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FERTILITY BASELINE STUDY OF MAJOR COCOA GROWING SOILS OF NIGERIA AND IMPLICATION FOR COCOA PRODUCTION IN NIGERIA

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ABSTRACT

Field and laboratory studies were conducted to evaluate the fertility status of the soils of three major cocoa producing States in Nigeria. Survey of the selected Local Government Areas was carried out and soil samples were collected at 0-30 and 31-60 cm depths. The physico-chemical properties of the soils were assessed in relation to cocoa nutritional requirements using standard methods while descriptive statistics was used to interpret the results. The physical properties of the soils indicated that the mean sand, silt and clay content of the soils were 64.84%, 9.09% and 26.09% respectively. The average texture of the soils (sandy clay loam) was assessed to be adequate for cocoa production. However, the soil pH in water (pHw) which ranged from 4.25-6.90 was considered sub-optima especially in Cross River State where the mean pHw was <5.0. The exchangeable Mg, Ca and K which averaged 0.62, 4.21 and 0.17 cmol kg-1 respectively were also considered inadequate for cocoa production. Furthermore, the soil total nitrogen (TN) and available P (Bray-1 P) contents which averaged 0.11% and 2.77 mg kg-1 were also not adequate for cocoa production. While the level of the copper (Cu), Zinc (Zn) and Boron (B) which had mean values of 9.0, 0.49 and 1.34 mg kg-1 were considered adequate, the soil average content of iron (243.60 mg kg-1) and manganese (363.00 mg kg-1) were considered toxic. It was therefore concluded that due to the low effective cation exchange capacities (ECEC <10 cmol kg-1) of these soils, sustainable cocoa production on these soils will require split application of appropriate inorganic fertilizers.

Keywords: Soil fertility, Micronutrients, Particle size distribution, Cocoa producing areas, Nigeria

INTRODUCTION

Nigeria is the world's fourth largest producer of cocoa and produced 170,000 tons of cocoa in 2005/2006 which accounted for about 5% of global production (Amoa-Awua, et al; 2007). Cocoa accounts for about 30% of Nigeria's Agricultural Gross Domestic Product with the Amazon variety accounting for about 70% of the cocoa and the rest being mainly the Amelonado variety (Olaiya, 2006). Cocoa is produced by small-scale farmers on small farms ranging in size between 1 – 5 hectares and relying mainly on family labour (70%), hired labour (20%) and caretaker labour (10%) (Hamzat et al., 2006).

Cocoa is the single largest agricultural export

commodity crop in Nigeria and worth more than 120 billion naira in terms of trading. There are over five million people employed in Nigerian Cocoa Industry ranging from peasant farmers to processors and exporters driving its value chain. Cocoa is one of the major sources of revenue to its fourteen producing states that has been grouped into three according to the level of production (Hamzat et al., 2006). However, the production of this important export crop in Nigeria has suffered a decline in the recent years as a result of a number of factors such as low yield arising from old and poor planting material; depletion of humid rainforest and decline in soil fertility; and lack of good agricultural practices in the management of Cocoa plantation (Iremiren et al., 2012). There is the need for improvement in all the series of activities from site selection to primary processing that will ensure sustainable Cocoa farming in Nigeria.

As a first step towards revitalization of cocoa production in the country, it is the objective of this study to carry out the fertility baseline study of the major cocoa producing areas of the country.

MATERIALS AND METHODS

Three major cocoa producing states were selected for this study based on the report of cocoa production survey carried out between 2005 and 2007 (Iremiren et al., 2012). The selected states were Ondo, Cross River and Osun states in order of production. In each state, the Local Government Area with the highest production record was selected. These Local Government Areas are Idanre LGA in Ondo State, Etung LGA in Cross River State and Atakumosa West LGA in Osun State. In each of the LGA, thirty (30) bulk samples were collected from established soil series; fifteen (15) each from 0 – 30 cm and 31 – 60 cm depth. Each composite sample was made up of at least ten (10) to fifteen (15) random samples taken within the established soil series.

The collected soil samples were air dried, sieved using 2 mm sieve and analyzed for the soil physical properties, macro and micro nutrient contents.

Particle size distribution was determined by the hydrometer method (Buoyoucos, 1962) after the removal of organic matter with hydrogen peroxide and dispersion with sodium hexametaphosphate (IITA, 1979). The pH was determined with glass electrode pH meter in soil: water and soil: KCl media, each at ratio 1: 1. Exchangeable cations (calcium, magnesium, potassium and sodium) were extracted with neutral normal sodium acetate (NH4OAc at pH 7.0). Calcium and magnesium in the ammonium acetate extract were determined by atomic absorption spectrophotometry, while potassium and sodium were determined by flame photometry. The effective cation Exchange capacity (ECEC) was determined by the summation of the exchangeable bases (Ca, Mg, Na and K) and exchangeable acidity.

