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Full Length Research Paper

Soil management strategies for rubber cultivation in an undulating topography of Northern Cross River State

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This study was conducted to evaluate the soil fertility status of an undulating topography of a young rubber plantation located at Ikot- Ukpora, Biase Local Government Area of Cross Rivers State and its implication for rubber cultivation. The result showed that the soils of the area ranged from loamy sand to sandy loam on the surface overlying a slightly heavier textured sub-soil ranging from sandy loam to sandy clay loam. Most areas of the soils studied have gravely layers less than 100 cm from the surface leading to a matured plantation in the area to adopt a survival mechanism of curly tap root geometry with preponderance of extensive lateral root system that compensates for the tap root. The soils were slightly acidic and low in most essential nutrients. Total N, P and ECEC were generally low. Fertilizer recommendations were made for the different stages of rubber growth while other management strategies were suggested aimed at reducing organic matter losses and minimizing soil erosion as well as control of termite infestation.

Key words: Rubber, soil fertility, soil properties, Nigeria.

INTRODUCTION

Rubber (*Hevea brasiliensis* Wild ex A. de Juss. Muell. Arg.) is an economic crop and one of the most important cash crops in the rainforest agro ecological zone of Nigeria. The crop has attracted a lot of attention recently as a result of growing uncertainties in the National income as a result of over dependency on oil and the current attractive prices of the crop in the international market. It is a major source of employment opportunity especially for the restive youths of the Niger Delta region (Anschel, 1965; Aigbekaen and Nwagbo, 1999).

Rubber belt of Nigeria covers land area of about 7.6 million ha of land that lies in the southern part of Nigeria extending from Ogun State to Cross Rivers State. Apart from rubber cultivation, the land is also utilized for the cultivation of other crops, mining and urban development (RRIN, 1998). The soils of the area are predominantly coarse textured ultisols and oxisols derived from cretaceous sandstones and Pleistocene unconsolidated coastal sediments (FDALR, 1990) characterized by high acidity, low nutrient status, low activity clay and are subjected to rapid fertility decline on land clearing for cultivation (Asawalam and Ugwa, 1993; Eshett, 1991; Juo 1981; Kang and Juo, 1986). Therefore, economical and sustainable rubber plantation enterprises depend largely on high rate of fertilizer supplementation because rubber is a high nutrient demanding crop especially during the immaturity phase of their growth and development (1 - 6 years). Optimum rubber growth and high quality latex output therefore depend largely on the ability of the farmer to determine controlling factors and properly adjust them to suit rubber production. A major factor in any plant growth is the soil which determines the availability of nutrients required by the plants. A proper understanding of the physical and chemical properties of the soil is necessary to make proper amendments early enough that would ensure good return on investment at later productive stages of rubber.

This study therefore, evaluates the fertility potential of the undulating topography of soils supporting a 1000 ha of rubber plantation located at Ikot Ukpora, Biase Local Government Area of Cross Rivers State and its implication for rubber cultivation aimed at recommending appropriate measures necessary for sustainable and economically viable rubber cultivation

MATERIALS AND METHODS

The study was carried out in a land area covering an existing and proposed rubber plantation at Ikot Ukpora, Biase Local Government Area of Cross Rivers State. The area is a triangular shaped land area lying approximately within latitude 5°26.644' and 5°28.420' N

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and longitude 8°3.898' and 8°7.183' E covering about 1000 ha of land. Ikot Ukpora lies essentially in the humid rain forest zone with two distinct seasons (raining and dry seasons) which alternate annually with a mean annual rainfall of about 1950 mm distributed in about 9 months of the year with a peak between July and September. Relative humidity is approximately 89.9% while mean temperature is about 31.2°C. Cloud cover is about 80%, during the rainy season. The vegetation is mostly secondary forest re-growth. Young rubber plantations have undergrowths of broad leaves such as *Aspilla africana, Chromolaena odorata* etc with patches of grass species. Some perennial shrubs were scattered almost evenly while bamboo trees grow luxuriantly close to the streams and lowland areas. The cropping history is subsistence mixed plantain based arable cropping system with slash-and burn land clearing system along the contours and up to the peaks of the ridges.

