Available online at:
http://journal.unila.ac.id/index.php/tropicalsoil
DOI: 10.5400/jts.2013.19.2.85

Soil Nutrient Dynamics under Old and Young Cocoa, Coffee and Cashew Plantations at Uhonmora, Edo State, Nigeria

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Received 10 January 2014 / accepted 1 May 2014

ABSTRACT

A study was conducted to assess nutrient dynamics of soils under old and young cocoa, coffee and cashew plantations and the leaf nutrient contents of the crops at Uhonmora, Edo State, Nigeria for proper cultural and soil fertility management of the plantations. Soil and crop leaf samples were collected from each plantation using a random sampling technique. The samples were analyzed using standard procedures for sand, silt, clay, pH (H_2O), electrical conductivity (EC), total N, available P, K, Ca, Mg, Na, and Effective Cation Exchange Capacity (ECEC). Leaf samples were analyzed for N, P, K, Ca, Mg and Na. Data were compared with the corresponding soil and foliar critical nutrient values for each crop. Results indicated that the soils were texturally sandy clay loam and acidic. The soils varied in their nutrient contents, with soil P for the old cocoa, young coffee and cashew plantations far below critical values. The young cashew plot was low in N content but adequate for other plots. However, the soil ECEC increased with the increasing of calcium contents. Leaf N was below critical for all the crops. Leaf K was low for cocoa and coffee plants, leaf Ca was low for the young cashew plants, while leaf Mg was low for the young cocoa and old cashew. The high soil Mg/K ratio of 8.7- 22.3 as against the established value of 2.0 might have resulted in gross nutrient imbalance which must have affected the absorption and utilization of other nutrients. Hence, adequate soil N did not translate the same availability to the crops. The ECEC showed that the soil needs to be improved upon for sustainable productivity. Soil nutrient content variation across the plantations with age of establishment will necessitate the need for consistent routine soil nutrient assessment for proper and balanced soil nutrient supply to the crops, for healthy crop growth and optimum yield. Management practices of soil surface mulching using organic wastes and cover crops under compatible cropping systems are needed for successful plot establishment and better growth performance of the young seedlings.

Keywords: Nutrient dynamics, plantation crops, rehabilitation, soil fertility management

INTRODUCTION

Cocoa (*Theobroma cacao*), coffee (*Coffea arabica)* and cashew (*Anacardium occidentale* L.) are crops of economic importance that contributes substantially to foreign exchange earnings of Nigeria (Tijani *et al*. 2001; Famaye *et al*. 2012; Famaye *et al*. 2011). Most of the cocoa, coffee and cashew plantations are on small holdings of less than one hectare, established more than three decades ago and managed by very old men and women on self ownership or as tenant farmers (Adegeye 2000). The national output for the crops has declined from 300,000 tonnes to just 155,000 tonnes per year for cocoa (Daramola 2004; CBN 2010), 350,000 mt yr^{-1} to about 186,000 mt yr^{-1} for coffee (Ibiremo and Fagbola 2008) while cashew currently stands at 660,000 mt yr^{-1} (FAO 2010; Scott and Riggs 2011).

The current global economic meltdown and unstable world petroleum price has resulted to substantial fall in the foreign earnings from crude oil to Nigeria economy. This has prompted the Federal Government of Nigeria to look inward to improving on the agricultural sector of the economy. In the light of this, cash crops of foreign exchange earnings like cocoa, coffee and cashew become very relevant. With the current initiative on Agricultural Transformation Agenda of the Federal Government of Nigeria, efforts are being geared towards rehabilitation of old, abandoned and moribund cocoa, cashew and cashew farms as well as opening up of new plantations.