The organic carbon content of the soils was determined by the modified wet oxidation method (Shamshuddin et al., 1995), available P was extracted with Bray-1 solution and P concentration in the extract was determined colorimetrically by the method of Murphy and Riley (1962). Available Zn, Cu, Fe and Mn in the soils were extracted with 0.04M EDTA and their concentrations determined by atomic absorption spectophotometry. The data generated were analyzed using descriptive statistics.

RESULTS

Soils of Etung LGA, Cross River State

The soils of Etung local government in Cross

river state consist of Agbokim Series (RED) and Ajassor Series (WHITE). The farmers are more favourably disposed to the use of the Agbokim series than Ajassor series in the production of Cocoa. The major differences that exists between these two soil series is the clay and gravel contents of the soils. Agbokim series has higher clay and lower gravel contents than the soils of Ajassor series. Also, the soils of Agbokim series has rhodic colour while those of Ajassor has yellowish colour. This is likely to translate to differences in their iron oxide mineralogy.

The physical and chemical characteristics of the samples taken from 0-30 cm is presented in Table 1. Characteristically, the soils of Ajassor series had sand particle size fraction that ranged from 73.00 to 82.40% whereas the silt fraction of the soils ranged from 4.80 to 10.40% and the clay fraction ranged from 12.80 to 21.60%. The variance of the distribution of particle size fractions were 17.15, 7.39 and 10.27 for sand, silt and clay, respectively (Table 1). However, the soils of Agbokim series had sand particle size fraction that ranged from 48.40 to 77.00% while the silt size fraction ranged from 7.40 to 16.40% and the clay fraction had values that ranged from 9.60 to 40.80% with a mean value of 28.44%. The variability in the distribution of the particle size fraction in the soils of Agbokim series was higher than those of Ajassor series. The variance of the distribution of the particle size fractions were 147.57, 9.84 and 13.31 respectively for sand, silt and clay.

Table 1: Physical and chemical properties of the soils of cocoa growing areas of Etung LGA of Cross River State (0 – 30 cm depth)

SERIES	Ajassor				Agbokim			
	Mean	Min	Max	Vari	Mean	Min	Max	Vari
Sand (%)	76.16	73.00	82.40	17.15	59.14	48.40	77.00	147.57
Silt (%)	6.96	4.80	10.40	7.39	12.42	7.40	16.40	9.84
Clay (%)	16.88	12.80	21.60	10.27	28.44	9.60	40.80	13.31
pHw	4.93	4.25	5.75	0.33	4.84	4.40	5.35	0.12
pHC	4.42	3.85	5.10	0.37	4.17	3.75	5.05	0.17
OC (%)	1.08	0.94	1.22	0.02	1.78	1.40	3.21	1.06
TN (%)	0.08	0.03	0.11	0.00	0.14	0.03	0.24	0.00
TEA (cmol kg^{-1})	0.64	0.10	1.30	0.25	0.23	0.10	0.40	0.02
Mg (cmol kg^{-1})	0.45	0.34	0.54	0.01	0.66	0.58	0.76	0.00
Ca (cmol kg^{-1})	2.10	0.91	5.32	3.34	2.22	0.57	8.75	5.70
K (cmol kg^{-1})	0.21	0.12	0.42	0.02	0.16	0.10	0.27	0.00
Na (cmol kg^{-1})	0.34	0.25	0.64	0.03	0.26	0.21	0.31	0.00
ECEC (cmol kg^{-1})	3.746	2.49	6.53	2.540	3.52	1.78	10.12	5.88
BS (%)	80.96	58.60	95.99	26.97	91.92	86.50	99.01	21.10
ESP (%)	10.17	3.94	20.23	37.23	9.17	2.57	17.19	15.45
Avail-P (mg kg^{-1})	2.11	1.40	3.56	0.725	3.37	1.34	7.52	4.88
Fe (mg kg^{-1})	183.80	78.40	381.50	151.00	418.70	61.20	701.60	54.00
Mn (mg kg^{-1})	33.40	5.90	97.20	160.10	395.60	1.10	571.50	60.00
Cu (mg kg^{-1})	0.72	0.17	1.42	0.29	9.27	0.96	22.31	57.42
Zn (mg kg^{-1})	1.60	0.04	7.70	11.64	0.47	0.07	1.60	0.22
B (mg kg^{-1})	1.71	0.59	3.03	1.15	1.33	0.15	4.21	1.63

pHw = pH in water; pHC = pH in $CaCl_2$; OC= Organic carbon; TN= Total Nitrogen, TEA= Total Exchangeable Acid; BS = Base Saturation; ESP= Exchangeable Sodium Percent.

The reactions of the soils in distilled (pHw) ranged from extremely acid to strongly acid. The soils of Ajassor series had pH that ranged from 4.25 to 5.75 while Agbokim soil series had pH which ranged from 4.40 to 5.35 (in water). The distribution of the pH of the two soil series was fairly uniform with a variance of 0.33 and

0.12 in the soils of Ajassor and Agbokim series respectively. The pH values of the soils of Ajassor and Agbokim series in CaCl2 (pHc) were expectedly lower than the pH in water (pHw) and ranged from and 3.85 to 5.10 in Ajassor series but ranged from 3.75 to 5.05 in Agbokim series.

