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Influence Of Soil Conditions on the Growth of Duka Nut (*Irvingia gabonensis var*) In Mid Western Nigeria

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ABSTRACT

Duka nut (Irvingia gabonensis var) is widely cultivated in mid western Nigeria, but mostly by peasant farmers. Little information is available on the agronomy of the crop, particularly those that relate to its nutrition with soils. This paper examines the composition of the soil of this region and its relationships to the growth of the crop in plantation. Multiple regression analysis revealed that topsoil pH, organic matter, and extractable nickel contents, as well as the electrical conductivity, total nitrogen, and available phosphorus of subsoil were the most significant or crucial soil properties influencing the growth of the crop in Midwestern Nigeria.

INTRODUCTION

Food shortage is a major component of poverty in Africa. The African food crisis emanated mainly from the inability of most African countries (especially Sub-Saharan Africa) to produce enough food for the region. A number of reasons are responsible for this condition. These include:

(i) decline in yield of cultivated crops resulting largely from environmental degradation;

(ii) changing socio-economic conditions, which have made farming unattractive and have, therefore, forced able bodied youths into other, more rewarding informal sector jobs;

(iii) crop failures are due to the changing climatic conditions, especially the decline in rainfalls and increasing desertification; and

(iv) rapid population growth (Agboola, 1979).

It has recently been proven that low per capita food production in African countries has added to trade deficits in many of these countries and food import bills have also risen astronomically. There have been several efforts at increasing food production, either through intensive cropping or expansion of cultivated areas. In either case the potential for soil degradation has been identified (Lombin, 1986).

Crop production involves a complex interaction between the environment, soil parameters, and nutrient dynamics (Ukpong and Moses, 2001). Because of this fact, the soil must be studied in terms of the productive potentials. It is also important to understand environment – crop relationships. Failure to understand these complexities has resulted in lack of good crop production and management techniques; hence agricultural production has tended to be low.

In Nigeria, and elsewhere in the tropics, extensive studies have been carried out on many tree crops including cocoa (Ekanade 1985a, 1985b, 1988), kola nut (Egbe, 1977; Ekanade and Egbe, 1990), rubber (Pushiparajah 1969, 1977; Aweto, 1987); oil palm (Aweto and Ekuigbo, 1994; Ogidiolu, 1995, 2000); cashew (Aweto and Isola, 1995). So far, the findings have shown that different tree crops have different interactions with soil properties. Conspicuously absent in the literature is the interrelationships between *Irvingia gabonensis* and the soils. Two strains of this tree are widely grown in Nigeria, the sweet types with fleshy succulent mesocarp, which is highly edible; thereby, commanding high price in domestic markets and the bitter varieties with hard, strong fibrous mesocarp. The sweet strain is a major staple food item in Southern Nigeria where it is used for preparing soup. The tree itself has other commercial importance. Recent trend indicates a decline of emphasis in its cultivation amongst peasant farmers either due to its long maturity period or poor yield (Opeke, 1978). The aim of this study is to examine the relationships between soil and growth of *Irvingia gabonensis (var)* with a view to identifying the soil properties that substantially influence the growth, hence, productivity of the crop. The outcome of this study should form the basis formulating agronomic/management strategy for the cultivation of the crop in south western Nigeria.

STUDY AREA

The study was conducted around Auchi (Lat. 7^o 05' long. 6^o16') metropolis using a plantation which covers an area of about 2.5ha (Figure 1). The specific plot was planted with *Irvingia gabonensis*, whose age is about 20 years. The plantation is located within the Savanna woodland belt of Midwestern Nigeria. The climate of the area is the tropical wet and dry type characterized by a high mean annual temperature (about 29.^{0}C) with an annual temperature range that rarely exceeds 50^{0}C and a mean annual rainfall of about 1400mm. In general, the study area overlies metamorphic rock of the Basement complex, the majority of which are of the Precambrian age (Short and Stuble, 1967). More specifically the plantation studied is underlain by coarse-grained granites and gneisses. The soils are sandy, deeply weathered ferruginous soils and have been intensely leached. The natural vegetation is the savanna woodland, but it is now covered by fallow regrowths and tree plantation, usually monocultural plantation of exotic species, such as *Tectona grandis* and *Gmelina arborea.*