The field study was carried out based on a field map of the entire landscape. A visual appraisal of the whole area was done and the field was mapped out for sampling based on the physiographic units, observed variabilities in landforms and geological materials. Spot elevations, slope gradients and aspects were obtained with a global positioning system (GPS) (Garmin etrex vista model). Soil samples were collected in various blocks shown in the map at Hillcrests, middle slopes and the valley bottoms. Samples were collected at two depths that is, 0 - 20 and 20 - 40 cm depths and a composite sample were collected for each depth at each of the sampling units. A total of 60 composite samples were collected, bagged, labelled and transported to the laboratory for analysis.

Soil pH was determined at 1:1 soil/water ratio using glass electrodes pH meter. Organic carbon was determined by chromic acid oxidation method. Available P was extracted using Bray 1 solution and the phosphate in the solution assayed by the Molybdenum blue colour method. Exchangeable cations were extracted with neutral normal ammonium acetate solution. Ca and mg were determined by EDTA titration, while Na and K were determined by flame photometry. Effective cation exchange capacity (ECEC) and base saturation were computed. Particle size analysis was by the modified Bouyoucous Hydrometer method as modified by Day (1965).

The interpretation of the results for fertility evaluation was based on the interpretation rules for tropical and subtropical soils as adopted by FDALR (1995). With respect to rubber cultivation, the information contained in Watson (1999), Orimoloye et al. (2004) and Orimoloye et al. (2005) was utilized at arriving at the conclusions and recommendations in conjunction with expert advice. Other criteria used for soil data interpretation and the sources of information are presented in Table 1.

RESULTS AND DISCUSSION

The area is underlain principally by quartz and quartzite schists characterized by ridges and steep slopes with no visible rock outcrop within the whole area though some remarkably high peaks were observed. Fragmented rocks of the mica and granite gneiss were encountered sporadically. In some exposed areas, it was observed that the quartzites exhibit lineaments that are North - South in orientation. The area is characterized by a remarkably undulating topography with slope gradients measuring between 5 - >25%. Global positioning system (GPS) elevation averaged about 89 m with the highest peak standing at 141 m. The area appears to be a watershed with numerous slopes ending invariably in a rivulet cutting deep into the hills. Principally, the area is drained by a tributary of the Cross River called Rubo river which flows westward in a very serpentine manner. The drainage pattern is dendritic in nature and most of the tributaries and rivulets joining the main stream almost at right angles. The courses of streams and rivers cut very sharp into the riverbeds and swampy narrow floodplains. The sharp angles and deep river beds are distinct features of resistance to weathering by underlying materials (Fagbami, 1981).

The soil analysis data were averaged across the land area as shown in Table 2 while the soil properties according to physiographic positions are presented in Table 3.

Soil physical properties

The soils of the study area ranged from loamy sand to sandy loam on the surface overlying a slightly heavier textured sub-soil ranging from sandy loam to sandy clay loam. This shows a degree of profile development and is desirable for rubber cultivation (Asawalam and Ugwa, 1993). Rubber has an extensive root system with taproots that could be as deep as 3 - 4 m and lateral roots that can extend from 15 - 20 m accordingly; a fairly deep, well drained soil with good physical structure on a gently sloping terrain with minimal soil erosion is required by rubber for optimum growth. Sandy clay loams and clay loams are among the most suitable textural classes. Hard pans and stoniness can greatly restrict root growth. Some of the soils of the study area have gradients that are higher than the recommended degrees for rubber but they are not under any serious threat of erosion due to the stability of the underlying parent material and a favourable orientation of the lineaments of the parent rock. However, most areas of the soils studied have gravelly layers less than 100 cm from the surface. In a matured plantation near the study area, an adaptation mechanism through modification in the tap root geometry of some rubber trees was observed (Plate 1). There was also a preponderance of extensive lateral root system that compensates for the tap root. It is however advised that clones that have high branching and dense canopy system should be avoided to minimize lodging and wind damage when rubber is fully established.

