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Nutrients Dynamics in Cocoa Soils, Leaf and Beans in Ondo State, Nigeria

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ABSTRACT Soil samples, young but matured foliage and Cocoa beans were collected from the farms of some Cocoa farmers across Idanre, Owena and Bamikemo in Ondo State. Samples were prepared according to standard procedure and analyzed chemically in the laboratory to determine the nutrient status of the samples. Result showed that the soils were deficient in Magnesium and Phosphorus. Foliar samples had some of the vital nutrients below critical level. Potassium was found limiting in the foliage which is at variance with K content in the soil. The findings showed that, old cocoa soils in the studied area were depleting in some vital soil nutrients which is a consequence of continuous mining of nutrient from the soil by cocoa without replacement. Result also showed that, leaf litter may not be sufficient to replace the lost nutrient. However, to correct the nutrient deficiency in the investigated soils for optimal Cocoa yield and quality, farmers within the area investigated need to adopt the use of inorganic fertilizer which must be applied according to recommendation.

INTRODUCTION

Cocoa, known as the food of the gods (*Theobroma cacao* L.) is a major cash crop in many tropical countries. Cocoa is produced within 10°N and 10°S of the equator where the climate is suitable for growing cocoa trees (Fig. 1). West Africa has been the center of cocoa cultivation for many decades, as two-thirds of the world's cocoa is produced in West Africa. However, in 1900, Africa's share of the total world cocoa production was a mere 17% (Duguma et al. 2001). Currently, the main producers are the Ivory Coast, Ghana, Indonesia and Nigeria. The Ivory Coast is the largest cocoa producer with a 95% increase in output over the 1980s and it now holds more than 40% of the world market. In Ghana, cocoa export accounts for about 60% of the country's foreign earnings, whereas in Indonesia, the revenue of cocoa is over $600 million per year. Yields in 2001 were about 540 kg /ha in the Ivory Coast and 280 kg /ha in Ghana and Nigeria. A considerable part of the cocoa in the world is produced by smallholders, and the International Cocoa Organization (ICCO) estimates that approximately 14 million people are directly involved in cocoa production. The most significant contribution to the rise in global output is expected from Africa where production is forecast to rise by close to 9%, followed by the Americas, whereas production in the Asia and Oceania region is likely to remain static. Africa remains the main cocoa-producing region, accounting for 69% of world cocoa production in 2002 and 2003, followed by Asia and Oceania (18%) and the Americas (13%) according to ICCO (2003). Compared to other agricultural activities, cocoa has been a leading subsector in the economic growth and development of several West African countries (Duguma et al. 2001).

Cocoa ranked first amongst agricultural export crops in its contribution to foreign earnings (Tijani et al. 2001). It is a crop of economic importance with more than 650,000 ha being cultivated in Nigeria (Sanusi and Oluyole 2005) Cocoa has generally enhanced the economy of Nigeria over the years. It is exported either as raw cocoa beans or cocoa products. Some 70% of Nigeria's annual cocoa exports are to Europe with a further 10% to the United States of America and up to 15% to Eastern Europe. Nigeria is currently the 4th largest producer of cocoa.

In Nigeria, most of the Cocoa plantations are old and less productive (Ayoola 2000). Most soils under Cocoa plantations and adaptable areas in Nigeria are marginal to moderately suitable in fertility status. The soils are well drained, thoroughly leached and deeply weathered. Cocoa is exceptionally demanding in its soil requirement (Smith 1975). Wessel (1971) showed steady decline in almost all nutrients with length of cultivation. Omotoso (1975) reported that a crop of 1000kg dry Cocoa beans removed about 20kg N, 41kg P and 10kg K from the soil. It has been reported by Ogunlade et al. (2009) that most Nigerian Cocoa farmers don't use fertilizers on their farms.