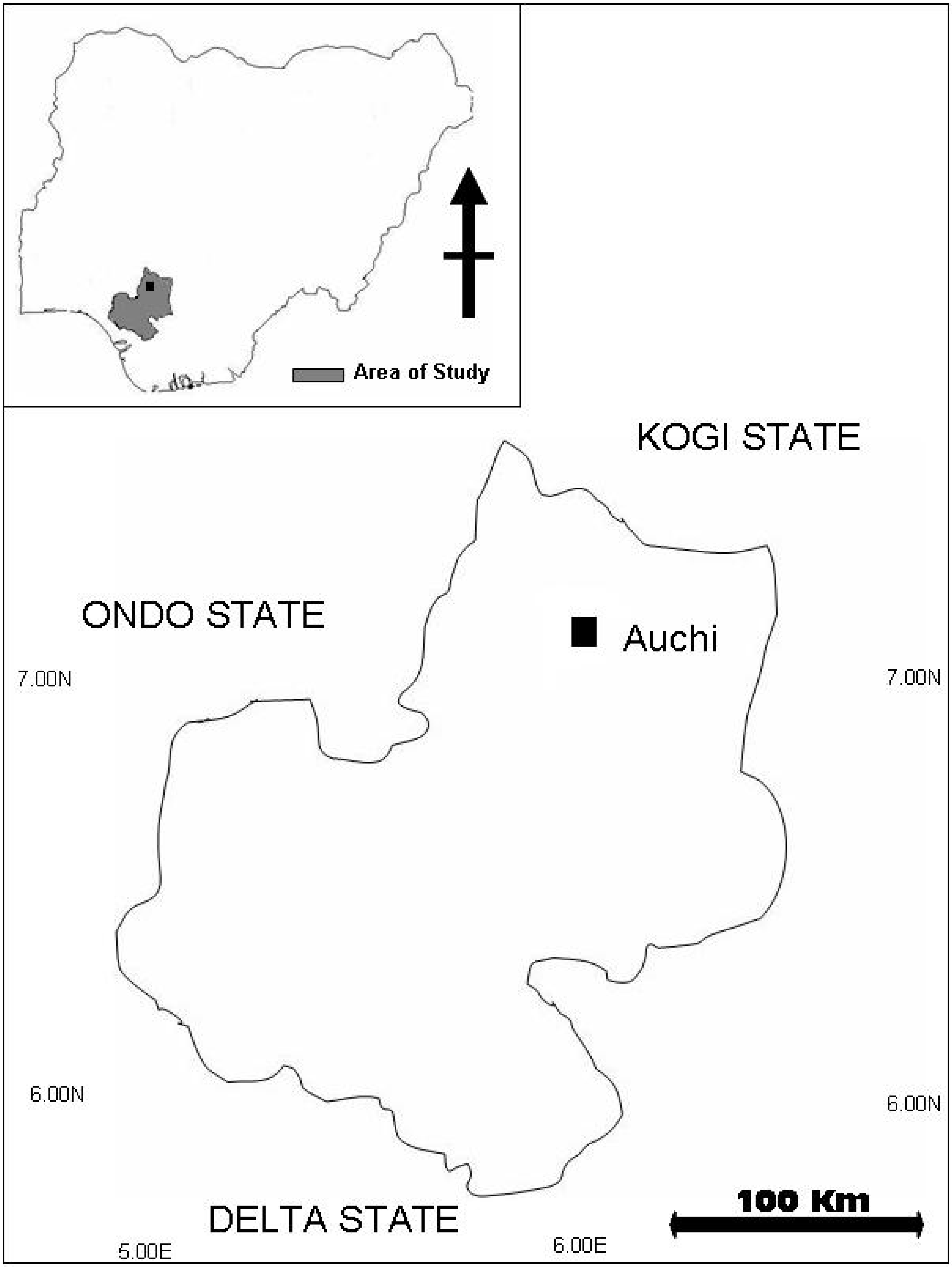

Fig 1: A Map of Edo State showing the Study Area

MATERIALS AND METHODS

Sampling

A crucial issue in quantitative plant ecology is the selection of sample from which data is to be collected. This is because the reliability of the final conclusions depends largely on how well the data have been built (Kershaw, 1985). Sampling design for this study was based on two premises: first, the need to spread sample sites objectively over the study area and second, the need to ensure that plant and site characteristics are adequately depicted.