Organic carbon (OC) content of the soils was generally low to moderate and ranged from 0.94 to 1.22% in Ajassor series but ranged from 1.4 to 3.21% in the soils of Agbokim series. The mean value of the OC content of the two soil series were 1.08% for Ajassor series and 1.78% for Agbokim series while the variance of the distribution of the OC content of the soils were 0.02 and 1.06 respectively for Ajassor and Agbokim series.

The mean total nitrogen (TN) content of the soils was very low and the variation in spatial distribution was equally small. The values of TN ranged from 0.03 to 0.11% in the soils of Ajassor series while the soils of Agbokim series had TN content that ranged from 0.03 to 0.24%

The magnesium content of the soils was very low and ranged between 0.34 and 0.54 cmol kg-1 in Ajassor series and between 0.58 and 0.76 cmol kg-1 in the soils of Agbokim series. Also, the calcium (Ca) contents of the soils ranged from very low to moderate. The of Ca content of the soils of Ajassor series ranged from 0.91 and 5.32 cmol kg-1 with a mean of 2.10 cmol kg-1 while that of Agbokim soil series ranged between 0.57 and 8.75 cmol kg-1 with a mean of 2.22 cmol kg-1. The potassium (K) content of the soils also ranged very low to moderate and ranged from 0.12 to 0.42 cmol kg-1 in Ajassor soil series while Agbokim soil series had potassium contents that ranged from 0.10 to 0.27 cmol kg-1.

Table 2: Physical and chemical properties of the soils of cocoa growing areas of Etung LGA of Cross River State (31 – 60 cm depth)

SERIES	Ajassor				Agbokim			
	Mean	Min	Max	Vari	Mean	Min	Max	Vari
Sand (%)	69.16	56.40	78.00	87.05	50.08	31.00	73.00	228.74
Silt (%)	6.36	3.40	10.80	9.73	10.30	2.80	16.40	19.74
Clay (%)	24.48	13.60	32.80	70.35	39.62	10.60	55.60	245.07
pHw	4.63	4.35	5.15	0.09	4.76	4.35	5.20	0.09
pHC	4.02	3.80	4.30	0.05	4.13	3.55	4.60	0.10
OC (%)	0.80	0.07	1.34	0.21	1.06	0.43	2.27	0.29
TN (%)	0.08	0.03	0.12	0.00	0.10	0.05	0.18	0.00
TEA (cmol kg^{-1})	0.80	0.20	1.60	0.34	0.40	0.10	0.90	0.07
Mg (cmol kg^{-1})	0.39	0.16	0.72	0.05	0.52	0.20	0.69	0.03
Ca (cmol kg^{-1})	2.24	0.20	7.17	7.92	1.15	0.18	5.47	2.54
K (cmol kg^{-1})	0.14	0.10	0.20	0.00	0.14	0.09	0.28	0.00
Na (cmol kg^{-1})	0.29	0.22	0.43	0.01	0.28	0.22	0.34	0.00
ECEC (cmol kg^{-1})	3.86	2.31	8.83	7.83	2.50	1.39	6.73	2.54
BS (%)	70.12	30.95	96.60	696.95	79.57	49.67	98.51	236.97
ESP (%)	9.01	4.90	12.34	7.08	13.64	4.98	22.13	21.97
Avail-P (mg kg^{-1})	3.78	1.28	9.04	10.31	3.09	1.28	6.82	3.18
Fe (mg kg^{-1})	166.40	62.20	361.60	14639.00	377.50	55.00	526.90	31157.00
Mn (mg kg^{-1})	18.90	2.50	70.70	853.00	380.70	39.10	557.10	52943.00
Cu (mg kg^{-1})	0.82	0.26	1.35	0.23	5.35	0.47	12.02	12.09
Zn (mg kg^{-1})	0.07	0.04	0.18	0.00	0.31	0.08	1.03	0.09
B (mg kg^{-1})	1.21	0.68	2.07	0.42	0.82	0.25	1.64	0.27

pHw = pH in water; pHC = pH in $CaCl_2$; OC= Organic carbon; TN= Total Nitrogen, TEA= Total Exchangeable Acid; BS = Base Saturation; ESP= Exchangeable Sodium Percent.