Fig. 1. Main cocoa-producing countries in the world (Map from the International Cocoa Organization)

Several studies have been conducted in Nigeria, which is the fourth largest cocoa producer in the world . Near Ibadan, Ekanade et al. (1991) found soil organic C contents under forest 29 g / kg, whereas this was 19 g C /kg under cocoa. Available P was much higher under cocoa than under forest, but exchangeable K was lower. In Oyo State (Nigeria), Adejuwon and Ekanade (1987) found topsoil organic C levels of 26 g/ kg under forest and 19 g C/ kg in the top soils under cocoa. All major nutrients and the pH were lower under cocoa compared to soils under forest. In another study in the Oyo state of Nigeria, Adejuwon and Ekanade (1988) sampled a large number of soils under forest, and soils that had been under cocoa for 10 to 15 years. Soils were classified as Alfisols, and mean annual rainfall at the sites was about 1300 mm. The soil pH under forest was 6.8, whereas the pH under cocoa had decreased to 5.5. Soil organic C levels were 27 g kg^{-1} under forest but only 13 g C /kg under cocoa. Also, total N and levels of exchangeable cations were much reduced when the soils under forest were compared to those under cocoa (Adejuwon and Ekanade 1988). In southern Nigeria it was found that soil organic C under a secondaryforest was about 35 g /kg ; under 10-year-old cocoa, levels were 25g C/ kg (Ogunkunle and Eghaghara 1992).

Total N and most other soil properties were about the same under cocoa and secondary forest. Ekanade (1988) sampled 60 cocoa plots of ages from 1 to 55 years and collected 30 soil samples under forest on Alfisols in south-western Nigeria. Soil organic C was, on average, 26 g/ kg under forest and 19 g/ kg under cocoa, and the soil reaction was 6.8 under forest and 5.9 under cocoa. All soil chemical properties were significantly lower under cocoa. These studies from West Africa provide insight into the differences and changes that may be expected when the natural forest is converted to perennial cropping. The studies consistently show that soil organic C equilibrium data under cocoa settle below those of the soils under natural forest. Carbon storage under cocoa is, however, often higher than in comparable soils under annual cropping (Duguma et al. 2001). Studies have shown that nutrient levels on cocoa farms are generally very low (Okuneye et al. 2003) due to the relatively low use of inorganic fertilizers. The soil chemical fertility was significantly lower under cocoa compared to soils under forest, and this is often found under perennial crops (Hartemink 2003).

Based on the outcome of the national cocoa survey of 2005 which ranked Ondo state first among the fourteen cocoa producing states in Nigeria, it is worthwhile to carry out a nutrient dynamics study on the cocoa plantation soils in order to know their present nutrient status moreso that, most of these cocoa farms are more than forty-five years.

MATERIALS AND METHODS

Soil samples used for this study were collected from Cocoa plantations of some major cocoa farmers in Ondo State. Precisely, the farms investigated in this study were in Idanre ($7^0$06'N, $5^0$6'E), Owena (0708'N, 5.06'E) and Bamikemo ($07^0$18'N, $4^0$45'E). The ages of the cocoa farms are between 7 and 50yrs.

The leaf samples were air-dried and pulverized before chemical analysis while the beans were fermented for five days and sun dried followed by grounding to powder before chemical analysis.

The soil samples were taken with soil auger at 0-30cm depth because nutrient stocks are restricted to the upper 30 cm, as most feeding roots of cocoa are concentrated to that depth. The root system of a cocoa tree consists of a thick tap root and a mat of lateral roots that lies in the top 20 cm of the soil; these lateral roots are the main channel for moisture and nutrients (Wood and Lass 1985). De Oliveira Leite and Valle (1990) found that 85% of the roots are concentrated in the first 30 cm of the column, and Thong and Ng (1978) also found that cocoa is a surface-root feeder with most lateral roots found in the surface soil layer (0–30 cm). In most soils in the tropics the major part of the nutrients are also found in the top 25 cm. Core samples were taken from different points about 5-10 meters apart and bulked into bags. Ten core samples constituted a composite sample. Twenty-eight composite samples collected were air-dried, crushed, thoroughly mixed and passed through 2mm sieve in readiness for analysis.

The samples were leached with 1N ammonium acetate. The leachate was analyzed for exchangeable cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) determination (Sharman et al. 1942; Schollenberger and Simeon 1945). Soils were analyzed for particle size by the Boyocous hydrometer method soil pH was measured with glass electrodes in 1:2.5 soil-water suspension. The organic carbon was determined after Walkley and Black (1934). Total Nitrogen was determined by the Macro Kjedahl method (Bremner 1996). Available Phosphorus was determined using Bray and Kurtz (1945) method.

