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SOIL FERTILITY EVALUATION OF COFFEE (*Coffea canephora*) PLANTATIONS OF DIFFERENT AGES IN IBADAN, NIGERIA

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ABSTRACT

Iloyanomon CI, Daniel MA, Aikpokpodion PE (2011) Soil fertility evaluation of coffee (*Coffea canephora*) plantations of different ages in Ibadan, Nigeria. *J. Soil Nature* 5(1), 17-21.

A study was carried out to investigate the nutrient status of coffee plantations of different ages, *viz.* 6 years, 19 years, 37 years and 42 years. Each coffee plantation was divided into four blocks. Soil samples were collected at soil depths of 0-15cm, 15-30cm and 30-45cm from five different points within each block. The soil samples collected were processed and analyzed for some of their physical and chemical properties. Plant samples taken from the coffee plants were also processed and analyzed for some of their chemical properties. Results indicated that the nitrogen content of the coffee plantation ranged between 0.9-2.4g/kg for 0-15cm soil depth, 0.7-1.3g/kg for 15-30cm soil depth and 0.6-1.2g/kg for 30-45cm soil depth. This was above the soil critical level of 0.9g/kg required for coffee. This is reflected in the high nitrogen level of the coffee leaf 1.56-2.0%, which is higher than the foliar critical level of 1.10% required for coffee. Soil phosphorous was also adequate across the coffee plantations irrespective of age, with phosphorous content ranging between 18.45-22.65mg/kg soil. This was well above the soil critical level of 6mg/kg soil required for coffee. Similar high phosphorous content of 1.1%-1.37% was observed on the coffee leaf. The potassium content of the soils across the coffee plantations ranged between 0.07-0.30cmol/kg. This was inadequate for coffee production. There is need to return potassium mined from the soil through guided fertilizer application to supply deficient K and enhance coffee production.

Key words: *Robusta coffee, nutrient status, critical level*

INTRODUCTION

Coffee is a cash crop with great economic potential as a foreign exchange earner. Of all the beverages worldwide, it is the most stimulating and mood elevating non alcoholic beverage.

Coffee production in Nigeria is spread over a variety of agro ecological zones. This connotes a variety of soils with different nutrient status *viz.* alfisol, oxisol and ultisol, with *Coffea canephora* (Robusta coffee) constituting a large portion of the coffee produced in Nigeria. Coffee production in Nigeria is on the decline. In 2006, Nigeria produced 5340 metric tonnes of coffee (FAOSTAT 2011) by 2009 production had dropped to 1600 metric tonnes. Reasons for this decline are numerous among which are the low price of coffee beans over the past years in the international market, poor market for coffee beans produced, poor nutrient status of the soil, inconsistent government policies just to mention a few. These had led to abandonment of coffee plantations and in some cases cutting down of coffee trees to plant more financially rewarding crops.

The problem of poor nutrient status of the soil is challenging. A major factor in coffee production is the suitability or otherwise of the soil. Soil plant nutrient relationship envisages removal of nutrients from the soil to enhance growth and yield. Coffee production in Nigeria receives little or no fertilizer and is in the hands of low income small scale farmers who produce without proper soil management practices. This has led to continuous mining of nutrients through harvesting of the coffee berries without adequate replenishment of the lost nutrients; with coffee leaf litter being the main source of nutrient for coffee trees.

Continuous cultivation of coffee on the same soil has been reported to lead to decline in soil quality (Carvajal 1985; Ai Darrah *et al.* 2008) with potassium depletion of up to 93% on soils cultivated with coffee for over 22 years (Carvajal 1985). Nutrient management is therefore important to sustain and improve soil health. Jarayama (2003) stated that soil and foliar samples were useful tools for diagnosing nutrient status of fruit trees including coffee. There is therefore need to evaluate the nutrient status of these coffee plantations to determine their nutrient status, identify the limiting nutrient, understand the effect of continuous cultivation on soil property to ensure proper recommendation.

The objectives of this study are:

1. Evaluate the nutrient status of coffee plantations at different ages;
2. Determine the effect of continuous cultivation of coffee on soil quality;
3. Determine the limiting nutrients in coffee plantations at different ages.