Soil chemical properties

The soil pH of the study area range from 4.8 - 5.9 which is within the suitable range for rubber without any need for liming (Watson, 1989; Ugwa et al., 2006). Rubber is essentially adapted to high rainfall areas which are often associated with leaching and acidity, the plant tolerates soils with an acid reaction (Akamigbo and Asadu, 1983). Most suitable soils for rubber are strongly to moderately acid with pH (in H_2O) ranging from 4.0 - 6.5. The

Table 1. Average soil physical and chemical properties at depth 0 - 20 and 20 - 40 cm in each block.

Block	Depth (cm)	Sand	Silt	Clay	Texture	pH (H2O)	Org C (%)	Aval P (mg kg^{-1})	Total N (%)	Exch Ac	Ca	Mg	Na	K	ECEC	BS (%)
			(%)									(Cmol kg^{-1})				
65	0 -20	71.9	7.99	20.11	SL	5.86	1.61	4.52	0.14	0.15	4.14	1.01	0.48	0.77	6.56	97.68
	20 - 40	67.23	8.25	24.52	SCL	5.31	2.12	2.42	0.05	0.34	2.06	0.33	0.30	0.56	3.61	90.58
66	0 - 20	58.18	14.92	26.90	CL	5.38	1.21	8.29	0.11	0.51	3.25	1.21	0.19	0.26	5.42	90.60
70	0 - 20	69.12	6.58	24.30	SCL	5.21	1.98	2.60	0.05	0.67	1.95	0.40	0.38	0.45	3.85	82.60
	20 - 40	55.78	14.92	29.30	SC	5.34	1.80	1.80	0.05	0.42	1.63	0.96	0.33	0.38	3.73	88.74
71	0 - 20	66.81	11.88	21.30	SL	5.85	1.99	11.33	0.04	0.32	4.14	1.01	0.48	0.77	6.76	95.26
	20 - 40	61.16	11.11	27.72	SCL	5.40	1.40	4.19	0.02	0.59	1.57	0.58	0.45	0.63	3.87	84.76
72A	0 - 20	60.48	13.22	26.30	SCL	5.28	1.64	6.34	0.10	0.26	1.95	0.29	0.23	0.08	2.85	90.88
	20 - 40	59.52	10.92	29.56	CL	5.13	1.04	3.94	0.08	0.67	1.62	0.18	0.18	0.05	2.73	75.47
75	0 - 20	67.48	13.22	19.30	SL	5.36	2.28	4.09	0.09	0.48	2.49	1.01	0.26	0.27	4.33	88.91
	20 - 40	61.48	16.22	21.30	SiCL	5.29	2.05	2.94	0.07	0.28	2.17	0.12	0.24	0.47	3.26	91.41
76	0 - 20	68.81	9.48	21.70	SL	5.42	1.77	5.77	0.12	0.28	1.46	0.52	0.38	0.61	3.27	91.43
	20 - 40	60.81	13.35	25.83	SCL	5.29	2.05	4.09	0.06	0.64	2.17	0.12	0.24	0.47	3.6	82.23
77	0 - 20	66.14	13.82	20.03	SL	5.28	1.65	6.32	0.10	0.26	1.46	0.20	0.16	0.19	2.74	90.51
	20 - 40	65.48	11.42	23.10	SCL	5.06	2.32	4.29	0.06	1.07	0.97	0.49	0.18	0.11	2.76	61.23
78A	0 - 20	66.81	15.22	17.63	SL	4.91	2.27	3.11	0.11	1.05	1.62	0.56	0.27	0.12	3.93	73.28
	20 - 40	57.83	14.79	27.38	SCL	4.84	1.74	1.51	0.08	0.95	2.06	0.32	0.43	0.12	2.73	65.50
Mean		63.83	12.19	23.90		5.30	1.82	4.56	0.07	0.52	2.15	0.54	0.31	0.37	3.88	84.77

