 1982;403-430.
9. Bray RH, Kurtz LT. Determination of total, organic and available form of phosphorus in soils. Soil Science. 1945;59:45-59.
10. McLean EO. Aluminium. In Black, C.A. (ed). Methods of Soil analysis in Agronomy 9, ASA Madison Wisconsin. 1982;978-998.
11. Isirimah NO, Dickson AA, Ikpe FN. Introductory soil chemistry and biolology for agriculture and biotechnology. Osita Int. L Publishers Ltd. 2010;270.
12. International Institute of Tropical Agriculture. IITA. Laboratory Manual 2nd Edition 70; 1982.
13. Wessel M. The soils of Gambari Experi-mental station, CRIN Annual Report; 1966.
14. Egbe NE, Ayodele EA, Obatolu CR. Soils nutrition cacao, coffee, kola, cashew and tea. Progress in tree Crops Research, Eds., Olunloyo, A.O and E.B Esan., Cocoa Research Institute of Nigeria Printing Press, Ibadan. 1989;8-38.
15. Ibiremo OS, Ipinmoroti RR, Ogunlade MO, Daniel MA, Iremiren GO. Assessment of soil fertility for cocoa production in Kwara State: Southern Guinea Savanna Zone of Nigeria. J. Agric. Sci. 2010;1(1):11-18.
16. Mossu G. Cocoa CTA Publication. The Tropical Agriculturist Ed. Rene Coste. 1992;24–26.
17. Wood GAR, Lass RA. Cocoa, 4th Edition, London: Longman. 1989;620-632.
18. Ibiremo OS, Daniel MA, Iremiren GO, Fagbola O. Soil fertility evaluation for cocoa production in Southeastern

Adamawa State, Nigeria. World Journal of Agricultural Sciences 2011;7(2):218-223.
19. Hardy F. Cacao soils. Proc. Soil Crop Science Soc Florida. 1958;18.
20. Egbe NE, Omotosho TI. Nutrition of cocoa in Nigeria. Annual Reports of Cocoa Research Institute of Nigeria (CRIN), Ibadan; 1971.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/22241