RESULTS AND DISCUSSION

Calcium content of the soil ranged from 6.11-11.23cmol/kg with a mean value of 7.23 cmol/kg. All the values obtained for calcium from the various Cocoa farms were adequate for Cocoa production. The report of Ipinmoroti et al. (2009) on the nutrient assessment of some cocoa plantations in Ibadan, Nigeria showed similar calcium trend. The case of calcium deficiency in cocoa plantation is very rare. This may be as a result of calcium rich parent material of most soils in the south-western part of Nigeria. Hence, the application of Calcium fertilizer is not necessary on the investigated soils for optimal yield. Magnesium content of the soil ranged from 0.006-0.026 cmol/kg with a mean value of 0.016 cmol/kg. Table 3 showed that, all the cocoa farms investigated had their magnesium content lower than 0.8cmol/kg which is the critical level for magnesium in cocoa soil. Lombin and Fayemi (1979) reported that some highly leached soils are near the deficiency level and require magnesium fertilization. They anticipated serious magnesium deficiencies in Nigeria in the near future. The anticipation of Lombi and Fayemi in 1979 seemed to be what Nigerian soil is experiencing at the moment regarding magnesium deficiency in cocoa soil. Obatolu and Chude (1987) reported Mg deficiency in Cocoa soil which had effect on the beans quality. Ipinmoroti et al. (2009) also reported low Mg content in some Cocoa plantation in Ibadan, south-western Nigeria. The deficiency of magnesium in cocoa soil may be attributed to the high sand content of the studied soils. Table showed the result of particle size which revealed that, the soils contain 70% sand on the average while the percentage of clay is just 15% on average. This might have predisposed the soil magnesium to leaching depending on the pattern and intensity of rainfall. Mokunye and Melsted (1973) tested nine temperate and tropical soils and found that the distribution of magnesium in the soil separate: Clay fraction of the soil contained 51 to 70% of the total magnesium present; Silt fraction contained 22 to 42% of the total magnesium and sand contained 0.1 to 11% of the total magnesium. They also found that severe weathering, soil erosion and clay eluviations all tend to reduce the magnesium content of surface soil horizons. The report of Choudhury and Khanif (2000) stated that, there was magnesium deficiency in rice grown area where irrigation scheme was carried out.

Combination of the mentioned factors coupled with the annual mining of nutrients by the tree

Table 1: Concentration of some cations, pH and available P in Cocoa soil.

Farm description	*Ca*	*Mg*	*Na*	*K*	*Fe*	*Mn*	*Zn*
	C mol/kg				*mg/kg*		
Idanre 1	5.89	0.01	0.66	0.56	13.92	66	10.56
Idanre 2	5.14	0.009	0.76	0.36	16.44	63.9	5.52
Bankemo 3	6.12	0.022	0.6	0.1	15.96	56.94	3.96
Owena 3	8.27	0.009	0.64	0.24	19.44	77.04	9
Idanre 3	11.23	0.019	0.74	0.28	76.08	40.62	5.04
Owena 1	5.74	0.02	0.54	0.08	37.26	30.12	5.4
Bankemo 1	10.7	0.008	0.8	0.2	32.65	58.49	4.97
Idanre 4	6.13	0.006	0.44	0.09	21.06	62.4	6.72
Owena 2	7.12	0.026	0.56	0.15	14.34	76.5	10.36
Bankemo 2	6.11	0.026	0.68	0.11	17.28	64.02	5.52
Idanre 5	7.11	0.007	0.6	0.17	18.42	76.92	5.46
Mean	7.23	0.015	0.64	0.213	25.71	61.18	6.59
Std	1.94	0.01	0.1	0.14	17.46	14.1	2.18

Std: Standard deviation

crop for the formation and development of pod and beans might be responsible for the depletion of magnesium in the studied soils more so that, farmers in the studied area do not replenish the soil with any form of fertilizer to replace the lost nutrients. It is therefore necessary to apply magnesium fertilizer on the investigated cocoa soil for optimal yield. Table 1 showed that sodium content of the soil ranged from 0.44-0.80cmol/kg with an average of 0.64 while table 2 showed that available phosphorus of the soil range from 6.15-30.26mg/kg with an average value of 18.04 mg/kg. The soil available phosphorus was generally adequate for cocoa soil except Idanre 4, Owena 2 and Bankemo 2 had their available Phosphorus lower than the critical level of 10 mg/kg P in cocoa soil. The low phosphorus content in cocoa soil in the south-west was also reported by Ogunlade and Aikpokpodion (2006). A large part of the P in a cocoa 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 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 rainwash and litter. A relatively large amount (6 to 8%) of the available P in the soil is removed by the cocoa beans (Alfred 2005). It was reported by Ogunlade et al. (2006) that leaf litter fall in cocoa plantation was not sufficient to supply the Phosphorus required for optimal yield. Therefore, phosphorus fertilizer is recommended for the soils limiting in phosphorus for optimal yield.

