International Journal of Plant & Soil Science
11(6): 1-10, 2016; Article no.IJPSS.27037
ISSN: 2320-7035

SCIENCEDOMAIN *international*
www.sciencedomain.org

Soil Physical and Chemical Properties of Cacao Farms in the South Western Region of Cameroon

Nkengafac Jetro Njukeng[1*] and Virupax C. Baligar[2]

[1]Institute of Agricultural Research for Development (IRAD), Ekona Regional Research Centre, PMB 25 – Buea, SW Region, Cameroon.
[2]USDA –ARS- Beltsville Agricultural Research Center, Beltsville, Maryland, USA.

Authors' contributions

This work was carried out in collaboration between both authors. Author NJN collected the samples and determined chemical analysis. Author VCB was involved in discussion of experimental setup and assisted in the write up. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/27037
Editor(s):
(1) Bin Gao, Department of Agricultural & Biological Engineering, University of Florida, USA.
Reviewers:
(1) Mercy Ijenyo, University of Ibdan, Nigeria.
(2) Raimundo Jimenez Ballesta, Universidad Autónoma de Madrid, Madrid, Spain.
Complete Peer review History: http://sciencedomain.org/review-history/15145

Original Research Article

Received 16th May 2016
Accepted 20th June 2016
Published 24th June 2016

ABSTRACT

Aims: To evaluate important physical (texture) and chemical [(pH, N, C content, exchangeable bases (K, Ca, Mg), exchangeable Al, CEC and % BS] properties of major cacao (*Theobroma cacao* L) growing soils of the South Western Region of Cameroon.
Place and Duration of Study: Cocao farms in the South West Region of Cameroon and the Institute of Agricultural Research For Development (IRAD) Ekona, Soil and Plant Analytical Laboratory from March to December 2013.
Methodology: Soil samples were collected from cacao plantations in the humid forest zone of South West Cameroon. Locations were referenced using a GPS (Model Garmin 600). Seventeen matured farms which ranged in size from 2 to 5 ha were selected for this study. Composite soil samples were collected using soil auger at 0-30 cm depth. These soils were analyzed for particle size, pH and exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+). The organic carbon, Total Nitrogen, Cation Exchange Capacity (CEC), Effective Cation Exchange Capacity (ECEC), %BS, and %Al saturation were also determined.
Results: The soils of the studied sites were slightly acidic, with pH (H_2O) range of 4.58-6.46. The

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

soils were clayey in texture, ranging in clay content from 19.79 to 77.04% and sand content from 4.25 to 64.42%. The total nitrogen levels for all the studied sites ranged between 0.11 and 0.82% with an average of 0.30%. Soil organic carbon levels were quite good for crop production (1.02 – 7.75 %). The exchangeable potassium and magnesium levels ranged between 0.11–0.67 cmol/kg and 0.31–2.41 cmol/kg respectively. The exchangeable calcium levels in these soils ranged from 1.11–18.00 cmol/kg while available phosphorus levels ranged between 0.01-26.00. mg/kg.

Conclusion: The soils evaluated were generally adequate in required nutrients but could become deficient in nutrient content in the near future especially as there is no fertilizer application being practiced and further increase in yields might deplete the essential nutrients and such a situation could lead to soil infertility in this region. Therefore it is essential to formulate and follow best nutrient management strategies for this cacao growing region to maintain adequate soil nutrient status for sustainable cacao bean production.

Keywords: Cacao; soil; soil organic matter; macro nutrients.

1. INTRODUCTION

Cacao (*Theobroma cacao* L) is a major cash crop for Cameroon, contributing substantially to the national economy in terms of employment and foreign exchange earnings. Cameroon is the fifth largest producer of cacao in the world [1,2] and smallholders are the main producers of cacao beans. Although a considerable number of farmers continue to plant young cacao trees, a greater part of the area is under old trees in major cacao growing regions. Generally, soils under old cacao plantations are depleted in nutrients as a result of continuous crop harvest without fertilizer application [3]. The low soil fertility under cacao is one of the major causes for the poor cacao yields [4,5]. Soils under the cacao plantation have been degraded and exhausted in many of the essential nutrients due to natural processes, acidification, loss of nutrients through erosion and leaching, many years of poor management, broad spaced planting, lack of inclusion of cover crops in early stages of crop establishment, and low or non-usage of manures, fertilizers and amendments [4-6]. Ideal soils for best cacao performance should have pH of 6.0 to 7.5, CEC of 12 me/100g, % base saturation of 35%, organic matter of 3.5%, available P of 40 µg/g and Ca of 8, Mg of 2 and K of 0.24 all in me/100 g and C/N ratio of not less than 9 [4,7,8]. Hardy in 1960 [7] further suggested that ratios of bases such as Ca:Mg not more than 4, and (Ca +Mg):K not less than 25 are good soils for cacao.