MATERIALS AND METHODS

Study site

The study was conducted in Cocoa Research Institute of Nigeria (CRIN) headquarter in Ibadan, Nigeria (latitude $07^{0}10^{1}$N and longitude $03^{0}51^{1}$E) and on an altitude of 122 meters above sea level. CRIN is located in Idi-Ayunre, the South Eastern end of Ibadan city. Ibadan is a forest ecological zone with a bimodal rainfall of about 1300mm per annum. The dry season runs from early November to March, while the rainy season runs from March to October or early November with two weeks of dry spell in August. The maximum temperature ranges between 26^{0}C to 35^{0}C with an average of 30.5^{0}C and the minimum ranges from 15^{0}C to 24^{0}C with an average of 19.5^{0}C. The soil is classified s an alfisol (Smyth and Montgomery, 1962).

Four coffee plantations were selected with robusta coffee plantations of ages 6years, 19 years, 37 years and 42 years respectively. Each coffee plantation was divided into four blocks and soil samples were collected from the coffee plantations at soil depths of 0-15cm, 15-30cm and 30-45cm, using a soil auger. The soil samples collected were air-dried, passed through a 2mm sieve and some of the physical and chemical properties of the soil determined. Soil samples were analyzed for its texture, organic carbon, pH, N, P, K, Ca, Mg, Na, Cu, Zn, Mn, and Fe. CEC, base saturation and exchangeable acidity were calculated. The particle size was determined by hydrometer method, while pH was in soil-water ratio of 1:2. Organic carbon was determined by wet dichromate oxidation method. Total N by Kjeldahl method, available P by Bray 1 method. The cations were extracted with ammonium acetate and Ca, Mg, Zn, Cu, Fe, Mn were read with the Atomic absorption spectrophotometer, while K and Na were read by flame photometer. The leaf samples were put in envelopes, oven dried, milled and analyzed for some of their chemical properties.

RESULTS AND DISCUSSION

The result of the physical and chemical properties of the soil is presented in (Table 1). The soil is slightly acidic with pH of 6.6-6.9 across the 0-45cm soil depth and across the coffee plantations of different ages. This soil pH is slightly above the recommended pH of 5.1-6.5 for robusta coffee reported by Obatolu and Chude (1987).

Sand fraction ranged between 624-764g/kg across 0-45cm soil depth and across coffee plantations of different ages (Table 1). Silt fractions ranged between 194-314g/kg across the soil depths and coffee plantations of different ages. Except for the 6 year old coffee plantation, silt content decreased with increasing soil depth. Soil clay content ranged between 42-202g/kg with clay content increasing with soil depth. Soils of 6 year old plantation were loamy sand, while that of the other plantations was sandy loam.

The organic carbon in the coffee plantations ranged between 17.8-22.3g/kg, 8.4-9.2g/kg and 4.3-9.8g/kg for soil depths of 0-15cm, 15-30cm and 30-45cm respectively (Table 1), with organic carbon decreasing with increasing soil depth and increasing age of coffee plantation. Organic carbon was highest in the 6-year-old coffee plantation and least for the 42 years old coffee plantation. This decrease in organic carbon with increasing age of coffee plantation could be attributed to cropping over the years without adequate replenishment of organic materials. Though leaf litter is generated in coffee plantation, it was probably not sufficient to replenish the lost organic carbon. This coupled with the fact that the coffee plantations received no form of organic fertilization led to decrease organic carbon with increase years of cultivation.

Table 2 shows coffee soil and foliar critical levels of nutrient elements. The soil nitrogen content of the coffee plantations ranged between 0.9-2.4g/kg for 0-15cm soil depth, 0.7-1.3g/kg for 15-30cm depths and 0.60-1.20g/kg for 30-45cm depths, with N values decreasing with increasing soil depth (Table 1). The values on the topsoil were high and adequate for coffee production as it was above the soil critical level of 0.9g/kg recommended for coffee (Table 2). This high N in the soil is reflected in the high N levels in the leaf 1.56-2.00% (Fig. 1) which is higher than the foliar critical level of 1.10% required for coffee (Table 2). Similar observation was made by Ogunlade and Iloyanomon (2009) in cocoa and Iloyanomon and Ogunlade (2009) in kola plantations. N sufficiency was observed in cocoa and kola plantations of different ages. This could be attributed to leaf litter generated under these plantations. Coffee leaves contain 53kgN/ha which was 47% of N uptake by coffee plant (Coffeeasean 2008). Where these leaves are dropped as leaf litter, substantial amount of N is returned back to the soil. The leaf litter generated in these coffee plantations probably had sufficient N to meet the N needs of coffee plantations irrespective of age of coffee plantation.