Table 2 showed that soil pH of the investigated farms ranged from 5.70-7.20 with an average of 6.53. The pH value of Bankemo 1, tends toward alkaline. This might be as a result of high concentration of sodium and calcium in this soil. Generally, the soils were slightly acidic. This is normal from this type of humid soils which are subject to leaching by bases Alloway (1996)

Table 1 showed that, Potassium content of the soil ranged from 0.08-0.56cmol/kg with an aver-

Table 2: Concentration of nitrogen, phosphorus, pH and particle size.

Farm description	*N*	*Carbon*	*Sand*	*Clay*	*Silt*	*Available P*	*pH*
			%			*ppm*	
Idanre 1	0.22	2.43	70.24	15.52	14.56	25.96	6.9
Idanre 2	0.21	1.65	70.24	15.52	14.56	21.9	6.7
Bankemo 3	0.23	1.65	74.24	15.5	10.26	22.5	6.3
Owena 3	0.23	3.29	70.24	13.2	16.56	19.8	6.6
Idanre 3	0.25	2.9	54.24	21.2	24.56	23.7	6.1
Owena 1	0.2	1.33	71.24	14.2	16.56	28.35	5.7
Bankemo 1	0.22	2.35	68.24	13.2	18.56	30.26	7.2
Idanre 4	0.2	1.25	72.24	15.2	12.56	6.3	6.5
Owena 2	0.21	1.8	72.24	15.2	12.56	6.15	6.71
Bankemo 2	0.2	1.49	74.24	15.2	14.56	6.16	6.4
Idanre 5	0.22	2.11	70.24	13.2	16.56	7.5	6.7
Mean	0.22	2.02	69.79	15.2	15.62	18.05	6.53
Std.	0.015	0.63	5.21	2.11	3.59	9.14	0.384

Std : Standard deviation

age of 0.21cmol/kg. The various values from all the investigated Cocoa farms were above the critical level of (0.03cmol/kg) K required for Cocoa cultivation. It is therefore not necessary to apply potassium fertilizer on the investigated soil for optimal yield. Ipinmoroti et al. (2009) also reported adequate potassium in some Cocoa soils in Ibadan south western Nigeria.

Table 1 showed that, Fe^{2+} content of the soil ranged from 13.92-76.08mg/kg with an average value of 25.71mg/kg, zinc content of the soil ranged from 5.04-10.36 mg/kg with a mean value of 6.59 mg/kg while manganese content ranged from 30.12 -77.04 mg/kg with an average value of 61.18mg/kg.

Table 2 showed that, nitrogen content of the soil ranged from 0.20-0.25% with a mean value of 0.22%. Nitrogen contents of all the investigated soils were adequate for Cocoa since all the values were higher than the critical level (0.09%) of nitrogen for Cocoa cultivation according to Egbe et al. (1989). The soil N content was generally above critical level. This may be as a result of 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. In the report of Alfred (2005), partial balances were calculated in which losses, additions, and transfer of nutrients were calculated for the cocoa ecosystems in Malaysia, Venezuela, Costa Rica, and Cameroon. In all cocoa ecosystems, it was found that N removed by cocoa beans (yield) is lower than in the litter fall . For Cameroon, N in the litter was about twice the amount removed by the yield, whereas for Malaysia, this ratio is nearly 5. If about 6000 kg N /ha is present in the topsoil, N removed by the yield is, on average, less than 0.5%. Addition of N by wet and dry deposition is fairly high and ranges from one sixth to almost half of the yearly N removal. The turnover of N is large compared to the additions and losses, particularly when the cocoa is not fertilized. In Costa Rica where fertilizer N is applied at a rate of 120 kg N/ ha, the total transfer is lower than the yearly addition. The beans remove only 16 to 21% of the applied N. Data of Malaysia and Costa Rica suggest that inorganic fertilizer has no effect on the transfer of N with the litter. A major part of the N requirement is supplied with litter decomposition, which may explain the absence of a significant yield response after inorganic fertilizer applications. It is well known that inorganic fertilizers have little or no effect under shaded cocoa (de Geus 1973; Wessel 1985). Table 2 showed that Organic carbon content of the soil ranged from 1.25-3.29% with a mean value of 2.02%.