Cacao plants require adequate supply of N, P, K, Ca and Mg for optimal growth and deficiency of these reduce yields. P is the major limiting nutrient in almost all the soils under cacao, mainly due to its low content in soil and greater fixation of applied P by these soils. In West African soils P availability is associated with pH, Fe, Clay and organic C, where as in Brazilian soils dominant P controlling factor is the high amount of soil exchangeable Al [9]. According to Wessel, 1971 [10] there is a steady decline in almost all essential soil nutrients with length of cultivation. Compared to other tropical perennial crops, cacao has higher nutrient requirements [11]. On an average, 1000 kg of cacao beans contains about 30 kg of N, 4 kg of P, 33 kg of K, 9 kg of Ca and 6 kg of Mg [12]. Omotoso, 1975 [13] earlier reported that amelonado and amazon cacao dry bean of 1000 kg removed about 20 kg N, 41 kg P and 10 kg K from the soil. In West Africa and Brazil cacao is widely grown on soils with either neutral pH or slightly acidic infertile soils [3,4,5,14,15]. Soils under cacao have become acidic and infertile due to long term cultivation, bad management practices, lack of proper levels of fertilizer and lime additions and loss of nutrients through erosion and leaching. Although essential nutrient deficiency is a major problem in acid mineral soils (pH below 5.2), aluminum toxicity is also a major constraint for cacao productivity in tropical soils [16-20]. Although, there is some information available on growth and nutrition of cacao in controlled conditions [19-22] the information is limited on influence of soil Al on cacao growth, development and yield potentials in field under different management systems. For improved cacao productivity it is worthwhile to carry out fertilizer application studies on the soils of cacao farms in order to know their present nutrient status and plan for fertilization and other nutrient management strategies for improved cacao bean yields.

Cacao farmers are often not provided with adequate information by extension services on fertilization and there is also scarcity of needed fertilizers. In addition, on average cacao bean yields/ha in Cameroon are low, due to many factors, including labor shortages, low levels of farm maintenance (e.g. pruning, shade control, in adequate spraying of pest control chemicals and weeding) and lack of appropriate agronomic knowledge. Most of the cacao farms in the studied area have never been fertilized thus, the possibility of nutrition-related limitations to productivity is wide spread.

Therefore development of research on the most appropriate and effective soil fertilization and management practices is very relevant to promote sustainable crop yields [23]. Hartemink, 2003 [6] states that soil fertility decline can be serious under plantation cropping which will sooner or later affect production and thus reduce the income of farmers. The main objective of the current research was to evaluate important soil physical (texture) and chemical [(pH, N, C content, exchangeable bases (K, Ca, Mg), exchangeable Al, CEC and % BS] properties of major cacao growing soils of the South Western Region of Cameroon.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Soil samples were collected from cacao plantations of the major cacao growing areas located in the humid forest zone of South West Cameroon. Locations, GPS coordinates, elevation (meters above sea level (Masl)) of the major locations (Town) around which cacao plantations were selected for evaluation are presented in Table 1. These locations are amongst the highest cacao bean production zones in the south west region which is one of the highest cacao producing regions in Cameroon.

The farms sampled were all matured (older) farms in production with very few shade trees. There were however, a few plantain stands in some of the sampled farms. In most of the farms the cacao trees were of different ages as there was infilling of trees over different years.

2.2 Soil Sampling

Seventeen matured farms which ranged in size from 2 to 5 ha were selected for this study. At each location, a composite soil sample was collected using soil auger at 0-30 cm depth. On each spot where core samples were to be collected, all surface organic material, dried leaves and weeds were removed. Core soil samples were taken at random from different points about 5-10 meters apart and bulked into bags. Ten core samples constituted a composite sample. For farms that were larger than 3 ha, two composite samples were collected. The samples were air dried, ground, and passed through 2 mm sieve prior to analysis.