Soil N was highest in the 6 year old plantation and lowest in the 19 year old plantation. There was decrease in soil N content from 6 year old coffee plantation to 19 year old coffee plantation. This could be attributed to continuous cropping of the land without nutrient replenishment. This probably led to reduction of soil N. There was also increase in soil N from 19-37 year old coffee plantation. This could be attributed to increase plant biomass, hence increase leaf litter and N from the leaf litter.

Further increase of age of the coffee plantation from 37-42 years saw a decrease in plant nitrogen. This is probably due to decreasing plant biomass with increasing age of coffee plantation which probably led to decrease in quantity of leaf litter and corresponding decrease in N.

The available P content of the soil across the coffee plantations of was between 18.45-24.10mg/kg soils (Table 1). These values are much higher than the soil critical P value of 6 mg/kg required for coffee (Table 2). This is reflected in the high P leaf content of between 0.05-0.13% P (Fig 1) which is above the foliar critical level of 0.07% (Table 2). This is in contrast with finding of (Ogunlade and Iloyanomon, 2009) and (Ogunlade and Aikpokpodion, 2006) who reported P deficiency in cocoa plantations of different ages. However, this is in agreement with (Iloyanomon and Ogunlade, 2009) who reported P sufficiency in kola plantations.

This P sufficiency in coffee plantations of different ages could be attributed to the low P removal (7kgP_2O_5) removed by coffee berries from the field on harvesting (Nelliat 1978). Similarly, one tonne of coffee has been reported to remove 7kgP_2O_5 (Jessy 2011). Coffee leaves have been reported to contain 11kg P/ha (Coffeeasean 2008). The P in the leaf litter was therefore sufficient to meet the P requirement of the coffee irrespective of the age of the coffee plantation.

The potassium content of the soil of the coffee plantation ranged between 0.07-0.30 cmol/kg soils (Table1). These values were very low as they were below the soil critical value of 0.40% (Table 2). This is reflected in the low K content of the leaf 1.12%-1.37% (Fig 1) which was well below the foliar critical level of 1.4% required for coffee (Table 2). Similar observation was made by (Carvajal 1985) who reported K depletion of up to 93% on a soil cultivated with coffee for over 22 years. This low K value could be contributed to the high demand and use of K by coffee during the berry development and ripening states. Filho *et al.* (2003) observed that the fruit was the main sink of K. Thus, harvesting of these coffee berries with high concentration of K without replenishment of the lost K through K fertilization leads to loss of K from the coffee plantations.

K requirement and absorption is highest at the berry development stage with its peak during the ripening stage (Jessy 2011). K uptake increases immediately after the main flowering at the last stage of fruit development and latter as the plant recovers from fruit bearing where water is not limiting (Jessy 2011).

Nellait (1978) and Mitchell (1988) reported that robusta coffee removes 35kg N, 7kg P_2O_5 and 89kg K_20, while the amount of nutrient required to build the coffee berries are twice the quantity removed by the coffee berries. A tonne of coffee beans has also been reported to remove 35kg N, 7kg P_2O_5 and 50kg K_2O (Jessy 2011). Thus, harvesting of these coffee berries with high concentration of K without replenishment of the lost K through K fertilization led to loss of K from the coffee plantation. Though some of the K is returned through leaf litter, the quantity is not sufficient to meet the K requirement of coffee. There is therefore need to return mined K to supplement nutrient returned back to the soil through leaf litter. The return of coffee pulp and parchment should be encouraged and appropriate K fertilizer used.