Most soils under cocoa, coffee and cashew production in Nigeria are marginal to moderately suitable in fertility status (Egbe *et al*. 1989). Soils under these plantations therefore requires good cultural and fertilizer management techniques to achieve optimum crop production on sustainable basis. Due to inadequate quantity of fertilizer supply and the high procurement cost (Agbede and Kalu 1995), most farmers do not use fertilizer (Iremiren 1989) and the farms therefore depend on native soil nutrient supply. Over the years research efforts have indicated that there was short supply of N, P, K and Mg on soils under cocoa, coffee and cashew plantation resulting from nutrient mining from harvests of cocoa pods, coffee berries and cashew apple and nuts, which subsequently results in nutrient deficiency symptoms and low yields (Wood and Lass 1985; Mamani-Pati *et al*. 2012). The soil nutrient factor has therefore been found to be very important in the production of cocoa, coffee and cashew in Nigeria (Ipinmoroti *et al*. 2011; 2006; Ipinmoroti and Akanbi 2012). The evaluation of the soil physical suitability and constant monitoring of soil and leaf nutrient status have been advocated, to ensure appropriate farm management and optimal fertilizer usage for profitable arable and tree crop production in Nigeria (Ayoola and Agboola 2002; Egbe *et al*. 1989).

This investigation was conducted to assess the nutrient status of old and young plots of cocoa, coffee and cashew in Cocoa Research Institute of Nigeria experimental station at Uhonmora, Edo State, Nigeria.

MATERIALS AND METHODS

Six plots which were made up of a very old cocoa plot established in 1949 (old), a juvenile cocoa plot established in 2012 (young), coffee plots established in 1996 (old), coffee plot established in 2007 (young), cashew plot established in 1971 (old) and a juvenile cashew plot established in 2011 (young) at CRIN Uhonmora Station (6^O 53'N and 5^O 58'E). Each of the six plots was 1.0 ha and were demarcated into four sub-plots of 0.25 ha size where 10 soil samples were collected using a random sampling technique. Soil samples were collected from 0 -30 cm soil depths from each sub plot using soil auger. Leaf samples for each of the plots and crops were collected from the fourth leaf on the branches of the four adjacent trees next to the point of soil sample collections.

The soil samples were air dried, sieved through 2 mm sieve and the 10 samples per sub-plot were thoroughly mixed to form a uniform composite sample. Four composite samples were then obtained per plot to give a total of 24 composite samples from the 6 plots. The composite samples were analyzed for sand, silt, clay, pH (H_2O), EC, total N, organic carbon (OC), available P, exchangeable K, Ca, Mg, Na, and Effective Cation Exchange Capacity. Soil particle size distribution was by hydrometer method, while the soil pH was in soil/water ratio of 1:2.5 and read with electronic pH-meter. Soil total N was determined by micro-kjeldah method (Bremmer 1996) and available P was by Bray 1 method (Bray and Kurtz 1945). The exchangeable bases were extracted by 1*N* NH_4OAC at pH 7 and the K, Ca, Mg and Na contents were read using atomic absorption spectrophotometer (Tel and Rao 1982) and the ECEC was by titration. The electrical conductivity was determined in 1:2 soil/water ratio using conductivity bridge (Rhoades 1982). Leaf samples were analyzed for N content by micro-kjeldah approach and P by vanadomolybdate colorimetry (IITA 1979). The K, Ca, Mg, were read using atomic absorption spectrophotometer (AAS). Nutrient values of the composite soils per plot were averaged and compared across the plots with the soil critical values. Leaf sample results were also compared across the plots with the corresponding leaf nutrient critical values. This was done for appropriate soil and fertilizer management needs for continuous optimal and sustainable cocoa, coffee and cashew plant yield performance.

RESULTS AND DISCUSSION

Soil Particle Size Analysis

The soils of the plantations varied in their sand, silt and clay contents. Sand ranged from 757-857 g kg^{-1}, silt 111-191 g kg^{-1} and clay 32-52 g kg^{-1} (Table 1). The soils were generally sandy clay loam in texture. The silt + clay values ranged from 143-246 g kg^{-1} soil, which falls below 320 g kg^{-1} soil considered optimal for better water retention for most tree crops (Egbe *et al*. 1989). This indicated that the soils might not retain and supplied sufficient water to meet the needs of the plantation crops. There will be a need for irrigation, most especially over a long period of dry spell. Sufficient water supply, most importantly during flower and fruit settings for the crops, is very critical. The failure of water supply at such a time will lead to flower and fruit abortions with resultant low fruit yield. The plantation soils could be better managed by making sure that plantation canopies were covered by not allowing missing stands, while the plantation floor was covered with leaf litter falls to serve as preventive measures against loss of soil water through evaporation (Loria 1999; Ogunlade and Iloyanomon 2009).