The range of other nutrients content of the soils of Ajassor series were 1.40 to 3.56 mg kg-1 for available phosphorus (P), 78.40 to 381.50 mg kg-1for iron (Fe), 5.90 to 97.20 mg kg-1 for manganese (Mn), 0.17 to 1.42 mg kg-1 for copper (Cu), 0.04 to 7.70 mg kg-1 for zinc (Zn) and 0.59 to 3.03 1.34 mg kg-1 for boron (B). Similarly the soils of Agbokim series had available P that ranged from 1.34 to 7.52 mg kg-1, Fe that ranged from 61.20 to 701.60 mg kg-1 and Mn contents that ranged from 1.10 to 571.50 mg kg-1. Furthermore, the Cu content of the soils of Agbokim series ranged from 0.96 to 22.31mg kg-1 while the Zn and B contents ranged from 0.07 to 1.60 mg kg-1 and 0.15 to 4.21 mg kg-1 respectively.

At 31- 60 cm depth, the characteristics of the two soil series were similar to those of 0 – 30 cm depth in trend but the absolute values differed. Generally, the quantity of sand and silt were lower at 31 - 60 cm depth in both soil series (Ajassor and Agbokim) but the clay contents were higher than those of 0 – 30 cm depth (Tables1 and 2). For example, the mean sand, silt and clay contents of the soils of Ajassor series at 31 – 60 cm depth were 69.16%, 6.36% and 24.48% respectively (Table 2) as against 76.16% sand, 6.96% silt and 16.88% clay (Table 1) observed at 0 – 30 cm depth. This same trend was observed for the soils of Agbokim series.

Comparing the mean values of other soil properties at 0 – 30 cm with those of 31 – 60 cm, the values of OC, TN, K, Na, BS, ESP, Fe, Mn, Zn and B at 31 – 60 cm depth in the soil of Ajassor series were lower than those of 0 – 30 cm depth. However, the mean values of TEA, Mg, Ca, ECEC, P and Cu at 31 – 60 cm depth were higher than those of 0 – 30 cm depth. The differences in the values of all the soil properties at 0 – 30 cm and 31 – 60 cm depth ranged from < 10 to >50%.

For the soils of Agbokim series, apart from the Na content and ESP, the mean values of all the other soil chemical properties at 31 – 60 cm depth were lower than the values of these properties at 0-30 cm depth. And as observed in the soils of Ajassor series, the differences in the mean values of these properties at 0-30 cm and 31–60 cm depth ranged in most cases from <10 – >50%

Soils of Atakumosa West LGA, Osun State

In Atakumosa West LGA of Osun State, the three soil series identified in the cocoa producing areas were Itagunmodi, Owena and Araromi series.

The soils have sandy loam to sandy clay loam texture on the surface (0 – 30 cm depth). The soils of Itagunmodi series had 69.00 – 81.00% sand, 7.40 – 11.40% silt and 11.60 – 21.60% clay. Similarly owena soil series had sand content that ranged from 63.00 – 75.00%; 7.40 – 13.40% silt and 13.60 – 23.60% clay while the particle size composition of the soils of Araromi series was 69.00 – 72.40% sand, 7.40 – 8.80% silt and 18.80 – 23.60% clay (Table 3).

Itagunmodi soil series had pHw that ranged from extremely acid to neutral (4.40 – 6.90) and pHc that ranged from extremely acid to slightly acid (3.85 – 6.30). For the soils of Owena series, the soil reaction in water (pHw) ranged from very slightly acid to slightly acid (4.85 – 6.25) while the pH in CaCl2 (pHc) was slightly acid (5.05 – 5.40). The pHw of the soils of Araromi series ranged from moderately acid to slightly acid (5.65 – 6.25) whiles the pHc ranged from slightly acid to moderately acid (5.40 – 5.60).

The OC content of the three soil series ranged from very low to high (0.15 – 2.04%). Among

the three soil series, Itagunmodi series had the highest OC content followed by Owena series while Araromi series ranked the least in OC content. The OC content of the soils of Itagunmodi series ranged from 1.26 to 2.04%, that of Owena series ranged from 0.79 to 1.44% while the Araromi series had OC content that ranged from 0.15 – 1.48%.

The values of total nitrogen (TN) observed in the soils of Itagunmodi, Owena and Araromi series followed the same pattern of distribution as that of OC distribution. As such the TN content of these soils were generally low (0.04 – 0.16%). The values of the TN ranged from 0.11

to 0.16%, 0.08 to 0.12% and 0.04 to 0.13% respectively for Itagunmodi, Owena and Araromi series respectively.

The mean Mg content of the soils were fairly uniformly distributed but lower than the critical requirement of 0.9 cmol kg-1 for cocoa production. The Mg content of the soils ranged from 0.55 – 0.74 cmol kg-1, 0.43 – 0.75 cmol kg-1 and 0.69 – 0.71 cmol kg-1 respectively for Itagunmodi, Owena and Araromi series. Although the exchangeable Ca content of the soils at Itagunmodi and Araromi series were above the critical requirement (5 cmol kg-1) for Cocoa production, the variability in the spatial distribu-

tion of the Ca content of the soils was very high in the soils of Itagunmodi series (mean = 8.79 cmol kg-1 and variance = 45.20) . The mean Ca content of the soils of Owena series was however lower than the critical requirement for Cocoa production. The Ca content of the soils ranged from 0.63 – 20.09 cmol kg-1 in Itagunmodi, 3.08 – 6.99 cmol kg-1 in Owena and 4.61 – 6.10 cmol kg-1 in Araromi series.