2.3 Analytical Methods

Soil moisture content was determined by gravimetric method where soil samples were dried at 105℃ for 16 hours to a constant weight. Non corrodible containers were cleaned and dried with lids and weighed (W1). The specimen of sample was placed in the container and weighed with lid (W2). The container was kept in the oven with lid removed. The specimen was dried for 16 hours at 105℃. The final weight (W3) of the container with dried soil sample was taken.

Moisture content (%) = [(W2-W3)/(W3-W1)]X100

Table 1. Location of the sites for soil sample collection

Location (Town)	Division	Number of farms	GPS waypoints	Elevation (masl)
Bafia town	Fako	2	N 04°21.220', E 009°19.048'	2 52
Kumba central (Bonakama)	Meme	3	N 04°36.748', E 009°26.672'	218
Ikiliwindi	Meme	3	N 04°45.395', E 009°29.249'	3 34
Ehom town	Kupe Maneguba	3	N 04°45.171', E 009°3 6.336'	236
Munyenge	Fako	3	N 04°25.186', E 009°15.055'	222
Konye	Meme	2	N 05° 01.493', E 009°25.210'	283
Mbakwa supper	Meme	1	N 05° 01.592', E 009°24.210 '	360

Masl = metres above sea level

Soils were analyzed for particle size by the Boyocous, 1962 [24] hydrometer method; soil pH was measured with glass electrodes in 1:2.5 soil-water suspensions. The exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) were determined by adapting Thomas, 1982 [25] method where soil samples were extracted with 1N ammonium acetate and the leachate was analyzed for exchangeable cations. The K^+ and Na^+ were determined by flame photometer (Digital Flame Analyser, Gallenhamp, Germany) while the Mg^{2+} and Ca^{2+} were determined by atomic absorption spectrophotometer [Perkin Elmer]. The organic carbon was determined using Walkley and Black, 1934 [26] method. Total Nitrogen was determined by the Kjedahl method [27]. Ammonium acetate (NH_4OAc), pH 7.0, was employed for the determination of soil CEC [28]. CEC, Effective Cation Exchange Capacity (ECEC), %BS, and %Al saturation were calculated as follows;

Calculations: All Elements are in cmol/kg

CEC {Cation Exchange Capacity} = $\sum(Ca^{2+} + Mg^{2+} + K^+ + Na^+)$

%BS [Base Saturation (%)] = $[(Ca^{2+} + Mg^{2+} + K^+)/ECEC] \times 100$

%Al Saturation = $[Al^{3+} / \sum(Ca^{2+} + Mg^{2+} + K^+ + Na^+ + Al^{3+})$ X 100

Available phosphorus was determined using Bray and Kurtz, 1945 [29] method while exchangeable acidity and Al was determined by the method of Yuan, 1954 [30].

3. RESULTS AND DISCUSSION

3.1 Results

The results presented in Table 2 showed that, the sand fraction of the soils studied ranged from 4.25 – 64.42% with a mean of 24.10%, while the clay fraction ranged from 19.79 - 77.20% with a mean of 51.99% and the fine silt ranged from 9.72 – 57.72%.

Soils under the study area based on textural classes were grouped under clay, sandy clay, sandy clay loam, silty loam and sandy loam.

Soil pH of the investigated locations ranged from 4.58 - 6.46 with an average of 5.70 (Table 3). The percentage Al saturation ranged from 0.005 – 3.03 with one of the farms in Kumba having the highest percentage Al saturation (3.03). Exchange acidity ranged between 0.09 cmol/kg to 4.84 cmol/kg.

The organic carbon content of the studied soils ranged between 1.02 to 7.75% with farm no 9 in Ehom location having the highest value while farm no 13 in Muyengene location had the lowest organic carbon content (Table 4). Total nitrogen values were between 0.11 and 0. 82% with farms in Muyenge having the lowest amount of total nitrogen. The concentration of available phosphorus in studied farms ranged between 0.01 to 26.00 mg/kg and the lowest level of available P was present in Ehom location.