exchangeable bases (Ca, Mg, Na and K) are generally low in the study area. The effective cation exchange capacity (ECEC) is also low this could be partly due to continuous cropping and leaching. Cox and Uribe (1992) observed soil cation decrease with cropping. An optimal value for CEC for rubber is 15 cmolkg^{-1}. Watson (1989) had suggested that soils that has less than 5 cmol kg- 1 requires supplementary fertilizer programme for optimum rubber development. Base saturation mostly above 80% shows that the exchange complex of the soil particles are occupied by bases rather than reserved acidity (Al3+ and H+). The observed base saturation might be attributed to the fact that majority of the land area are well under vegetation cover and are just being opened up for cultivation. The status of the soil exchange complex is desirable for long term fertility management. The soil available P, total N and organic carbon contents of 4.71 mg/kg, 0.07 and 1.59, respectively are low to moderate in the soils. This is an indication of low fertility for rubber and characteristic of many of the rubber growing soils earlier studied (Eshett, 1991; Asawalam and Ugwa, 1993; Ugwa et al., 2006). These nutrients are mainly influenced by vegetation cover, bush burning and organic matter management. It is noteworthy here that some of the soils sampled are newly opened up from fallow and some in blocks 75, 76 and 77 have some fertilizers applied to some growing young rubber there. However, nitrogen is easily lost through several processes in the soil while P is easily immobilized by microbial activities as well as chemical reactions.

RECOMMENDATIONS

Based on field observations and soil analysis, the following recommendations are proposed.

(1) 50 g 0f NPK Mg with 100 g rock phosphate per plant should be thoroughly mixed with top soil and applied to the planting holes 1 - 2 weeks before planting. If the Mg component is not available, 15 g of dolomitic limestone may be applied.

(2) The rides of rubber should be kept clean of weeds before and after planting.

Table 2. Average soil chemical properties at three physiographic locations in all the field blocks sampled.

Physiography	Depth (cm)	Sand	Silt	Clay	Texture	PH (H_2O)	Org C	Av P (mg/kg)	Total N	Exch Ac	Ca	Mg	Na	K	ECEC	BS (%)
		($g\ kg^{-1}$)					($g\ kg^{-1}$)		($g\ kg^{-1}$)	($Cmol\ kg^{-1}$)						
	0 - 20	693.10	112.80	194.00	SL	5.51	15.70	8.45	01.20	0.45	3.79	0.49	0.29	0.71	5.73	92.15
Hill crest	20- 40	622.00	132.40	242.40	SCL	5.29	10.30	6.12	00.60	0.61	2.02	0.37	0.30	0.35	3.65	83.28
	0 - 20	696.50	98.40	203.30	SL	5.40	16.60	5.04	00.40	0.22	3.92	0.56	0.40	0.55	5.65	96.11
Middle slope	20- 40	625.40	100.40	274.20	SCL	5.28	10.00	2.13	00.20	0.34	2.80	0.55	0.35	0.53	4.57	92.56
Valley bottom	0 - 20	649.80	138.90	211.20	SL	5.39	24.90	3.31	01.00	0.44	2.12	0.27	0.34	0.49	3.66	87.97
	20- 40	610.40	133.50	256.10	SCL	5.19	18.40	3.24	00.60	0.44	2.01	0.46	0.34	0.47	3.72	88.17
Mean	-	649.5	119.4	230.20	-	5.34	15.90	4.71	00.70	0.42	2.77	0.45	0.33	0.51	4.38	90.41

Table 3. Criteria for soil data interpretation.

Soil parameter	Very poor	Low	Moderate	Good	Authority
Ca ($Cmol\ kg^{-1}$)	1.0	1. - 2.3	2.3 - 5	7.0	FDALR (1995)
Mg ($Cmol\ kg^{-1}$)	0.4	0.5 - 1.0	1.1 - 1.5	3.0	FDALR (1995)
K ($Cmol\ kg^{-1}$) ECEC	0.01	0.01 - 0.2	0.2 - 0.4	0.4 - 0.8	FDALR (1995)
($Cmol\ kg^{-1}$)	<4	4 - 9	9 - 12	>12	Ugwa et al. (2006)
Available P (mg/kg)	< 5	5 - 8	8 - 10	>10	FDALR (1995)
Total N (%)	<0.04	0.05 - 0.12	0.12 - 24	>0.24	Watson (1989)

(3)Application rate of 33 kg N/ha, 13.64 kg P2O5 /ha, 20.94 kg K2O per ha and 12.96 kg MgO /ha in two split applications is advised for the first year (Table 4) while a schedule for the first 5 years in Table 5 should be followed.