The K content of the soils ranged from very low to low (0.10 – 0.31 cmol kg-1) but the lowest K value was observed in the soils of Araromi series where the value of available K ranged from 0.15 to 0.17cmol kg-1. The soils of Itagunmodi series had available K that ranged from 0.10 to 0.30 while Owena series had K that ranged from 0.14 to 0.31 cmol kg-1.

The exchangeable sodium (Na) content of the soils ranged from low (0.22 cmol kg-1) to high (0.89 cmol kg-1). The spatial variation in the value of Na was highest in the soil of Itagunmodi series where the Na content ranged from 0.22 to 0.89 cmol kg-1 and least in the soils of Owena series were the Na content ranged from 0.22 to 0.30 cmol kg-1

The effective cation exchange capacity (ECEC) of the soils were very low. The ECEC of the soils ranged from 2.23 to 21.25 cmol kg-1 in Itagunmodi series, 4.31 to 8.28 cmol kg-1 in Owena and 6.10 to 7.28 cmol kg-1 in Araromi series.

The soils of Atakumosa West LGA were deficient in available-P (Bray-1). The P content of the soils ranged from 1.28 to 6.28 mg kg-1 in the soils of Itagunmodi, 1.28 to 1.38 mg kg-1 in Owena and 1.28 to 2.37 mg kg-1 in Araromi series.

The micronutrients content of the soils of AWLGA were moderate to high. In Itagunmodi soil series, the ranges of the micronutrients were 123.60 to 324.80 mg kg-1for iron (Fe), 299.40 to 536.90 mg kg-1 for manganese (Mn), 4.56 to 38.62 mg kg-1 for copper (Cu), 0.31 to 1.47 mg kg-1 for zinc (Zn) and 0.22 to 2.69 mg kg-1 for boron (B). Similarly the soils of Owena series had Fe that ranged from 196.90 to 306.10 mg kg-1, Mn contents that ranged from 453.10 to 552.60 mg kg-1, Cu content which ranged from 4.80 to 27.11 mg kg-1 while the Zn and B contents ranged from 0.34 to 1.74 mg kg-1 and 1.39 to 2.79 mg kg-1 respectively. Furthermore, the soils of Araromi series had Fe that ranged from 157.50 to 167.20 mg kg-1, Mn which ranged from 499.40 to 503.30 mg kg-1 while the Cu content ranged from12.37 to 15.33 mg kg-1. Also, in the soils of Araromi series, the Zn content ranged from 0.22 to 0.84 mg kg-1 while the B content ranged from 1.74 to 2.08 mg kg-1.

A comparison of the physical and chemical properties of the soils of Itangunmodi series at 31 – 60 cm depth with those at 0 – 30 cm depth shows that apart from the clay, available P, Zn, B, ECEC, base saturation and ESP, which had higher mean values at 31 – 60 cm depth, the mean values of all the other properties had lower values at 31- 60 cm depth. Similarly, it was the mean values of the clay, ESP, available P and B that were higher at 31-60 cm depth in the soils of Owena series while in the soils of Araromi series, the mean clay, pHw, OC, TN, Mg, K, P and ESP were higher at 31 – 60 cm depth (Tables 3 and 4).

The soils of Idanre LGA, Ondo State

Three soil series namely Fagbo, Ondo and Oba were selected in the cocoa producing area of Idanre Local Government Area of Ondo State. The fertility status of these soils was inadequate

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for sustainable high productivity of cocoa in the area.

Characteristically, the soils of Fagbo series had sand content that ranged from 68.40 to 78.40%, silt content that ranged from 6.80 to 10.80%, and clay content, which ranged from 14.80 – 20.80, The soil texture ranged from sandy loam to sandy clay loam. Oba soils on the other hand had soil texture that ranged from sandy loam to sandy clay loam. The particle size fractions had sand content that ranged from 53.00 to 79.00%, silt content which ranged from 9.40 to 13.40%, and clay content that ranged from 11.60 to 33.60%. The soils of Ondo series had sand content which ranged from 70.40 to 79.00%, silt contents that ranged from 7.40 to 10.80% and clay contents between 13.60 and 18.80% (Table 5).

The pHw of the soils ranged from 5.10 to 5.60, 5.35 to 6.20 and 5.60 to 5.85 respectively for Fagbo, Ondo and Oba series. The pH of these series of soils in CaCl2 (pHc) were lower than pHw and ranged from 4.55 to 5.45, 4.95 to 5.40 and 5.00 to 5.40 respectively for the soils of Fagbo, Ondo and Oba series.