Data presented in Table 5 shows that the exchangeable K content of the soils ranged from 0.11 to 0.67 cmol/kg with an average of 0.33 cmol/kg. Exchangeable Mg content of the studied soils ranged between 0.31 – 2.41 cmol/kg with an average of 1.22 cmol/kg. Exchangeable Ca levels ranged between 1.11 and 18.00 cmol/kg with an average value of 7.66 cmol/kg. The CEC for the studied sites ranged between 1.60 and 20.69 with Bafia location having the highest value and Kumba location having the lowest. The percent base saturation was quite high for all the sites (~99%).

3.2 Discussion

Based on USDA soil textural triangle, the investigated soils were mostly clayey with a few sandy soils. Nitrogen is easily leached from sandy soils and loss of soil nitrogen (denitrification) is more common on heavy, clay soils.

Generally, these soils were slightly acidic. This is normal for soils of humid tropical region where soils are subject to frequent leaching of bases [31]. The effect of soil pH is profound on the solubility of minerals and nutrients and it is regarded as a useful indicator of other soil parameters. For instance, it provides useful information about the availabilities of exchangeable cations (e.g Ca^{2+}, Mg^{2+}, K^+, e.t.c) and P in soils [32].

Table 2. Particle size and textural classes of soils sampled

Location	Bafia			Kumba		Ikiliwindi				Ehom		Muyenge			Konye		Mbawka super	Average (std.)
Farm number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	
2 µ (clay) %	33.61	45.9	56.35	66	32.99	60.95	49.83	71.51	23.64	38.24	66.33	76.64	77.04	77.2	19.79	42.41	45.55	51.99 (18.80)
2-20 µ (fine silt) %	40.59	24.65	12.66	19.78	14.4	14.17	21.85	18.32	57.72	17.19	27.92	11.08	9.72	9.93	13.96	19.39	26.45	21.16 (12.26)
20-50 µ (coarse silt)%	3.37	2.31	2.34	3.23	2.67	2.72	2.47	2.16	6.17	2.38	1.5	2.56	2.1	3.31	1.82	2.76	2.64	2.74(1.01)
250-500 µ (sand) %	22.45	27.14	28.65	10.99	49.94	22.16	25.86	8	12.46	42.19	4.25	9.71	11.13	9.56	64.42	35.44	25.36	24.1 (16.47)
Moist. (105^{oc}) %	14.21	12.68	5.65	7.94	3.02	8.64	7.88	9.66	26.87	8.64	15.24	8.73	8.56	8.52	3.71	5.96	5.16	9.47 (5.58)
Textural class (USDA)	clay loam	Sandy clay	Clay	Sandy clay loam	Clay	Clay	Clay	Clay	Silty loam	Sandy clay	Clay	Clay	Clay	Clay	Sandy loam	Sandy clay	Clay	

Std. = Standard deviation

Table 3. pH, Exc Al and % Al saturation

Location	Bafia			Kumba		Ikiliwindi				Ehom		Muyenge			Konye		Mbaka super	Average (std)
Farm number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	
pH (H20) 1:2.5	5.96	6.23	5.76	4.58	5.67	6.46	6.3	5.28	6	6.1	5.74	5.78	5.04	4.96	5.99	5.12	5.87	5.70(0.53)
pH(KCl)1:2.5	5.41	5.67	5.08	3.97	4.65	5.96	5.77	4.65	5.22	5.08	5.02	4.13	4.06	4.05	4.94	4.31	4.73	4.86(0.63)
% Al saturation	0.005	0.006	0.022	3.025	0.036	0.006	0.005	0.095	0.007	0.015	0.025	1.48	1.31	1.82	0.006	0.521	0.013	O.49(0.88)
Exc.Acidity Al (KCl) cmol/kg	0.11	0.11	0.17	4.84	0.19	0.11	0.09	0.46	0.1	0.15	0.24	3.33	3.15	3.58	0.06	1.65	0.13	1.09(1.59)