The entire plantation (2.5ha plot) was divided into 100 plots of 25m x 25m. Twenty-five (25) of these plots were randomly selected for soil and plant sampling.

Soil Sampling

From each of the 25m x 25m quadrant, five (5) soil samples were randomly collected from two sampling depths 0–15cm and 15–30cm, hereafter referred to as topsoil and subsoil, respectively. The sampling was restricted to this zone because it provides the bulk of plant nutrients (Russell, 1978). Soil samples were air-dried, sieved, and analysed in the laboratory using standard techniques. Particle size composition was obtained by hydrometer method (Bouyoucos, 1962). Soil pH was determined potentiometrically in 0.01m calcium chloride using a soil to calcium chloride solution ratio of 1:2 (Peech, 1965). Organic carbon was determined by the Detjareff method (Walkley and Black, 1934). The value of organic matter was obtained by multiplying organic carbon by 1.724. Extracts of soil sample leached with 1NB ammonium acetate were used to determine the concentrations of exchangeable cations, thereafter Ca, K and Mg were determined by atomic absorption and Na was determined by flame photometry. Exchange acidity was determined by extraction with barium acetate and titration with NaOH (Jackson, 1962). Cation exchange capacity (CEC) was obtained by summation of exchangeable cations and exchange acidity. Total nitrogen was determined by the Kjedahl method and available phosphorus was determined by the Bray method (Jackson, 1970). Base saturation was computed as the percentage of the total CEC occupied by cations. Extractable micronutrients (Zn, Cu, Ni, and Mn) were measured after extraction with 0.02M EDTA using atomic absorption spectrophotometer (Isaac and Korber, 1971).

Sampling for Plant Characteristics

In each of the 25 square meter plot, five growth characteristics, which have been found to be related to yield (Bada, 1981; Ogidiolu, 1997), were measured. These are: total or top height, diameter at breast height, basal area, bole volume, and crown diameter. The mean value of each parameter was recorded for the plot. Top height was measured with a Hagar altimeter. Basal area was measured with a girthing tape. Bole volume was computed using Spurr and Barnes (1980) volume equation and basal area was estimated from a known relationship with diameter at breast height using the formula A=∏d, where d= diameter at breast height (Husch, 1963). Crown diameter was obtained by the crown diameter method (Mueller–Dombois and Ellengberg, 1974). Multiple regression analysis techniques were used to determine the effect of variation in soil properties on the growth of crops. Descriptive statistics, such as mean, standard deviation, and coefficient of variation were used to further analyze the data.

RESULTS AND DISCUSSION

The physical and chemical properties of soils under *Irvingia gabonensis* are shown in Tables 1 and 2. The soil contain a high proportion of sand (more than 80% of the mineral fragments), hence the soil of this area is sandy. The electrical conductivity of the soil is high. The value in the topsoil is about 90.1. Electrical conductivity is a measure of the rate of water transmission in soils; therefore, the high value obtained in this study may be due to the sandy texture of the soils, which enhances free water flow (Lombin, 1986). Soil pH reveals that the soil is mildly acidic. This condition in soil is favorable to nutrient uptake by plants (Tisdale and Nelson, 1975). Organic matter content especially is the topsoil is moderate with a mean value of 3.74%.

The exchangeable cations occur in moderate concentrations, with calcium being the most abundant. The level of exchangeable cations in this soil is adequate compared to the values which Jones and Wild (1975) reported are required for high fertility in Savanna soils. Total nitrogen and available phosphorus are also high, especially in the topsoil layer.

Table 1: Descriptive Statistics of Topsoil Proper (0 – 15cm) in the Study Area

Soil Properties	Mean	Standard Deviation (±)	Coefficient of Variation (%)
Sand (%)	89.3	10.82	12.1
Silt (%)	6.10	0.82	13.2
Clay (%)	4.90	0.59	12.0
Electrical Conductivity	90.1	17.29	19.1
PH (Cac_{l2})	5.83	1.44	24.7
Organic Matter (%)	3.74	0.55	14.7
Exch. Na^{+} (mmol Kg^{-1})	0.15	0.04	26.7
Exch. Ca^{++} (mmol Kg^{-1})	3.85	0.82	21.3
Exch. Mg^{++} (mmol Kg^{-1})	0.85	0.08	9.75
Cation exchange capacity (mmol Kg^{-1})	5.27	0.77	14.6
Exchange acidity (mmol Kg^{-1})	0.32	0.17	53.1
Available phosphorus (ppm)	45.88	6.97	15.2
Total nitrogen (%)	0.81	0.10	1.13
Base saturation (%)	84.90	6.95	8.19
Zinc (%)	0.48	0.34	70.8
Nickel (%)	2.55	0.54	21.2
Copper (%)	0.60	0.22	36.7
Manganese (%)	0.93	0.61	65.6