Good agricultural management practices on young plantations of these crops will require the use of soil surface mulching by the use of organic wastes and cover crops under special cropping systems that are compatible with each of the plantation crops for successful plot establishment and better growth performance of the young seedlings. At the Cocoa Research Institute of Nigeria (CRIN), various cropping systems have been found suitable and adaptable to the various crops which includes: cocoa/ plantain/maize, cocoa/oil palm in hollow-square arrangement, cocoa/plantain/rice for cocoa (Famaye *et al*. 2010); coffee oil palm, coffee/melon, coffee/ soybean, coffee/maize for coffee (Famaye *et al*. 2012) and cashew/maize, cashew/cowpea, cashew/ soybean, cashew/plantain for cashew (Famaye and Adeyemi 2011). The organic wastes, mulch and vegetative covers would help to reduce surface water loss through intense evaporation that could result through the high sun isolation and heat that was characteristic of tropical conditions, coupled with the changing climatic conditions.

Soil pH

The soil pH values between the young and old plantations differ across the crop types (Table 1). The soil of Uhonmora area was characterised with pH value of 6.5. For the cocoa plantation, the young cocoa still maintained the native pH value of 6.5, while the older cocoa plantation had its soil pH increased to 6.9. This indicated an improvement on the soil pH condition, which might probably be due to the thick layer of leaf mat that was peculiar of old cocoa plantations. The leaves help to cover the soil surface, reduced erosion and under-go gradual decomposition which must have helped to increase the soil pH level.

The young and old coffee plantations with pH values of 5.8 and 5.9 were similar. This showed that similar chemical reactions were taking place in the two plantation soils. Coffee plant geometry allowed for interplant row spaces which were left bared and made rainfall impacts to be seriously felt and soil surface layer prone to erosion and seepages. The young and old cashew plantations differed greatly in their soil pH values. This was expected in that soils under cashew cultivation were noted for their acidic conditions with pH range of 4.5 – 5.5 (Owaiye 1989). The older the cashew plantation was, the more acidic the soil condition became. This results from built up of natural biochemical exudates from cashew roots in the rhizosphere that made the soil to be acidic. Hence, the old cashew plant with pH 5.1 compared with 6.1 for the young cashew plot showed that greater amount of root exudates had been released over the years by the cashew plants in the old cashew plot compared with the young cashew plot. The old cashew plot therefore need soil amendments to increase the soil pH value from time to time by application of liming materials, slurry wastes and manures (Onwuka *et al*. 2009; Nikoli and Matsi 2011; Whalen *et al*. 2000).

Soil EC and ECEC

The soil electrical conductivity (EC) ranged from 12.1-30.6 ds m^{-1} (Table 1). The EC was highest for the young cocoa plantation and least for the old coffee plantation. The values therefore increased with increase in Mg content except in the young and old cashew plots. The soil effective cation exchange capacity (ECEC) was observed to increase as Ca content increase. The ECEC value was lowest for the young cashew plot with a value of 6.48 cmol kg^{-1} soil, while it was highest for the young cocoa plantation with a value of 29.46 cmol kg^{-1} soil (Table 2). The plantations ECEC showed that the soils naturally may have depend on the decomposed materials as organic matter for its nutrient exchangeable sites and nutrient availability to crops (Ayoola and Agboola 2002). This was true in that Nigerian soils were noted to be very low in clay content of 32-52 g kg^{-1} that were mainly of kaolinitic type which were inherently low in ECEC (Ogunwale *et al*. 2002). This showed that soil organic matter contents need to be improved upon for sustainable productivity on the soils.