The Organic carbon (OC) content of the soils which ranged from 0.80 - 1.55%, 0,29 - 2.34% and 1.27 - 2.09% respectively for Fagbo, Ondo and Oba series were considered moderate for cocoa production. Also, the total nitrogen (TN) content of the soils were very low and ranged from 0.08 to 0.13% in the soils of Fagbo series, from 0.05 to 0.18% in the soils of Ondo series while the soils of Oba series had TN content that ranged from 0.11 to 0.17%

The exchangeable cations content of the soils were generally very low. The Mg content of the soils ranged from 0.68 - 0.73 cmol kg-1, 0.59 - 0.78 cmol kg-1 and 0.69 - 0.76 cmol kg-1 respectively for the soils of Fabo, Ondo and Oba series. Similarly, the Ca content of the the soils of Fagbo ranged from 4.95 - 7.41 cmol kg-1, Ondo series had Ca that ranged from 3.14 - 11.94 cmol kg-1 while the Ca content of the soils of Oba series ranged from 6.80 - 10.12 cmol kg-1. Furthermore, the values of K ranged from 0.14 - 0.47 cmol kg-1, 0.14 - 0.35 cmol kg-1 and 0.11 - 0.22 cmol kg-1 for Fagbo, Ondo and Oba soil series respectively. Equally, the exchangeable sodium (Na) content of the soils ranged from 0.21 - 0.37 cmol kg-1, 0.23 - 0.30 cmol kg-1 and from 0.23 - 0.25 cmol kg-1 respectively for Fagbo, Ondo and Oba series.

The effective cation exchange capacities (ECEC) of the soils were very low. The ECEC of the soils ranged from 6.16 to 8.60 cmol kg-1 in Fagbo series, 4.26 to 13.40 cmol kg-1 in Ondo and 7.93 to 11.44 cmol kg-1 in Oba series.

The soils of IDLGA were deficient in available-P (Bray-1). The P content of the soils ranged from 1.28 to 1.84 mg kg-1 in the soils of Fagbo, 1.59 to 2.21 mg kg-1 in Ondo and 1.28 to 1.73 mg kg-1 in Oba series.

The micronutrient content of the soils of Fagbo ranged from 167.10 to 172.60 mg kg-1 for iron (Fe), 372.60 to 429.90 mg kg-1 for manganese (Mn), 2.61 to 23.31 mg kg-1 for copper (Cu), 0.12 to 0.43 mg kg-1 for zinc (Zn) and 1.28 to 2.07 mg kg-1 for boron (B). Similarly the soils of Ondo series had Fe that ranged from 148.90 to 194.60 mg kg-1, Mn that ranged from 432.60 to 492.00 mg kg-1, Cu that ranged from 2.87 to 30.12 mg kg-1, Zn which ranged from 0.19 to 0.36 mg kg-1

Comparing the mean values of the physical and chemical properties of these soils at 0 – 30 cm with those of 31 – 60 cm indicated that in the soils of Fagbo series the mean clay, pHw, TEA,

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Na, ESP, available P and Fe content of the soils were higher at 31 – 60 cm depth while the mean values of all the other properties were lower at 31 – 60 cm depth. In the soils of Ondo series however, it was the mean clay, OC, available P, Zn and B content that were higher at 31 – 60 cm depth. The other soil characteristic had lower values at 31 – 60 cm depth. Oba soil series had higher mean values of clay, pHw, Ca, Na and ESP at 31- 60 cm depth.

DISCUSSIONS

Ibiremo et al., (2011) quoting from different authorities indicated that for cocoa produc-

Table 5: Physical and chemical properties of the soils of cocoa growing areas of Idanre LGA of Ondo State (0 – 30 cm)