Source: Field work, 2007

Table 2: Descriptive Statistics of Subsoil Properties (15 – 30cm) in the Study Area

Soil Properties	Mean	Standard Deviation	Coefficient of Variation (%)
Sand (%)	84.5	8.64	10.2
Silt (%)	8.80	0.38	4.30
Clay (%)	6.70	0.32	4.75
Electrical Conductivity	51.9	17.8	14.8
pH ($CaCl_2$)	5.67	0.84	14.8
Organic Matter (%)	0.90	0.29	32.2
Exch. Na^+ (mmol Kg^{-1})	0.13	0.02	15.38
Exch. K^+ (mmol Kg^{-1})	0.13	0.01	7.69
Exch. Ca^{++} (mmol Kg^{-1})	3.34	0.17	5.09
Exch. Mg^{++} (mmol Kg^{-1})	0.79	0.12	15.2
Cation exchange capacity (mmol Kg^{-1})	4.68	0.78	16.7
Exchange acidity (mmol Kg^{-1})	0.29	0.14	48.3
Available phosphorus (ppm)	49.76	21.4	43.0
Total nitrogen (%)	0.14	0.01	7.14
Base saturation (%)	80.43	17.1	21.3
Zinc (%)	0.54	0.10	18.5
Nickel (%)	2.10	0.56	26.7
Copper (%)	0.80	0.44	55.0
Manganese (%)	0.22	0.10	45.4

Source: Field work, 2007

Table 3 gives the growth characteristics and reveals that they all show moderate variations within the plantation.

To establish the relationship between growth characteristics and soil parameters, stepwise multiple regression procedure was employed. The exact nature of the interrelationships was also depicted by correlation analysis. Tables 4 and 5 show the interrelation matrix of soil and plant characteristics for topsoil and subsoil, respectively.

Table 3: Descriptive Statistics of the Growth Characteristics

	Mean	Standard Deviation	Coefficient of Variation (%)
Top height (m)	18.18	0.87	4.78
Diameter at breast height (cm)	64.2	2.72	4.24
Basal area (m^2/ha)	50.3	0.03	0.61
Crown diameter (cm)	18.60	0.71	3.8
Bole volume (M^2/ha)	90.36	0.20	18.8

Source: Field work, 2007

Sand is the only textural class that shows significant correlation (0.50)=($P\geq0.05$) with all growth parameters in the topsoil, but not in the subsoil. The positive correlations tended to suggest that it plays some positive role in plant growth and exhibits significant positive correlations with most parameters. Soil acidity (measured by pH) is known to have significant influence on nutrient availability and its uptake in soils. The observation in this paper reveals that at high pH value, growth of *Irvingia gabonensis* is likely to be high, because this condition enhances nutrient availability and easy uptake (Ogidiolu, 1990). Other important relationships revealed by the correlations analysis between growth characteristics and topsoil properties include those between nitrogen and all the growth parameters. As indicated in Table 4, the results are as follows: nitrogen and total height (r=0.79), diameter at breast height (r=0.80), basal area (r=0.77), bole volume (r=0.84), and crown diameter (r=0.68). The high significant ($P\leq0.05$) correlations between the micro nutrients (Ni, Zn, Cu, and Mn) may not be unconnected with the influence they have on soil pH and by extension on plant growth and development. High concentration of micro nutrients increases acidity of soil. Highly acidic soil reduces availability of micro nutrients and, therefore, reduces the growth of crops. The subsoil, however, presents a different scenario for the same elements (Zn, Ni,Cu,Mn), probably because the elements have lower concentration in the subsoil. Some subsoil properties notably, electrical conductivity, total nitrogen, and available phosphorus exhibit significant correlations with growth parameters.