Soil Total N Content

The soil total N content ranged from 0.12-0.22 g kg^{-1} (Table 2) for the cocoa and coffee plantations. These values were above the critical levels of 0.09 g kg^{-1} for soils ideal for cocoa and coffee production. However, the values of 0.12 and 0.14 g kg^{-1} for the old plantation of coffee and cocoa respectively showed that adequate and proper management techniques that would improve on the N build up was necessary to avoid N inadequacy on the long run which might result due to harvest of berries from coffee and pods from cocoa. A harvest of 1.0 t of cocoa lead to a loss of over 45 kg N ha^{-1} (Wood and Lass 1985) while for coffee; it was about 54-57 kg N ha^{-1} (Mamani-Pati *et al*. 2012). The young cocoa and coffee plantations did not need N fertilizer application until the commencement of pod and berry harvest, at which time, the amount of N fertilizer need should be based on yearly harvest removal.

On the other hand, total N content for the old cashew plantation was well above critical value of 0.1 g kg^{-1} while that of the young cashew was far below critical value. The young cashew plot therefore needs N supplement. The variation in the soil nutrient contents across the plantation types and age of establishment necessitate the need for routine soil nutrient assessment in order to have the correct soil nutrient status for proper and balanced soil nutrients, for healthy crop growth and optimum yield.

Soil Available P

The soil available P content was highest for the young cocoa plantation with value of 22.93 mg $^{-1}$. The cocoa plantation value of 22.93 mg kg^{-1} P for the young cocoa plantation was adequate for sustainable cocoa growth and production, while the 8.93 mg kg^{-1} P value for the old cocoa plantation was far below the critical value of 10.0 mg kg^{-1}. Similar low level of available P values has been reported for soils under cocoa cultivation in Nigeria, for which the use of P supplying fertilizers has been advised (Ogunlade and Iloyanomon 2009). The soil under old coffee and cashew plantations had available P values which were well above critical levels of 6.0 and 3.7 mg kg^{-1} P established as suitable for coffee and cashew respectively, while the young coffee plantation with value of 1.24 mg kg^{-1} and the young cashew plantation with 2.25 mg kg^{-1} soils were all below the critical values for the crops. The adequate level of P in the old plantation of coffee and cashew might be due to addition from decomposition of litter falls on the plantations over the years.

Exchangeable Cations

The soil Ca contents ranged from 2.88 to14.8 cmol kg^{-1}, Mg contents 3.28-11.92 cmol kg^{-1} and K 0.25-1.37 cmol kg^{-l}. (Table 2). The soil Ca values for each of the plantation crops were above their critical values of 5.0 cmol kg^{-1} for cocoa, 0.89 cmol kg^{-1} for coffee and 0.8cmol kg^{-1} for cashew; Mg value was above critical value of 0.8 cmol kg^{-1} for the three plantations and K critical value were also above the established value of 0.3 cmol kg^{-1} for cocoa, 0.4 cmol kg^{-1} for coffee and 0.12 cmol kg^{-1} for cashew for K, respectively. The general low nutrient content for the young cashew plot must have been due to nutrient removal over the years through arable crop harvest without replacement because of lack of fertilizer usage. The soil Na contents of 0.22 – 0.38 cmol kg^{-1} soils were within the limits that could neither lead to soil structural impairment nor nutrition imbalance.

Plant Macronutrient Contents

The leaf N contents of the crops ranged from 0.40-0.56% (Table 3). The values were higher for the old coffee and cashew plants than for the young plants, while it was higher for the young cocoa plants than for the old cocoa plants. The leaf N values were generally below the leaf critical level for all the crops with values of 1.8% for cocoa, 1.1% for coffee and 1.24% for cashew. The adequate level of total soil N did not translate to availability of N to the plantation crops. This shows that N in the soil was not readily available for uptake by the plantation crops. This might be due to competition for the nutrient by weed and fixation into non-available forms in the soil that it was not accessible by plants. The level of soil N may be linked to the organic matter in the soil which may however translate to availability of the soil N for crop usage (Ayoola and Agboola 2002).

The leaf P contents for the crops ranged from 0.14-0.29% (Table 3). It was highest in the cocoa plants compared to other crops. The individual crop P value was higher compared to their leaf critical level of 0.2% for cocoa, 0.07% for coffee and 0.12% for cashew. The K contents for the young cocoa plants was 0.8% and 1.11% for old cocoa and this was below the critical value of 2%. Similar trend was obtained for the coffee plants with values of 1.14% for the young and 0.95% for the old coffee plants, which were below the critical value of 1.40 %. The leaf K content for cashew plants ranged from 0.58 – 0.81% and were however higher than the critical value of 0.34%. The cocoa and coffee plantations therefore need K fertilizer application in order to meet the crop demands.