SERIES	Fagbo				Ondo				Oba			
	Mean	Min	Max	Vari	Mean	Min	Max	Vari	Mean	Min	Max	Vari
Sand (%)	72.27	68.40	78.40	28.85	74.70	70.40	79.00	36.98	69.00	53.00	79.00	196.00
Silt (%)	9.33	6.80	10.80	4.85	9.10	7.40	10.80	5.78	10.73	9.40	13.40	5.33
Clay (%)	18.40	14.80	20.80	10.08	16.20	13.60	18.80	13.52	20.27	11.60	33.60	137.33
pHw	5.33	5.10	5.60	0.06	5.78	5.35	6.20	0.36	5.77	5.60	5.85	0.02
pHC	4.95	4.55	5.45	0.21	5.18	4.95	5.40	0.10	5.13	5.00	5.40	0.05
OC (%)	1.24	0.80	1.55	0.15	1.32	0.29	2.34	2.10	1.58	1.27	2.09	0.20
TN (%)	0.11	0.08	0.13	0.00	0.12	0.05	0.18	0.01	0.13	0.11	0.17	0.00
TEA (cmol kg^{-1})	0.10	0.10	0.10	0.00	0.10	0.10	0.10	0.00	0.13	0.10	0.20	0.00
Mg (cmol kg^{-1})	0.70	0.68	0.73	0.00	0.69	0.59	0.78	0.02	0.73	0.69	0.76	0.00
Ca (cmol kg^{-1})	6.25	4.95	7.41	1.53	7.54	3.14	11.94	38.72	8.03	6.80	10.12	3.31
K (cmol kg^{-1})	0.25	0.14	0.47	0.04	0.25	0.14	0.35	0.02	0.15	0.11	0.22	0.00
Na (cmol kg^{-1})	0.29	0.21	0.37	0.01	0.27	0.23	0.30	0.00	0.24	0.23	0.25	0.00
ECEC (cmol kg^{-1})	7.60	6.16	8.60	1.63	8.83	4.26	13.40	41.77	9.28	7.93	11.44	3.56
BS (%)	98.66	98.38	98.84	0.06	98.45	97.65	99.25	1.28	98.50	97.64	99.13	0.60
ESP (%)	3.87	2.47	4.58	1.46	4.34	1.73	6.95	13.62	2.65	2.20	2.90	0.15
Avail-P (mg kg^{-1})	1.47	1.28	1.84	0.11	1.90	1.59	2.21	0.19	1.46	1.28	1.73	0.06
Fe (mg kg^{-1})	169.60	167.10	172.60	8.00	171.70	148.90	194.60	1042.00	152.00	101.20	192.50	2161.00
Mn (mg kg^{-1})	399.00	372.60	429.90	838.00	462.30	432.60	492.00	1763.00	437.50	370.90	477.40	3370.00
Cu (mg kg^{-1})	9.83	2.61	23.31	136.51	16.50	2.87	30.12	371.28	29.80	19.35	45.24	186.20
Zn (mg kg^{-1})	0.24	0.12	0.43	0.03	0.28	0.19	0.36	0.01	0.33	0.22	0.43	0.01
B (mg kg^{-1})	1.60	1.28	2.07	0.17	1.74	1.15	2.32	0.68	1.01	0.53	1.76	0.44

pHw = pH in water, pHC = pH in $CaCl_2$; OC= Organic carbon; TN= Total Nitrogen, TEA= Total Exchangeable Acid; BS = Base Saturation
ESP= Exchangeable Sodium Percent.

tion the soil critical requirement were 0.9 g/kg N, 30.0 g/Kg OC, C/N ratio of 9; pH in water ranging from 5 – 8; 10.0 mg/Kg P, 0.30 cmolc/ Kg K, 5 cmolc/Kg Ca, 0.9 cmolc/Kg Mg, base saturation of 60% and Ca/Mg ratio of 1 – 3. FFD (2011) indicated that Zinc deficiency can affect Cocoa seedling while Boron was only recommended at the rate of 30 g of Borax per plant in mature F3 Amazon. In terms of the physical characteristics of the soils required for optimum cocoa production, cocoa require a deep (> 100 cm), fine to medium textured soil (Sandy clay, clay, silty clay), well drained soils with high water holding capacity (Ritung et al., 2007).

Table 6: Physical and chemical properties of the soils of cocoa growing areas of Idanre LGA of Ondo State (31 – 60 cm)

SERIES	Fagbo				Ondo				Oba			
	Mean	Min	Max	Vari	Mean	Min	Max	Vari	Mean	Min	Max	Vari
Sand (%)	67.30	66.40	68.40	1.10	68.00	65.00	71.00	18.00	60.60	52.40	66.40	53.30
Silt (%)	6.60	4.20	10.80	13.32	11.40	5.40	17.40	72.00	9.67	4.80	15.40	28.65
Clay (%)	26.13	22.80	28.80	9.33	20.60	17.60	23.60	18.00	29.73	21.60	38.80	74.61
PHw	5.42	5.25	5.75	0.08	5.63	5.50	5.75	0.03	5.62	5.50	5.80	0.03
Phc	4.65	4.35	5.05	0.13	5.00	4.75	5.25	0.13	5.27	5.10	5.40	0.02
OC (%)	0.82	0.56	1.30	0.17	1.49	1.30	1.67	0.07	1.11	0.67	1.81	0.38
TN (%)	0.08	0.06	0.11	0.00	0.13	0.11	0.14	0.00	0.10	0.07	0.15	0.00
TEA (cmol kg^{-1})	0.13	0.10	0.20	0.00	0.10	0.10	0.10	0.00	0.13	0.10	0.20	0.00
Mg (cmol kg^{-1})	0.67	0.65	0.69	0.00	0.65	0.56	0.73	0.01	0.72	0.70	0.74	0.00
Ca (cmol kg^{-1})	3.59	2.93	4.67	0.89	6.45	2.94	9.96	24.64	6.16	3.99	10.24	12.52
K (cmol kg^{-1})	0.12	0.11	0.12	0.00	0.20	0.14	0.26	0.01	0.12	0.10	0.15	0.00
Na (cmol kg^{-1})	0.34	0.24	0.54	0.03	0.25	0.24	0.26	0.00	0.28	0.27	0.30	0.00
ECEC (cmol kg^{-1})	4.86	4.03	5.82	0.82	7.65	4.00	11.29	26.57	7.42	5.21	11.50	12.53
BS (%)	97.19	95.77	98.28	1.66	98.31	97.50	99.11	1.30	97.87	96.39	99.13	1.91
ESP (%)	7.18	4.04	11.48	14.84	4.31	2.12	6.50	9.59	4.31	2.37	5.37	2.82
Avail-P (mg kg^{-1})	2.46	1.28	4.58	3.38	2.07	1.45	2.68	0.76	1.36	1.28	1.53	0.02
Fe (mg kg^{-1})	117.30	104.30	142.40	474.00	153.40	107.90	198.90	4135.00	149.20	109.60	195.90	1900.00
Mn (mg kg^{-1})	293.30	240.90	372.10	4824.00	382.30	299.70	465.00	13662.00	379.20	259.70	478.60	12271.00
Cu (mg kg^{-1})	2.44	0.55	5.92	9.12	6.75	1.85	11.64	47.92	7.26	4.29	12.26	18.99
Zn (mg kg^{-1})	0.09	0.04	0.17	0.01	0.38	0.08	0.68	0.18	0.18	0.09	0.29	0.01
B (mg kg^{-1})	1.45	1.18	1.98	0.21	1.86	1.66	2.05	0.08	0.89	0.33	1.45	0.31