Table 4: Correlation Coefficients Between Growth Parameter and Topsoil Properties

Soil properties	Total height	Diameter at breast height	Basal area	Crown diameter	Bole volume
Sand (%)	0.60	0.57	0.56	0.56	0.59
Silt (%)	0.48	0.37	0.42	0.43	0.33
Clay (%)	0.50	0.47	0.48	0.43	0.42
Elect. Conductivity	0.62	0.68	0.65	0.59	0.61
pH ($CaCl_2$)	0.70	0.89	0.80	0.89	0.79
Organic Matter (%)	0.70	0.69	0.63	0.64	0.67
Exch. Na^+ (mmol Kg^{-1})	0.08	-0.32	0.02	0.02	0.03
Exch. K^+ (mmol Kg^{-1})	0.32	0.38	0.44	0.46	0.31
Exch. Ca^{++} (mmol Kg^{-1})	0.52	0.69	0.54	0.58	0.57
Exch. Mg^{++} (mmol Kg^{-1})	-0.13	-0.22	-0.24	-0.08	-0.19
Cation exchange capacity (mmol Kg^{-1})	0.48	0.60	0.45	0.56	0.49
Exchange acidity (mmol Kg^{-1})	0.70	0.68	0.70	0.70	0.74
Available phosphorus (ppm)	0.38	0.36	0.33	0.26	0.28
Total nitrogen (%)	0.79	0.80	0.77	0.68	0.84
Base saturation (%)	0.46	0.56	0.55	0.52	0.48
Zinc (%)	-0.29	0.36	-0.27	-0.36	-0.42
Niickel (%)	-0.82	-0.80	-0.76	-0.74	-0.90
Copper (%)	-0.40	-0.24	-0.44	0.41	-0.42
Manganese (%)	-0.09	-0.07	-0.06	-0.10	-0.09

Source: Field work, 2007

Table 5: Correlation Coefficients Between Growth Parameter and Subsoil Properties.

Soil properties	Total height	Diameter at breast height	Basal area	Crown diameter	Bole volume
Sand (%)	0.05	0.23	0.19	0.15	0.25
Silt (%)	0.31	0.21	0.21	0.30	0.18
Clay (%)	0.25	0.07	0.13	0.12	0.06
Elect. Conductivity	0.10	0.30	01.23	0.30	0.17
pH ($CaCl_2$)	0.81	0.78	0.79	0.78	0.80
Organic Matter (%)	0.64	0.65	0.67	0.41	0.61
Exch. Na^+ (mmol Kg^{-1})	0.29	0.13	0.11	0.24	0.22
Exch. K^+ (mmol Kg^{-1})	0.53	0.54	0.57	0.57	0.53
Exch. Ca^{++} (mmol Kg^{-1})	0.72	0.74	0.67	0.69	0.68
Exch. Mg^{++} (mmol Kg^{-1})	0.15	0.21	0.20	0.52	0.11
Cation exchange capacity (mmol Kg^{-1})	0.69	0.69	0.62	0.56	0.61
Exchange acidity (mmol Kg^{-1})	0.75	0.71	0.72	0.65	0.75
Available phosphorus (ppm)	0.53	0.56	0.52	0.42	0.45
Total nitrogen (%)	0.61	0.76	0.80	0.69	0.65
Base saturation (%)	0.54	0.62	0.58	0.6	0.55
Zinc (%)	0.34	-0.30	-0.37	-0.36	0.46
Niickel (%)	0.60	-0.63	-0.48	-0.63	-0.55
Copper (%)	0.17	0.26	0.06	0.29	0.35
Manganese (%)	0.24	-0.13	-0.15	-0.10	-0.24

Source: Field work, 2007

Since many times, the results of simple correlation analysis have been found to be spurious, we can increase the degree of confidence by subjecting the data to further analysis using multiple regression.

Using these two modes together, better results are yielded. The multiple regression model was used in this study for clearer exposition of the relationships and to enable us determine the effects of variations in soil properties on the growth of this species. In this paper, each growth parameter was treated as a dependent variable against soil properties (independent variables).

Tables 6 shows the combinations of soil properties that account for variation in growth characters measured for this tree crop. For example, variation in top height was accounted for by nickel and sand content of topsoil, electrical conductivity, total nitrogen, available phosphorus, and zinc. The amount of nitrogen, available phosphorous, calcium, organic matter, electrical conductivity, C.E.C., nickel content, and base saturation accounted for the significant variation in ‘diameter at breast height’ in the subsoil. Bole volume was determined using the organic matter content of the topsoil, exchangeable potassium and extractable nickel in the topsoil and electrical conductivity and total nitrogen of the subsoil. The basal area was accounted for by the extractable zinc, manganese, soil acidity, and the silt content of the topsoil, plus electrical conductivity and total nitrogen of the subsoil.