(4) To ensure maximum nutrient capture, fertilizers should be applied in a ring form a few centimetres from the base of rubber during the first year. The radius of the ring should be increased progressively to 80 - 90 cm at the end of the second year. From year 3 to 4, band placement along a clean weeded strip at 80 - 250 cm from the base of the tree till year 5.

(5) Frequent dressings and split application at 6 monthly interval is encouraged. Time of application should be adjusted to avoid periods of excessive rainfall or very dry periods of the year.

(6) Rooting assistance (hormones) such as indole acetic acid (IAA) or Indole butyric acid (IBA) to stimulate root development and nutrient capture should be done.

(7) Due to stoniness and the soil depth observed, regular pruning to avoid dense foliage should be carried out. In the alternative, clones with light crowns should be planted.

(8) Fertilizer application to mature rubber trees take 2 - 3 years before the effects are felt and are mainly for stability and yield maintenance. Application of 320 kg/ha (equivalent of 550 g/tree) per year of NPK Mg mixture of ratio 10: 7: 9: 4 respectively is recommended from year 7 - 15. Fertilizer application for matured tree could be modified based on responses obtained from the above and fertilizer regimes maintained at the immature phase.

Other soil management suggestions:

(1) Creeping legume cover crops may be beneficial to rubber in the study area. Mulching around the base of the rubber trees is well encouraged.

(2) Where applicable, intercropping with maize, cassava, cowpea, soybean and other common food crops including plantain that is a common

Plate 1. A taproot of rubber modified by stone line. Notice the root bent sideways instead of growing vertically into the soil.

Table 4. Soil nutrient observed and fertilizer recommendations for young rubber at Ikot-Okpora rubber estate at the first year of planting.

Nutrient element	Soil available (kg/ha)	Amount required (kg/ha)	Deficit/Surplus (kg/ha)	Fertilizer material	Application rate
				Urea/tree)	75 kg/ha or 125 g/tree
N	78.4	112	33.6	Ammonium sulphate	160 kg/ha or 266 g/ tree
				Ammonium phosphate	120 kg/ha or 200 g/tree
				SSP	75.78 kg/ha or 126 g/tree
P (P_2O_5)	12.06	25.70	13.64	Ammonium phosphate	68.20 kg/ha or 114 g/tree
K (K_2O)	197.06	218	20.94	Murriate of potash	34.90 kg/ha or 58.17g/tree
Mg (MgO)	108	120.96	12.96	Commercial MgO	2.4 g/tree
				Dolomite	120 g/tree

Table 5. Schedule of fertilizer application for the first 5 years of rubber planting the study area (g/tree).

Months after planting	N	P_2O_5	K_2O	MgO
At planting	80 g of NPK with 100 g rock phosphate per planting hole			
6	18	11.35	17.45	10.63
12	18	11.35	17.45	10.63
18	18	11.25	17.45	10.63
24	28.4	14.25	22.68	10.63
36	56	28.5	34.9	14.40
42	100	84	40	21
54	120	80	45	25
66	120	80	45	25

crop in the environment is encouraged during the first four (4) years of rubber. This will bring early return on investment and ensure proper maintenance of the plantation. Planting arrangement should be such that rubber is not choked up and fertilizer should be adjusted to accommodate the food crops.
(3) Contour terracing or construction of silt pits in areas where slope gradient is higher than 10% is suggested. (4) Termite control by destroying the termite hills and drenching with DEVAP or any of its variants at 2% concentration is highly recommended in the termite prone areas.

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