The sand fraction of the soils ranged from 54.24-74.24% with a mean of 69.79%, while the clay fraction ranged from13.20-15.20% with a mean of 13.20% and the silt ranged from 10.26-24.56% with an average value of 16.56%. Result showed that all the soils with the exception of soil from Idanre 3, are sandy loam in nature while soil from Idanre 3 is sandy clay loam.

Table 3 showed data showing the result of calcium, magnesium, sodium, potassium and phosphorus in the leaves of investigated cocoa trees.

Calcium content of cocoa leaves ranges from 1.63-7.60% with an average value of 3.44% (Table 3). The calcium content in cocoa leaves from all the investigation Cocoa farms are above the critical level for calcium in cocoa leaf which is 0.6% according to Egbe et al. (1989), magnesium content of the cocoa leaves in the investigated cocoa farm ranged from 0.23-0.48% with an average value of 0.29%. Magnesium contents in the leaf of the plants from the various Cocoa farms investigated were below the critical level of magnesium in Cocoa foliage (0.5%). This may the consequence of the very low magnesium content found in the soils from all the investigated cocoa farms. Magnesium is vital to the production of chlorophyll because every molecule of chlorophyll contains a magnesium ion at the core of its complex structure. It is the only metallic element contained in chlorophyll (Thompson and Troeh 1978). Owing to the role of magnesium in plant, it is therefore recommended that magnesium fertilizer (dolomite) be applied to all the Cocoa soils on the farms that were investigated. Sodium content of the cocoa leaves ranged from 0.20-0.52% with a mean value of 0.30% (Table 3). Potassium content of the cocoa leaves ranges from 0.35-1.93% with a mean value of 0.72%. Potassium content in all the leaf samples from the various cocoa farms investigated were grossly below the critical level for potassium in cocoa foliage which is 2.0% except Idanre 5, with the value of 2% (Table 3). On looking at table 1 which contains the values of macronutrients in soil, it is observed that, all the cocoa soils investigated had potassium values well above the critical level for potassium in cocoa soil. Result showed that the level of potas-

Table 3: Concentration of some cations and phosphorus in Cocoa leaf (in percent)

Farm description	*Ca*	*Mg*	*Na*	*K*	*Fe*	*Mn*	*Zn*	*N*	*P*
Idanre 1	1.77	0.26	0.27	0.53	0.041	0.002	0.007	1.09	0.1
Idanre 2	4.78	0.28	0.21	0.62	0.045	0.002	0.008	1.64	0.09
Bankemo 3	2.1	0.23	0.52	0.63	0.031	0.005	0.009	1.34	0.08
Owena 3	1.78	0.24	0.3	0.35	0.054	0.006	0.007	1.32	0.4
Idanre 3	2.32	0.31	0.33	0.42	0.067	0.007	0.007	0.89	0.09
Owena 1	2.02	0.27	0.29	0.51	0.023	0.003	0.006	1.03	0.11
Bankemo 1	1.63	0.26	0.44	0.52	0.011	0.002	0.007	1.29	0.06
Idanre 4	5.73	0.32	0.24	0.73	0.037	0.004	0.006	1.09	0.3
Owena 2	7.6	0.28	0.2	0.63	0.03	0.005	0.008	1.06	0.25
Bankemo 2	5.38	0.48	0.28	1	0.028	0.005	0.007	0.99	0.09
Idanre 5	2.76	0.28	0.24	2	0.041	0.008	0.007	1.05	0.3
Mean	3.44	0.292	0.302	0.72	0.04	0.005	0.007	1.16	0.17
Std.	1.96	0.055	0.12	0.12	0.016	0.01	0.001	0.32	0.17