Std = standard deviation

Table 4. Organic carbon, total nitrogen, C/N, and available P

Location		**Bafia**		**Kumba**			**Ikiliwindi**			**Ehom**			**Muyenge**			**Konye**	**Mbaka super**	**Average (Std.)**
Farm number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	
Org. Carbon %	6.46	4.57	2.64	2.56	1.79	4.5	4.56	2.85	7.75	3.3	3.18	2.15	1.02	1.38	2.21	1.38	2.05	3.20(1.84)
Total N%	0.82	0.48	0.36	0.24	0.14	0.43	0.19	0.33	0.53	0.38	0.31	0.11	0.11	0.15	0.15	0.19	0.21	0.30(0.19)
C/N	8	10	7	11	13	10	10	9	15	9	10	20	9	9	15	8	10	10.77(3.27)
Av. P(Bray-2) mg/kg	5	18	2	1	2	8	26	0.3	0.01	1	1	1	1	0.25	3	1	2	4.27(7.10)

Std = standard deviation

Table 5. Exchangeable bases (Na, K, Ca, Mg), CEC and %BS

Location		**Bafia**		**Kumba**			**Ikiliwindi**			**Ehom**			**Muyenge**			**Konye**	**Mbaka super**	**Average (Std.)**
Farm number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	
Na+ (NH4 OAC, pH7) (cmol/kg)	0.06	0.03	0.02	0.03	0.04	0.08	0.05	0.03	0.03	0.08	0.06	0.02	0.08	0.02	0.03	0.05	0.02	0.04(0.02)
K+ (NH4 OAC, pH7)(cmol/kg)	0.55	0.43	0.15	0.15	0.32	0.49	0.37	0.23	0.36	0.52	0.39	0.11	0.67	0.26	0.18	0.25	0.15	0.33(0.16)
Mg2+ (NH4 OAC, pH7) (cmol/kg)	2.08	1.83	1.08	0.31	0.86	1.33	1.56	1.15	2.41	1.73	1.71	0.5	0.59	0.39	1.32	0.63	1.19	1.22(0.62)
Ca2+((H4 OAC, pH7)(cmol/kg)	18.00	15.13	6.51	1.11	4.07	16.00	14.81	3.43	11.6	7.88	7.55	1.62	1.06	1.30	8.90	2.24	8.99	7.66(5.74)
CEC(cmol/kg)	20.69	17.42	7.76	1.6	5.29	17.9	16.79	4.84	14.4	10.21	9.71	2.25	2.40	1.97	10.43	3.17	10.35	9.25(6.33)
%BS Base saturation	99.7	99.8	99.7	98.1	99.2	99.6	99.7	99.4	99.8	99.2	99.4	99.1	96.7	99.0	99.7	98.4	99.8	0.99(0.01)

Std. = standard deviation

Nitrogen contents of all the investigated soils were adequate for cacao since all the values were higher than the critical level (0.09%) of nitrogen for cacao cultivation according to Egbe et al. [33]. The fact that the soil N content was generally above the critical level was attributed to nitrogen in the annual litter fall which is about 20 to 45% of the total N in the vegetation and 2 to 3% of the total N in the soil. Hartemink in 2005, [5] reported that, partial balances of major nutrients were determined in which losses, additions, and transfer of nutrients were calculated for the cacao ecosystems in Malaysia, Venezuela, Costa Rica, and Cameroon. In all these cacao ecosystems, it was found that N removed by cacao beans (yield) is lower than the N in the litter fall. For Cameroon, N in the litter was about twice the amount removed by the yield, whereas for Malaysia, this ratio was nearly 5 times. If about 6000 kg N /ha is present in the top soil layer, N removed by the bean yield is, on an average, less than 0.5% of the soil N. Addition of N by wet and dry deposition is fairly high and ranges from one sixth to almost half of the yearly N removal. Thus a major part of the crop N requirement is supplied with litter decomposition, which may explain the absence of a significant yield response after inorganic N fertilizer applications. It is well known that applied inorganic fertilizers have little or no effect under shaded cacao [34].

The mean value of 3.13% for soil organic carbon was above the critical value according to Ibiremo et al. [35]. The mean C/N across the study sites was above the minimum requirement of 9 for cacao production [33].