The plant leaf Mg contents ranged from 0.05-0.90% (Table 3). The value was below critical value of 0.5% for the young cocoa but above for the old cocoa. For coffee, it was above critical level of 0.13% for both the young and old coffee plants. However, the old cashew was deficient in Mg content with value of 0.05% compared with the critical value of 0.18%. The high level of Mg in the soil with the low K value might have resulted to gross nutrient imbalance which must have affected the absorption and utilization of other nutrients. The Ca content ranged from 0.88-2.08% (Table 3). The value was lowest for the young cashew plants but for all of the other crops, their leaf Ca contents were above their critical values. The leaf Na contents were between 0.01-0.04 percent. The Na values were generally low that it could not cause any nutritional upset in metabolic activity of the crops.

CONCLUSIONS

The investigation revealed that there were great differences in the soil and leaf nutrient contents between the old and new plantations across the crop types. Since the deficiency and sufficiency levels of the various nutrient are specific to individual plantation the management practices to be adopted for optimal production at sustainable level will depend on the soil inherent characteristics and nutrient contents of the plantation crop.

ACKNOWLEDGEMENT

The authors acknowledged the management of Cocoa Research Institute of Nigeria for permission to publish this work.

REFERENCES

Adegeye A J. 2000. 'Nigerian Agriculture: Reaping Where We Do Not Sow' In Tropical Issues in Nigerian Agriculture: Desirable and Workable Agricultural Policies for Nigeria in the First Decade of the 21st Century. Department of Agricultural Economics, University of Ibadan, Ibadan, Nigeria.

Agbede OO and BA Kalu. 1995. Constraints of small-scale farmers in increasing crop yields: farm size and fertilizer supply. *Niger J Soil Sci* 11: 139-152.

Ayoola OT and AA Agboola . 2002. Influence of cassava planting patterns and organic/inorganic fertilizer source on the growth and yield of maize in cassava/ maize/melon intercrop in southwest Nigeria. *Moor J Agric Res* 3: 161-168.

Bray RA and LT Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Sci* 59: 39-45.

Bremmer JM. 1996. Methods of Soil Analysis, Part 3. Soil Science of America and America Society of Agronomy, SSSA Book series No. 5, Madison, USA.

CBN. 2010. Central Bank of Nigeria (CBN) Annual Report and Statement of Accounts for the year. Abuja, Nigeria. pp 182.

Daramola AG. 2004. Competiveness of Nigerian Agricultural in a Global Economy: Any dividends of Democracy? Inaugural Lecture Series 36, Federal University of Technology, Akure, Nigeria.

Egbe NE, EA Ayodele and CR Obatolu. 1989. Soils and nutrition of cocoa, coffee, kola cashew and tea. *Progress in Tree Crop Research*, 2: 28-38.

Famaye AO, GO Iremiren, AA Oloyede and KB Adejobi. 2010. Evaluation of Nutrient Uptake in an Intercropped Cocoa. *Niger J Soil Sci* 20: 92-84.

Famaye AO and EA Adeyemi. 2011. Effect of cashew/ rice/plantain intercropped on weed incidence in Edo State, Nigeria. *ARPN J Agric Biol Sci* 6: 62-65.

Famaye AO, GO Iremiren, K Ayegboyin and KB Adejobi. 2012. Evaluation of coffee intercropped with rice and plantain at early stage of field establishment in Nigeria. *J Agric Sci* 3: 347-350.

FAO. 2010. Food and Agriculture Organization of the United Nations 2010. Retrieved 21st, January 2010. www.fao.org

Ibiremo OS and O Fagbola. 2008. Effect of phosphorus fertilizer and abscular mycorhizal fungi inoculation on the growth of cashew seedlings in two soils in Nigeria. *Niger J of Soil Sci*18: 138-146.

IITA. 1979. Selected Methods for Soil and Plant Analysis. Manual Series No.1. International Institute of tropical Agriculture, Ibadan, Nigeria.