Crown diameter was determined by acidity of topsoil, organic matter, and clay content of topsoil, plus electrical conductivity of subsoil.

Table 6: Predictive Multiple Regression Equation Based on the Performance of the Growth Parameter for *irvingia gabonensis* on Soil Properties.

	Growth Parameter	Predict Multiple regression Equation
*1	Total height	Y=4,842 + 0.816 Ni + 0.042 Sd
*2	Total height	Y=10,635 + 0.808 Ec + 0.401 TN + 0.321AP – 0.249ZN
*1	Diameter at breast height	Y= -244.9 + 0.390pH + 0.433 NI
*2	Diameter at breast height	Y=3016.9 + 0772Ec + 0.441 TN + 0.367Ca + 0.312 OM + 0.478 CEC + 0.464 Ap + 0.218 NI = 0.163 BS
*1	Bole volume	Y=-4.701 = 0.897Ni + 0.306K + 0.024 M
*2	Bole volume	Y=-7.914 + 0.80Ec + 0,313 TN
*1	Basal area	Y= -48.4 + 0.806 Ni + 0.48EA + 0.349 CEC + 0.374 Ca + 0.15 Ap
*2	Basal area	Y=-23.59 + 0.802 Ec = 0.455K + 0.281 Ni = 0.227 OM
*1	Crown diameter	Y=-4.316 + 0.819pH = 0.372 Ni + 0.29 CL = 0.237 OM
*2	Crown diameter	Y=4.23.2 + 0.77 EC

Source: Field work, 2007

*1 = Topsoil relationship; *2 = Subsoil relationship; Ni = Nickel, Sd = Sand, Ec = Electrical conductivity, TN = Total Nitrogen, AP = available Phosphorus, Zn= Sinc, CL = Clay, pH = Soil reaction, Ca = Calcium, OM = Organic matter, CED = Carbon Exchange Capacity, BS= Base saturation, K = Potassium, EA = Exchange Acidity

In order to further ascertain the importance of each soil property and their relative effects on growth of this tree crop, the percentage contributions of independent variables in the multiple regression to the total variance of the crop growth were computed, along with the importance value index (Tables 7 and 8). The importance value index was the simple frequency or total occurrence in each soil property in the multiple regression (Gbadegesin, 1986; Ukpong and Moses, 2001).

The topsoil properties accounted for between 80.4 and 100 percent of the total variance in the growth parameters. Topsoil properties, which are very crucial to the growth of this tree crop, are soil pH, organic matter, extractable zinc and nickel. A corresponding analysis of the subsoil relationships reveals that electrical conductivity total nitrogen, available phosphorus, and extractable nickel are crucial to the growth and productivity of this tree crop.

The importance of organic matter, nitrogen, and available phosphorus is not in doubt. While nitrogen and phosphorus are essential organic nutrients necessary for plants growth, organic matter is a storehouse of these nutrients. Nitrogen is a major constituent of all proteins and, hence, all protoplasm; it causes increase in leaf growth (Woomer and Swift, 1994). Phosphorus is also a vital ingredient for many enzymic reactions that depend on phosphorylation and it is necessary for the development of meristern tissues (James, 1973).

This study also identifies soil pH as a critical factor affecting growth of *Irvingia gabonensis (var)*. In this area, soil pH affects the physical condition of the soil by rendering it unfavorable under low or high values. While high pH value generally lowers availability of all nutrients, except molybdenum and boron, low pH values result in the concentration of certain elements to toxic level (Tisdale and Nelson, 1975).

Table 7: Percentage Contribution of Independent Variables to the Total Variance in Growth of *Irvingia gabonensis* and Importance Value Index for Topsoil Analysis.