The soil available phosphorus was generally low for cacao soil except for two farms in Bafia and Ikiliwindi locations where available phosphorus were higher than the critical level of 10 mg/kg P (Table 4). The low phosphorus content in cacao soils in the south-west region is similar to the results reported by Ogunlade and Aikpokpodion [36]. A large part of the P in a cacao ecosystem is found in the vegetation and in the litter, whereas the amount of P in the soil is low. Both the quantity and the distribution of P within the ecosystem differ from those of N and K, which affect the nutrient balance. Phosphorus losses are equal to half of the transfer of P by rain wash and litter. A relatively large amount (6 to 8%) of the available P in the soil is removed by the cacao beans [5]. It was reported by Ogunlade et al. [36] that leaf litter fall in cacao plantation was not sufficient to supply the phosphorus required for optimal yields. Therefore, phosphorus fertilizer is recommended for the soils limiting in phosphorus for optimal cacao bean yields.

The base saturation across the soils in the study sites was above the minimum requirement of 60 % [37] for good cacao production. Acidity is a major degradation factor of soils under cacao. Productivity of cacao on acidic and low fertility soils is largely determined by level of aluminum toxicity and adequate supply of essential nutrients. In slightly acidic soils low productivity is due to combination of toxicities (Al, Mn, Fe, H) and deficiencies (N, P, Ca, Mg, K, Zn) of elements [38]. In tropical soils increasing soil Al saturation reduces cacao growth considerably and soil Al saturation greater than 30% appears to be toxic to cacao [17,18,39]. In East Malaysia on granitic soils poor cacao performance was related to high soil acidity and exchangeable Al, low base saturation and exchangeable Ca [16].

Table 5 showed that, Potassium values from all the investigated cacao farms were above the critical level of (0.03 cmol/kg) [15], which implies that large amounts of K required for good cacao cultivation are available in these soils. Therefore, based on the range of exchangeable K values observed in the soils studied, addition of K fertilizer is not needed to achieve optimal cacao yields [15]. Ipinmoroti et al. [40] also reported adequate potassium in some cacao soils in Ibadan, south western Nigeria.

With the exception of some farms in Kumba, the values obtained for exchangeable Ca from the various cacao farms were adequate for cacao production as they were above the critical value of 5 cmol/kg [8]. The report of Ipinmoroti et al. [40] on the nutrient assessment of some cacao plantations in Ibadan, Nigeria showed similar Ca trends. The case of Ca deficiency in cacao plantation in this region is very rare. The application of Ca fertilizer (lime) is not necessary on the investigated soils to achieve optimal yields. Most of the cacao farms investigated had their exchangeable Mg content higher than 0.8 cmol/kg which is the critical level for Mg in cacao soils [40]. Soils from Muyenge were however lower in exchangeable Mg levels. This suggests that soils in these areas were highly leached so much so that they were near the Mg deficiency levels and will require addition of Mg fertilization. The results of this study are in line with Obatolu and Chude [41] who reported Mg deficiency in cacao soil which had effect on the beans quality. Ipinmoroti et al. [40] also reported low Mg content in some cacao plantations soils in Ibadan, South-Western Nigeria. The high levels of exchangeable Mg in cacao soils for some sites in the study area may be attributed to the high clay content of the studied soils which retained high levels of exchangeable bases against the leaching process. Table 2 showed the result of particle size which revealed that, the soils contained on an average 55% clay which might have reduced the soil Mg leaching depending on the pattern and intensity of rainfall. In a study by Mokwunye and Melsted [42] on temperate and tropical soils, it was found that the distribution of Mg in the different soil fractions were: Clay fraction of the soil contained 51 to 70% of the total Mg present; silt fraction contained 22 to 42% of the total Mg and sand contained 0.1 to 11% of the total Mg. They also found that severe weathering, soil erosion and clay eluviation all tend to reduce the Mg content of surface soil horizons. The report of Choudhury and Khanif, [43] showed that, there was Mg deficiency in rice grown in area where irrigation scheme was carried out due to soil erosion. Nutrients are mined by the tree crop for the formation and development of pods and beans which might be responsible for the depletion of Mg in some of the studied soils more to that, farmers in the studied area do not replenish the soil with any form of fertilizer to replace the lost nutrients. The higher the CEC, the higher the negative charge of the soil and the more cations that can be held. The soils in Bafia were higher in CEC than the other locations and they consequently had higher values of the cations. This shows that the soils in this area may not need supplementation in cations through fertilization.