The soil calcium content in the coffee plantation ranged between 3.41-5.96 cmol/kg soil, (Table 1) across the 0-45cm soil depth and across the coffee plantations of different ages. The calcium content of these soils is much higher than the soil critical value of 0.89 cmol/kg required for coffee (Table 2). This is reflected in the high Ca content of the leaf 5.12-5.84% (Fig. 1) which is well above the foliar critical level of 0.37% required for coffee (Table 2). This is probably responsible for the slightly acidic pH of 6.6-6.9.

Soil Magnesium content in the top 0-30cm soil depth ranged between 0.84-1.31 cmo1/kg soil, (Table 1) with Magnesium content decreasing with increasing soil depth and increasing with age of coffee plantation from 6years to 37years. This increase was not observed 37 to 42 year old coffee plantation. The soil magnesium content was well above the soil critical level of 0.8cmol/kg soil required for Coffee (Egbe *et al*. 1989). This was reflected in the high foliar Magnesium content of 0.25-072% (Fig 1) which was higher than the foliar critical level of 0.31% for Coffee (Egbe *et al*. 1989).

Calcium : Magnesium ratio ranged between 3.47-6.53 (Table 1) and was highest in the 6 year old coffee plantation with mean value of 5.69 and lowest in 42 years old coffee plantation with mean value of 3.99. Calcium Magnesium ratio decreased with increasing age of the coffee plantation. These values were within the recommended 3-5 required for optimum coffee production (Coffeeasean 2008). Similarly, foliar Ca : Mg ratio ranged between 3.11-10.2% (Fig 1). This is well above the foliar critical level of 1.19% recommended for coffee (Egbe *et al*. 1989).

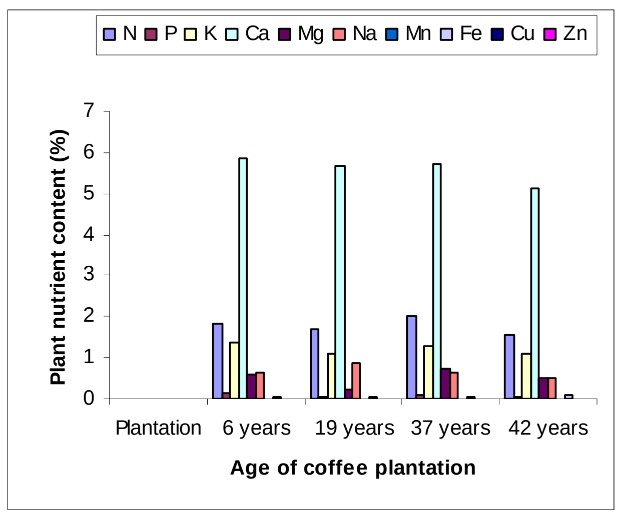

Fig. 1. Amount of nutrient (%) in leaf of coffee plantations of different ages

CEC was optimal for sandy loam and loamy soil with a range of 4.69-7.74. Zinc content of the 0-15cm, 15-30cm and 30-45cm soil depth ranged between 2.02-4.34 mg/kg, 0.97-1.66 and 0.84-1.36 mg/kg soil (Table 1) respectively across the coffee plantations with Zinc content decreasing with increasing soil depth. The zinc content of 0-15cm soil depth was within the 2-10mg/kg recommended for optimum coffee production (Coffeeasean 2008). Leaf zinc content ranged between 0.001-0.004% across the coffee plantations (Fig. 1). Except for the 37 year old coffee plantation which was slightly above the optimum leaf zinc level all the other coffee plantations fell within the recommended optimum leaf zinc level of 0.002-0.003 (Coffeeasean 2008).

Copper content ranged between 0.73-1.46 mg/kg soil across the soil depth (Table 1). This was within 0.3-10mg/kg recommended as optimum soil copper level for coffee (Coffeeasean 2008). The leaf copper content also ranged between 0.006-0.009% across the coffee plantations (Fig. 1). This was well above the optimum leaf nutrient 0016-0.002% (Coffeeasean 2008) required for coffee.