Soil properties	TH	DBH	BA	CD	BV	Importance value index
Sand (%)	-	-	-	-	-	1
Silt (%)	-	-	-	-	-	0
Clay (%)	-	-	-	8.3	-	1
Elect. Conductivity	-	-	-	67.0	-	2
pH (Cal_2)	-	79.3	-	-	-	0
Organic Matter (%)	-	-	-	4.4	-	2
Exch. Na^+ (mmol Kg^{-1})	-	-	-	-	-	0
Exch. K^+ (mmol Kg-1)	-	-	-	-	9.4	1
Exch. Ca^{++} (mmol Kg^{-1})	-	-	7.9	-	-	1
Exch. Mg++ (mmol Kg-1)	-	-	-	-	9.5	0
Cation exchange capacity (mmol Kg-1)	-	-	8.4	-	-	1
Exchange acidity (mmol Kg-1)	-	-	9.4	-	-	1
Available phosphorus (ppm)	-	-	9.5	-	-	1
Total nitrogen (%)	-	-		-	-	0
Base saturation (%)	-	-		-	-	0
Zinc (%)	-	-		-	-	0
Nickel (%)	-	9.11		5.4	80.5	4
Copper (%)	-	-		-	-	0
Manganese (%)	-	-		-	-	0

Source: Field work, 2007

Table 8: Percentage Contribution of Independent Variable to the Total Variance in Growth of *Irvingia gabonensis* and Importance Value Index for Subsoil Analysis

Soil properties	TH	DBH	BA	CD	BV	Importance value index
Sand (%)	-	-	-	-	-	0
Silt (%)	-	-	-	-	-	0
Clay (%)	-	-	-	-	-	0
pH (Cal_2)	-	-	-	-	-	0
Elect. Conductivity	65.4	59.6	64.4	60.4	64.1	5
Organic Matter (%)	-	4.7	2.10	-	-	2
Exch. Na^+ (mmol Kg^{-1})	-	-	-	-	-	0
Exch. K^+ (mmol Kg^{-1})	-	-	4.3	-	-	1
Exch. Ca^{++} (mmol Kg^{-1})	-	5.3	-	-	-	1
Exch. Mg^{++} (mmol Kg-1)	-	-	-	-	-	0
Cation exchange capacity (mmol Kg^{-1})	-	2.9	-	-	-	1
Exchange acidity (mmol Kg^{-1})	-	-	-	-	-	0
Available phosphorus (ppm)	8.9	2.8	-	-	-	2
Total nitrogen (%)	10.61	8.0	-	-	6.10	3
Base saturation (%)	-	2.8	-	-	-	1
Zinc (%)	3.7	-	-	-	-	1
Nickel (%)	-	1.8	4.00	-	-	2
Copper (%)	-	-	-	-	-	0
Manganese (%)	-	-	-	-	-	0

Source: Field work, 2007

Further findings of this study reveal that nickel and zinc (although micro nutrients) are critical to the growth of this crop. The negative relationship which these micro nutrients have with most growth parameter (Tables 4 and 5) indicate that their presence in high concentration in soils may hinder or reduce growth of this tree crop.

CONCLUSION

Soils of this region are moderately fertile and need to be well managed to avoid its degradation under mono-cultural plantation of this species. Furthermore, good growth and yield of this crop can be maximized through agronomic practice, which would enhance the level of organic nutrients and reduce soil acidity. Hence, application of green and farmyard manure and chemical fertilizers, which are rich in nitrogen and phosphorus, should be encouraged. Liming and other practices will reduce soil acidity; will also be a good soil management technique that will guarantee optimal growth and production of the crop.

REFERENCE

Agboola, A.A. (1979). Agricultural Atlas of Nigeria, Oxford University Press London.

Aweto, A.O. (1987). Physical and Nutrient Status of Soil under Rubber (Hevea brasiliensis) of Different Ages in South Western Nigeria. *Agricultural Systems, 23, 63-72*

Aweto, A.O. and Ekuigbo U.E. (1994). Effects of Oil Palm Plantations on Tropical Forest Soils in South Western Nigeria. *The Indonesia Journal of Geography 26,51-59.*

Aweto, A.O. and Ishola, M.A (1995). The Impact of Cashew (Anacardium occidentale) on Forest Soils. *Experimental Agriculture*, 30 337-341.

Bada, S.O. (1981). A Study of Growth of Obeche under Different Management System in Southern Nigeria, *Nigeria Journal of Forestry,* 1, 53-63.

Bouyoucos, G.J. (1962). Estimation of Colloidal Material in Soils. *Science,* 64, 632.

Busch, B. (1963). *Forest Measuration and Statistic,* Ronald Bess, Company, New York.

Egbe, N.E (1973). Soil of Kola (Cola nitida. Vent, Sciott and Endlicher) groves in Western Nigeria. *Ghana Journal of Agric. Science,* 6, 149-153.