4. CONCLUSION

Soils of the studied area were slightly acidic, relatively balanced in nitrogen and the cations. A majority of the soils were clayey in nature. Although most nutrients were above the critical levels, severe nutrient deficiency is likely to develop with continues cropping and without supplementing the needed nutrients through fertilization. It is therefore very necessary for fertilizers or other management strategies to be implemented to make up for nutrients in the depleted sites as well as provide enough nutrient reserves for the sustainable high cacao bean yields.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pipitone L. The future of the world cocoa economy: Boom or bust. Presentation Given at the International Conference on Cocoa Organized by the International Cocoa Organization, Rome, 28-30 May; 2012.
2. FAOSAT, Food and Agricultural Organisation of the United Nations Statistics; 2013.
3. Appiah MR, Sackey ST, Ofori- Frimpong K, Afrifa AA. The consequences of cocoa production on soil fertility in Ghana: A review. Ghana J. Agric. Sc.1997;30:183-190.
4. Wood GAR, Lass RA. Cocoa, 4th edition. Blackwell Science, Oxford UK; 2001.
5. Hartemink AE. Nutrient stocks, nutrient cycling, and soil changes in cocoa ecosystems-a review. Adv. Agron. 2005; 86:227-253.
6. Hartemink AE. Soil fertility decline in the tropics with case studies on plantations. CABI Publishing, Wallingford, UK; 2003.
7. Hardy F. Cacao manual. Inter-American Institute of Agriculture Science, Turriabla, Costa Rica; 1960.
8. Smyth AJ. The Selection of Soils for Cocoa, Soils Bulletin; 1966. No 5, Rome: FAO.
9. Ahenkorah Y. The influence of environment on growth and production of the cacao tree: Soils and nutrition. Proc. 7th Intl. Cocoa Res. Conf., Nov. 4-12, 1979, Douala, Cameroon.1981;167-176.
10. Wessel M. Fertilizer requirements of Cacao (*Theobroma cacao L*.) in South-Western Nigeria. Communication 61. London: Department of agriculture and natural resources, royal trop. Institute; 1971.
11. Cabala-Rosand P, Santana MBM, Santana CJL. Cacao. In Plucknett DL, Sprague HB. (ed.). Detecting mineral nutrient deficiencies in tropical and temperate crops. Westview Tropical Agriculture Series, Westview Press, Boulder, CO. 1989;409-425.
12. Willson K. Coffee, cocoa and tea. CABI Publishing, Oxon, UK. 1999;300.
13. Omotoso TI. Amounts of nutrients removed from the soil in harvested amelonado and F3 amazon cacao during a year. Turrialba. 1975;235:425-428.
14. Santana CJL, Cabala-Rosand FP. Soil acidity and cacao response to lime

application in South Bahia Brazil. Proc. 9th Intl. Cocoa Res. Conf., Lome, Togo. 1984; 199-203.