Std: Standard deviation

sium in the leaves samples is at variance with the potassium content of the soil. This suggest that, there may be immobilization of potassium within the tree. Wessel (1985) stated the possibility of nutrient immobilization within cocoa which are considered lost for the system as they are excluded from nutrient cycling. However, he stated that, immobilization of nutrient is particularly important for young cocoa, but unimportant for mature cocoa. Another possibility could be that, not all the extractable potassium is available for uptake. Kauffman and Bouiding (1967) observed that exchangeable K^+ ions cannot move to the plant root unless they are replaced by other cations on the exchange sites. Plant roots that come close enough to such K^+ ions may exchange H^+ ions for them. They also found that most of the potassium uptake is accomplished by root extensions that are less than a week and that almost all the absorbed K^+ comes from the zone within 4 to 5mm of the root. Farr et al. (1968) stated that some exchangeable potassium may have been absorbed by contact absorption while others would have entered the soil solution through an exchange reaction before being absorbed. The inadequate potassium content in the Cocoa leaves might be due to some of the above mentioned reasons. Most of the Cocoa trees are old and the rate of development of new roots may be low and consequently reduce the rate of potassium uptake. The exchangeable potassium that enters into solution through exchange reaction may be more than the potassium absorbed by contact absorption. There could also be a problem of potassium fixation in the investigated soils which could make it difficult for the roots to absorb the nutrient.

Phosphorus content of the cocoa leaves ranged between 0.08 and 0.40% with a mean value of 0.17% (Table 3). Out of the eleven cocoa farms investigated, only Owena 3, Idanre 4, Owena 2 and Idanre 5 had their phosphorus content in the leaves above the critical level for foliage which is 0.2% according to Egbe et al. (1989). The low

Table 4: Concentration some cations, nitrogen and phosphorus in cocoa beans (in percent).

Farm description	*Ca*	*Mg*	*Na*	*K*	*Fe*	*Mn*	*Zn*	*N*	*P*
Idanre 1	0.005	0.013	0.11	0.27	0.006	0.001	0.005	1.85	0.05
Idanre 2	0.004	0.01	0.12	0.19	0.012	0.002	0.005	1.91	0.02
Bankemo 3	0.005	0.027	0.19	0.24	0.008	0.002	0.005	2.12	0.03
Owena 3	0.007	0.013	0.13	0.21	0.011	0.001	0.004	1.98	0.04
Idanre 3	0.007	0.012	0.13	0.28	0.01	0.001	0.005	1.84	0.05
Owena 1	0.008	0.01	0.16	0.37	0.01	0.001	0.006	2.03	0.06
Bankemo 1	0.005	0.019	0.15	0.28	0.01	0.002	0.006	1.8	0.04
Idanre 4	0.006	0.01	0.14	0.28	0.008	0.001	0.005	1.9	0.05
Owena 2	0.005	0.014	0.14	0.42	0.005	0.002	0.006	2	0.04
Bankemo 2	0.004	0.01	0.1	0.28	0.003	0.001	0.004	1.87	0.04
Idanre 5	0.006	0.01	0.15	0.32	0.006	0.002	0.006	2.12	0.04
Mean	0.006	0.014	0.14	0.29	0.01	0.002	0.005	1.95	0.04
Std.	0.0012	0.043	0.04	0.002	0.019	0.017	0.015	0.014	0.014

Std : Standard deviation

phosphorus contents of the leaf may be due to fixation of inorganic P on the soil exchangeable sites.

Iron content of cocoa leaves from the investigated farms ranged between 0.11 and 0.067% with a mean value of 0.037% (Table 3). Manganese content of cocoa leaves in the investigated farm ranged between 0.002 and 0.008% with a mean value of 0.005% (Table 3). Zinc content of cocoa leaves from the investigated farms ranged between 0.006 - 0.009% with a mean value of 0.007% (Table 3). Nitrogen content of cocoa leaves from the investigated farms ranged between 0.89 and 1.64% with a mean value of 1.16% (Table 3). Nitrogen content of cocoa leaves from all investigated farms was adequate and up to the critical level of nitrogen in cocoa foliage which is 0.9%. The adequate nitrogen content of the leaf samples in a reflection of the high content of nitrogen in all the Cocoa soils investigated. Most of the values are well above the critical nitrogen level for cocoa and this is a reflection of the high nitrogen content of all the cocoa soils investigated in this work. It therefore suggests that, Nitrogen fertilizer may not be necessary for application on these investigated farms since the nitrogen in the soils is adequate. Notwithstanding, regular check should be made since large amount of nitrogen is taken from soils by cocoa crop during fruiting.