Ekanade, O. (1985a). The Impact of Cocoa Cultivation on Soil Properties in South Western Nigeria. Unpublished Ph.D Thesis, University of Ife 305pp.

Ekanade, O. (1985b). The Effect of Cocoa Cultivation on Some Physical Properties of the Soil in Southwestern Nigeria. *The International Tree Crops Journal 3, 113-124.*

Ekanade, O. (1988). The Nutrient Status of Soils under Peasant Cocoa Farms of Varying Ages in Southwestern Nigeria. *Biological Agricultural and Horticulture*, 5, 155 - 167.

Ekanade, O. & Egbe, N.E. (1990). An Analytical Assessment of Agroforestry Practices Resulting from Interplanting Cocoa and Kola on Soil Properties in Southwestern Nigeria. *Agriculture, Ecosystem and Environmental*, 30, 337-346.

Gbadegesin, A.S. (1986). A Method for Identifying Soil Properties Influencing Crop Yield: The Example of Maize in the Savanna Belt of Southwestern Nigeria *Geoforum*. 17 (1), 109-118.

Isaac, A.R. & Korber, J.D. (1971). Atomic Adsorption and Flame Photometry: Techniques and Issues in Soil, Plant and Water Analysis. In Saish, L.M *(ed) Instrumental Methods for Analysis. Of soil and Plant Issues.* Soil Science Society of America Publication Ind. Madison.

Jackson, M.L. (1970). *Soil Chemical Analysis, Prentice Hall, Englewood, Cliffs, New Jersey.*

James, W.G. (1973). *An Introduction to Plant Physiology*. 7th edition, Oxford University Press, London. Pg.181.

Jones, M.J. & Wild, A. (1975). Soils of the West African Savanna. *Techn. Comm. No 55* Comm. Bureau of Soils. Harpenden.

Kershaw, K.A. (1985). *Quantitaitve and Dynamic Plant Ecology*, Edward Arnold. London.

Lombin, G. (1986). *Introduction to Tropic Palm Agriculture*. London, Longman.

Muciler-Dombois, D. & Ellenbery, H. (1974). Aims and Methods of Vegetation Ecology Wiley, London.

Ogidiolu, A. (1990). An Analysis of Biomass and Nutrient Storage and Distribution in Mature Cassava (Manihot esculenta crants) Agroecosystem, Unpublished M. Phil University of Ibadan.

Ogidiolu, A. (1997). Productivity of Cultivated Indigenous Tropical Tree Species (Terminalia ivorensis and Tripoichiton scieroxylon) in Relation to Site Characteristics in a Part of Southwestern Nigerian Unpublished Ph.D Thesis, University of Ibadan.

Ogidiolu, A. (2000). Effect of Soil-Site Condition on Some Growth Characteristics of Oil Palm (Elaeis guineensis jacq) in Southwesern Nigeria. *The Nig. Geog. Journal New Series,* 3 & 4, 99-113.

Onuwaje, D.U. (1983). Field Response of Rubber (Hevea brasiliensis) to Fertilizer on an Ultisol in *Nigeria. Fertil., Res* 4, 357-360.

Opeke, O. (1978). *Tropical Tree Crops* Longman, Ibadan.

Peech, M. (1967). Hydrogen ion activity, In Black, C.A. (ed) *Methods of Soil Analysis Part 2*, 914 – 926 S.A. Madison Wisconsin.

Pushiparajah, E. (1969). Response in growth and yield of Hevea brasiliensis to fertilizer application on Regnam soil series, Journal Rubber Res. Inst. Malaya 21. 165-174.

Pushiparajah, E. (1969) Nutrient and fertilizer use in Hevea brasiliensis and associated covers, in peninsular Malaysia, Research Inst. Srilanaka 54, 270-283.

Russel, E.W. (1967) Soil condition and Plant Growth, 9th edition Longman London 688pp.

Short, K.C. & Stauble, A.J. (1967). Outline of Geology of Niger Delta. The American Association of Petroleum, *Codogist Bull*. No. 51, 761-779.

Spur, S.H. & Barnes, B.V. (1980). *Forest Ecology* 3rd Edition Wiley, New York.

Tisdale, S.L. & Nelson, W.L. (1975). *Soil Fertility and Fertilizers*. Long.