15. Aikpokpodion PE. Nutrients dynamics in cocoa soils, leaf and beans in Ondo State, Nigeria. J. Agric Sc. 2010;1(1):1-9.
16. Ng SK, Thamboo S, Cheah TE. Soil and leaf nutritional status of cacao on the East and West coast of Malaya. Malaysian Agric. J. 1970;47:390-408.
17. Santana MBM, Cabala-Rosand FP, Morais FI. Effects of increasing levels of lime on some soils of cocoa growing region of Bahia. Revista Theobroma. 1971;1:17-28.
18. Sónia Silva. Aluminium toxicity targets in plants. J. Bot. 2012;1-8. DOI: 10.1155/2012/219462
19. Baligar VC, Fageria NK. Soil aluminum effects on growth and nutrition of cacao. Soil Sci. Plant Nutr. 2005a;51:709-713.
20. Baligar VC, Fageria NK. Aluminum influence on growth and uptake of micronutrients by cacao. J. Food Agric. Environ. 2005b;3:173-177.
21. Shamashuddin J, Muhrizal S, Fauziah I, Husni MHA. Effects of adding organic materials to an acid sulfate soil on the growth of cocoa (*Theobroma cacao* L.) seedlings. Sci. Total Envi. 2004;323:33-24.
22. Ribeiro MAQ, Almeida AAF, Mielke MS, Gomes FP, Pires MV, Baligar VC. Aluminum effects on growth, photosynthesis, and mineral nutrition of cacao genotypes. J. Plant Nutr. 2013;36: 1161-1179.
23. Schoenholtz SH, Van Miegroet H, Burger JA. A review of chemical and physical properties as indicators of forest soil quality: Challenges and opportunities. Forest Ecol. Manage. 2000;138:335-356.
24. Bouyoucos GJ. Estimation of colloidal material in soils. Science. 1962;64:632.
25. Thomas GW. Exchangeable cations, In. Page AL, Miller RH, Keeney D, (Eds.). Methods of soil analysis. 22nd Edition. Medison: America Society of Agronomy. 1982;57-164.
26. Walkey A, Black IA. Methods of soil analysis. Science.1934;37:29-38.
27. Bremner JM. Determination of nitrogen in soil by the Kjeldahl method. J. Agric Sci. 1960;55:11-33. DOI: 10.1017/S0021859600021572
28. Rhoades JD. Cation exchange capacity. In Agronomy No. 9, Methods of Soil Analysis, Part 2, Page AL, Miller RH, Keeney DR. eds.1982;149-157.
29. Bray RA, Kurtz LT. Determination of total organic and available forms of phosphorus in soils. Soil Science. 1945;59:39-45.
30. Yuan TL. Determination of exchangeable hydrogen in soils by titration methods. Soil Science.1954;88:164-167.
31. Alloway BJ. Pollution and land contamination. In: Harrison RM, (Ed.). Pollution causes, effects and control. 3rd edition. New York: Willey Press. 1996;480-488.
32. Ololade IA, Ajayi IR, Gbadamosi AE, Mohammed OZ, Sunday AG. A study on effects of soil physico-chemical properties on cocoa production in Ondo State. Modern Applied Science. 2010;4:35–43. DOI: 10.5539/mas.v4n5p35
33. Egbe NE, Olatoye S, Obatolu C. Impact of rate and types of fertilizers on productivity and nutrient cycling in tree crop plantation ecosystem. MAB Workshop, Abuja, Nigeria; 1989.
34. Wessel M. Shade and nutrition. In 'Cocoa' (Eds Wood GAR, Lass RA) Longman, New York. 1985;166-194.
35. Ibiremo OS, Daniel MA, Iremiren GO, Fagbola O. Soil fertility evaluation for cocoa production in Southeastern Adamawa State, Nigeria. World J Agric Sc. 2011;7(2):218-223.
36. Ogunlade MO, Aikpokpodion PO. Available phosphorus and some micro-nutrient contents of cocoa soils in three cocoa growing ecological zones of Nigeria. Proceedings of 15th International Research Conference, Costa Rica; 2006.
37. Hardy F. Cacao soils. Proceedings of Soil and Crop Science Soc. of Florida. 1958;18: 75-87.
38. Baligar VC, Fageria NK. Nutrient use efficiency in acid soils: Nutrient management and plant use efficiency. In Moniz AC, Furlani AMC, Schaffert RE, Fageria NK, Rosolem CA, Cantarella H. (ed.) Plant-soil interactions at low pH. Brazilian Soil Sc Soc, Campinas, Brazil. 1997;75-95.
39. Sugiyono A. Critical levels of aluminum in the soil for cocoa. Bull. Perkeb. 1989; 20:175-186.
40. Ipinmoroti RR, Aikpokpodion PE, Akanbi O. Nutritional assessment of cocoa plots

for soil fertility management on some cocoa farms in Nigeria. 16th Int. Cocoa conf. Indonesia; 2009.
41. Obatolu CR, Chude VO. Soils and nutritional requirement of cocoa in Nigeria, review of soils and fertilizer use research in Southwestern Nigeria. Lagos: FPDD/FMAWR & RD; 1987.
42. Mokwunye AV, Melsted SW. Magnesium fixation and release in soils of temperate and tropical regions. Soil Science. 1973; 116:359-62.
43. Choudhury ATMA, Khanif YM. Potassium, magnesium and copper status of some rice soils of Malaysia. Thai J. Agric. Sci. 2000; 33:83-88.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/15145