pHw = pH in water; pHC = pH in $CaCl_2$; OC= Organic carbon; TN= Total Nitrogen, TEA= Total Exchangeable Acid; BS = Base Saturation; ESP= Exchangeable Sodium Percent.

The optimum pH for good performance of Cocoa ranges from 6.0 to 7.0 (pH in water). The pH of the two soil series of Etung Local Government Area were lower than this critical requirement and therefore, fertilizers application should aim at increasing the pH toward neutrality.

The exchangeable magnesium (Mg), Ca, and K content of the soils were also lower than the critical soil requirements of 0.90, 5.0, and 0.30 cmol kg-1 respectively for Mg, Ca and K. Thus the application of moderate- high quantities of Mg, Ca and K fertilizers will be required to raise the soil content of these elements above the critical soil requirement for coca production.

Furthermore the available P content of both Ajassor and Agbokim soil series were below the critical soil requirement of 10 – 12 mg kg-1 for cocoa production. The levels of copper and Boron were higher than the critical values of 0.5 – 1.0 mg kg-1 and 4 – 10 mg kg-1 respectively for boron and copper and were adequate in the soils of Agbokim series but deficient in the soils of Ajassor series. The soil content of Fe and Mn were far above the critical requirements of 50 – 100 mg kg-1 and 2 -20 mg kg-1 for Fe and Mn respectively. The levels of Fe and Mn in the soils of Ajassor series were considered adequate but toxic in the soils of Agbokim series. Although there had never been any reported case of Fe and Mn toxicity in the soils, most soils currently used for coca plantation in Nigeria have an averagely high concentration of these two micro-nutrients and the soils have been supporting good cocoa yields.

In Idanre Logal Government Area (IDLGA), the macronutrients content of the soils were lower than the minimum requirements for cocoa production. The CEC, exchangeable bases, available phosphorus and pH of the soils fell below the critical requirements for cocoa production.

The mean Ca contents of the soils of Oba (7.10 cmol kg-1) and Ondo (7.00 cmol kg-1) were higher than the critical requirement of 5 cmol kg-1 but lower in the soils of Fagbo (4.92 cmol kg-1) series. The value values of Mg in the soils were however lower than the critical value of 0.90 cmol kg-1 requires for Cocoa production. The available phosphorus content of the soils was below the critical soil requirement of 10-12 mg kg-1for cocoa production. The very high level of copper found in the soils of Oba and Ondo series could probably have resulted from accumulation of Cu on the soil surfaces as a result of the application of copper based fungicides used in the control of Black pod disease of Cocoa. Both Cu and Boron concentration in the soils are higher than the critical values of 0.5-1.0 mg kg-1 and 4-10 mg kg-1 respectively for boron and copper. The soil content of Fe and Mn were far above the critical requirements of 50 – 100 mg kg-1 and 2 - 20 mg kg-1 for Fe and Mn respectively.

A critical review of the properties of the soils of Atakumosa West Local Government Area (AWLGA) also showed that apart from the level of exchangeable Ca (7.47 cmol kg-1) the level of all other macronutrient elements were inadequate for cocoa production. Also, level of Zn was inadequate while the soil Fe and Mn contents were considered toxic.

CONCLUSION

The low fertility status of these soils could be one of the factors responsible for the current low yields (≤ 400 kg/ha) obtained in the farmers field (Iremiren et al; 2012). To achieve sustainable good yield (≥ 1000 kg/ha) of cocoa from these soils, it will be highly necessary to apply appropriate fertilizers in split because of the low ECEC of the soils.

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