Ipinmoroti RR, LA Adebowale M, O Ogunlade, GO Iremiren and GO Adeoye. 2006. Effect of inorganic and organic nutrient sources on growth, dry matter yield and nutrient uptake of Coffee (*Coffea canephora* L) seedlings. Proceedings International Coffee (ASIC) Conference, France, 13-19 September, 2006: 1196-1198.

Ipinmoroti RR, OSO Akanbi and EA Adeyemi. 2011. Cocoa seedlings performance as influenced by NPK, Manure and Micfert Fertilizers in the green house. Proceedings of the Second Technical Workshop on Organic Agriculture in Nigeria held at National Horticultural Research Institute (NIHORT), Ibadan, Nigeria from 12 – 16th Sep. 2011. pp. 91- 95.

Ipinmoroti RR and OSO Akanbi. 2012. Relative Effect of NPK and Organic Fertilizers on Growth Performance of Cashew Seedlings on Depleted Soils at Ibadan, Nigeria. *Niger J Soil Sci* 22: 137-141.

Iremiren GO. 1989. Response of maize to trash burning and nitrogen fertilizer in a newly opened secondary forest. *Camb J Agric Sci* 113: 207-210.

Loria SA. 1999. Litter Fall: The Most Wanted Waste. The Ecosystems Research and Development Bureau, Department of Environment and Natural Resources 25 J. Canopy International, Philippines, pp 12.

Mamani-Pati F, DE Clay, SA Clay, H Smetekop and MA Yujra-Callata. 2012. The Influence of Strata on the Nutrient Recycling within a Tropical Certified Organic Coffee Production System. ISRN Agronomy Vol. 2012 Article ID 389290, 8 pages, 2012. doi 10.5402/2012/389290.

Nelson DW and LE Sommers. 1982. Organic Carbon and Soil Extracts. In: Methods of Soil Analysis. Part 2- Chemical and Microbiological Properties. Agronomy Monograph No.9, 2nd Edition. American Society of Agronomy, Soil Science Society of America, Madison, WI, pp. 539-579.

Nikoli TH and TH Matsi. 2011. Influence of liquid cattle manure on micronutrient content and uptake by corn and their availability in a calcareous soil. *Agron J* 103: 113-118.

Ogunlade MO and CI Iloyanomon. 2009. Leaf litter fall and soil Nutrient Status under Cocoa Plantations of Different Ages in Ibadan, Nigeria. *Niger J Soil Sci* 19: 25-28.

Ogunwale JA, JO Olaniyan and MO Aduloju. 2002. Morphological, physico-chemical and clay mineralogical properties of soils overlaying basement complex rocks in Ilorin East, Nigeria. *Moor J Agric Res* 3: 147-154.

Onwuka MI, VE Osodeke and AO Ano. 2009. Use of liming materials to reduce soil acidity and affect maize (*Zea mays* L.) growth parameters in Umudike, Southeast Nigeria. *Prod Agric Technol J* 5: 386-396.

Owaiye AR. 1989. Effects of soil acidity on germination, growth and performance of cashew. Cocoa Research Institute of Nigeria (CRIN) Annual Report 1989; pp 49-52.

Rhoades JD. 1982. Soluble salts. In: A.L. Page, R.H. Miller and D.R. Keeney (eds). Methods of Soil Analysis Part 2: Chemical and Microbiological Properties. Soil Science Society of America, Inc., Madison, WI, pp 167-179.

Scott S and NJ Riggs. 2011. Top five cashew nut production countries of the world. Retrieved 26th, January 2011.http://www.top5ofanything.com/index.php?h=091ebdca

Tel D and F Rao. 1982. Animated and semi-anotamated methods for soil and plant analysis pp 201-207.

Tijani AA, AJ Farinde and AF Agboola. 2001. Measuring the impact of Extension on Cocoa Production in Ondo State, Nigeria. *Moor J Agric Res* 2: 186-190.

Whalen JK, C Chang, GW Clayton and JP Carefoot. 2000. Cattle manure amendments can Increase the pH of acid soils. *Soil Sci Soc Am J* 64: 962-966.

Wood GAR and RA Lass. 1985. Cocoa, 4th ed. London: Longman, 620- 632.