Table 4 shows the result of some nutrients in cocoa beans is presented in. Calcium content of the beans ranged from 0.004 – 0.008% with a mean value of 0.006%.

The average value for calcium in the beans 0.006% (60mg/kg) is higher than the value documented (25.5mg/kg) by Olaofe et al. (2006). Magnesium content of the beans ranged from 0.010-0.027% with a mean value of 0.014% (140 mg/kg). The mean value of magnesium obtained in this work is lower than the value (5179 mg/kg) obtained by Olaofe et al. (2006). The low magnesium content of the beans could be a consequence of magnesium deficiency in all the investigated cocoa soils. Magnesium being an essential element in diet needs proper attention because of its deficiency in cocoa soils in some areas in south western Nigeria. It is obvious that the magnesium content in the various cocoa soils investigated was low. Hence, an immediate measure has to be put in place to fertilize the various cocoa soils investigated in this work with Dolomite which will enhance magnesium supply to the crop.

Sodium content of the beans ranged from 0.10-0.19% with a mean value of 0.14% (1400mg/kg). The least value is from farm 10 and the highest value from 3. Potassium content of the beans ranged from 0.19-042% with mean value of 0.28% (2,800mg/kg). The least value is from farm 2 the highest value from farm 9. The mean value obtained is higher than 2,480mg/mg Mg obtained by Olaofe et al. (2006). The high potassium content of the bean is a true reflection of the adequate potassium content of the cocoa soils (Table 1). Iron content of the beans ranged from 0.003-0.012% with a mean value of 0.008%. (80mg/kg). Manganese content of the beans ranged between 0.001 and 0.002% with a mean value of 0.001% (10mg/kg). Zinc content of the beans ranged from 0.004-0.006% with a mean value of 0.005% (50mg/kg). Nitrogen content of the beans ranged from 1.80-2.12% with a mean value of 1.93% (19,300mg/kg). The high nitrogen content of the beans in table 2 could be a reflection of high nitrogen content of all the soil investigation. Phosphorus content of the beans ranged between 0.02 and 0.06% with a mean value of 0.04% (400mg/kg). Copper content of the beans ranged from 26.79-40.50mg/kg with a mean value of 32.31mg/kg. The value is higher compared to 8.2mg/kg obtained by Olaofe et al. (2006). This is a consequence of the continuous use of copper based fungicide in the control of black-pod disease which is the main disease of cocoa. Copper is not biodegradable being a heavy metal, it normally form complex with the soil organic matter and remain within the top soil and it is being absorbed by plant root and transported to various parts of the plant including the beans.

In order to manage the investigated Cocoa soils for optimal yield, the following recommendation of fertilizer application is made based on soil test result.

CONCLUSION

It was evident that the investigated Cocoa soils were adequate in calcium, nitrogen and potassium content but grossly deficient in magnesium. Some of the soils investigated were also deficient in phosphorus. The consequence of nutrient deficiency in these soils was reflected in their foliage which could have negative impact on Cocoa production in Ondo State. Therefore, organized efforts should be put in place to edu-

Table 5: Nutrient deficiency level and fertilizer recommended rate based on soil test for optimal Cocoa production ha^{-1}

Farm	Deficiency level		Recommended rate	
	Mg (mg/kg)	*P (mg/kg)*	*Mg (kg/ha)*	*P (kg/ha)*
1	7900	-	15800	-
2	7910	-	15820	-
3	7800	-	15600	-
4	7910	-	15820	-
5	7810	-	15620	-
6	7800	-	15600	-
7	7920	-	15640	-
8	7940	3.70	15880	7.40
9	7740	3.85	15480	7.70
10	7740	3.84	15480	7.68
11	7930	2.50	15860	5.00

cate and assist Nigerian Cocoa farmers to immediately embrace the use of fertilizer on their farms to enhance the production of Cocoa on their farms. The application of dolomite which is to take care of magnesium deficiency should be used according to the recommendations in table 5. On average, each of the cocoa farm should apply magnesium fertilizer at the rate of 15600 kg Mg per hectare while farm 8, 9, 10 and 11 should use 7.4,7.7,7.68 and 5 kg P per hectare.

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