Soil Manganese and Iron content ranged between 11.76-46.36mg/kg and 6.80-10.80mg/kg respectively across the coffee plantations of different ages (Table 1), with manganese content decreasing with increasing soil depth. These values were within the recommended range of less than 50mg/kg and 2-20mg/kg soil for soil manganese and iron respectively (Coffeeasean 2008). Leaf manganese content ranged between 0.004-0.009% respectively. This was within the optimum leaf magnesium level of 0.005-0.01% for manganese. However, foliar iron content fell below the optimum leaf nutrient level of 0.07-0.2% for coffee.

CONCLUSION

Nitrogen, phosphorous, calcium and magnesium were adequate irrespective of age of coffee plantation. Potassium was insufficient to meet the nutrient requirement of robusta coffee of all ages. There is therefore need to return potassium mined from the soil through guided potassium fertilization.

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Table 1. Physical and chemical properties of soils of coffee plantations of different ages in Ibadan, Nigeria

	Age of Coffee Plantations											
	6 years			19 years			37 years			42 years		
Parameters	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
pH	6.9	6.9	6.9	6.7	6.6	6.7	6.9	6.8	6.9	6.8	6.7	6.7
Org.C (g/kg)	22.3	8.9	4.3	20.3	8.5	5.5	18.1	9.2	9.8	17.8	8.4	7.8
N (gkg)	2.40	1.30	0.60	0.90	0.70	0.60	2.00	1.30	1.20	1.50	1.10	0.90
P (mg/kg)	21.30	18.45	22.50	22.65	22.15	21.50	21.70	21.20	19.65	21.05	24.10	20.00
K (cmol/kg)	0.22	0.11	0.07	0.30	0.26	0.17	0.24	0.20	0.19	0.26	0.19	0.19
Ca (cmol./kg)	5.10	4.25	5.29	4.85	3.54	4.79	5.96	3.57	5.10	4.26	3.88	3.41
Mg (cmol/kg)	0.84	0.95	0.21	1.14	1.02	0.98	1.31	1.04	1.18	1.01	1.00	0.88
Ca:Mg(cmol/kg)	6.07	4.47	6.53	4.25	3.47	4.89	4.55	3.43	4.32	4.22	3.88	3.88
Na (cmol/kg)	0.12	0.21	0.06	1.02	0.23	0.17	1.12	0.17	0.04	0.15	0.12	0.15
Ex. Acidity(,,)	0.08	0.06	0.07	0.07	0.08	0.05	0.06	0.04	0.05	0.07	0.08	0.06
Base Sat (%)	93.74	98.92	99.04	98.94	98.42	99.18	99.22	99.20	99.24	98.78	98.48	98.72
CEC (cmol/kg)	6.36	5.58	7.02	6.59	5.07	6.11	7.74	4.97	6.61	5.75	5.27	4.69
Zn (mg/kg)	4.34	1.30	0.90	2.04	1.10	0.84	2.02	0.97	1.16	3.16	1.66	1.36
Cu (mg/kg)	0.74	0.73	0.79	0.93	0.89	0.89	0.98	1.24	1.46	1.27	1.22	1.18
Mn (mg/kg)	46.36	20.32	11.76	38.64	22.88	15.24	45.84	22.20	25.32	37.36	24.32	15.44
Fe (mg/kg)	6.80	8.40	6.80	8.00	7.60	6.80	6.80	8.00	10.80	8.80	7.20	8.40
Sand (g/kg)	764.0	744.0	744.0	624.0	704.0	704.0	664	664	624	624	704	704
Silt (g/kg)	194.0	214.0	194.0	314.0	194.0	154.0	274	194	234	254	234	234
Clay (g/kg)	42.0	42.0	62.0	62.0	102.0	142.0	62.0	142.0	142.0	82.0	142.0	202.0
Textural class	Loamy sand	Loamy sand	Loamy sand	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

Table 2. Soil and foliar critical level of nutrient elements of coffee

Soil Critical level						Foliar critical level (%)				
(g/kg)	(mg/kg)	(cmol/kg soil)	(cmol/kg soil)	(cmol/kg soil)	(cmol/kg soil)					
N	P	K	Ca	Mg	Mg/k	N	P	K	Ca	Mg
0.9	6	0.4	0.89	0.8	2	1.10	0.07	1.4	0.37	0.13