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SURVEY OF PROPERTIES AND CONSTRAINTS OF SOME SOILS OF CROSS RIVER STATE, NIGERIA, FOR HIGHER YIELDS OF RUBBER (HEVEA BRASILIENSIS MUEL AGRO) TREES.

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ABSTRACT

Physical and chemical properties of some soils in Cross-River State, Nigeria grown to rubber (*Hevea brasiliensis* Muel Agro) and their constraints to higher productivity examined using seventy two soil sa1mples taken from twenty-four randomly distributed profile across the state. The results indicated that the soils are generally deep, sandy at the surface and clayey at the sub-surface layers, well-drained, friable when moist and slightly susceptible to water erosion. The soils were generally acid in reaction and moderate in their levels of organic carbon and available phosphorus on the surface soils but rather low in total nitrogen. Except for sodium, the levels of all exchangeable bases were low to very low particularly in the subsurface horizons of these soils. Consequently, the effective CEC values obtained were generally low being dominated by hydrogen and aluminum. Constraints associated with the poor physical and chemical constitution of the present soils and measures aimed at correcting these problems are discussed in relation to optimal growth and performance of rubber trees.

KEY WORDS: Rubber trees, chemical properties, physical properties, survey and constraints

INTRODUCTION

The rubber tree (*Hevea brasiliensis* muel Agro.) is one of the major tree crops grown in the rainforest zones of Nigeria, cultivated primarily for its fresh liquid exudates called latex. Organized production of natural rubber to meet industrial need is now 180 years old and was preceded by many centuries of localized rubber use in the tropics (Webster and Paardekooper 1989). In Nigeria, rubber was first introduced around 1895 (Amalu, 1991). Over these years the once simple activity of gathering wild rubber to make a few useful or ceremonial objects has developed into the extensive and complex plantation industry of today. However, since the early seventies both the yields and export of natural rubber have declined considerably following increased exploitation of existing plantations with little or no inputs and intensified land use resulting in loss of soil fertility.

Climate and soils constitute the major aspects of the environment that greatly affect the growth and yields of rubber species. Many areas of the rain forest zone of Nigeria are fairly well-suited for growing rubber since it thrives best in areas where mean annual rainfall exceeds 1750mm and mean temperature falls between 22^0c and 28^0c (Yew and Sys, 1984), on deep well drained sandy loam soils provided appropriate cultural practices are employed (Chan, et al 1982). However, the productivity of most acid upland soils in the humid tropics is limited by physical and chemical constraints, climatic constraints usually being unimportant (Von Uexhull, 1986). Besides it is common knowledge that even with the most adequate climatic conditions of any environment, optimum yields of most crops can hardly be obtained unless the soil environment is also free from serious constraints. The aim of this study therefore was to examine some physical and chemical properties of soils under rubber, identify constraints, if any, and based upon these, formulate better management practices to reverse the declining trend of rubber yields on such soils

MATERIALS AND METHODS

The rubber plantations used for this study are located at Nko, Odukpani, Oban and Uyanga. These plantations are located in different parts of the state (Fig. 1). Cross – River State lies between latitude $5^0$32' and $4^0$27' North and longitude $7^0$15' and $9^0$28' East and has warm, humid tropical climate. Annual rainfall is usually high ranging from 1875mm – 4000mm because of the favourable orographic conditions. Ambient temperatures are also high (27 to 35^0C with a mean of 29^0C. Generally, the soils formed from acid crystallined rocks are deep, porous, non-mottled and non-concretionary red, with strongly acid sub-soils deficient in plant nutrients. (Bulktrade, 1989). Composite soil samples were taken at 0-15, 15-30 and 30 – 45cm depths distributed randomly in each of the plantations and were analysed for their physical and chemical properties. Samples were air – dried; crushed and sieved to pass through a 2mm mesh prior to analysis. Particle size fractions were determined by the hydrometer method (Bouyoucous, 1951). Soil reaction (pH) was measured in 1:2:5 soil: water suspension using a glass electrode pH meter. Soil organic carbon was estimated on 1g soil samples by the dichromate wet oxidation method described by Walkely and Black (1934). Total nitrogen was determined on soil samples by the regular macro-kjeldhal method (Jackson, 1968). Available phosphorus was determined by extraction with acid fluoride using the Bray P-1 method (Bray and Kurtz, 1945). Exchangeable K and Na were determined using an EEL flame photometer while Ca and Mg were estimated using the EDTA Versenate titration method. Exchange acidity (H^+ + Al^{3+}) were extracted with IN KCL and estimated in the extracts by titration (Mclean, 1965).

Effective cation exchange capacity of the soils was computed by summing up the ammonium acetate extracted bases and exchanged acidity. Base saturation was obtained by expressing the sum of the exchangeable bases as percentages of the effective cation exchange capacity.

RESULTS AND DISCUSSIONS

Soils grown to rubber in the four locations are fairly constituted in terms of textural fractions being mainly sandy loam and in all profiles mean clay contents ranging from 7.5 to 14.5% in the surface horizon (0-15cm) and only 24.2 to 56.8% clay in the subsurface horizon (30-45cm). Silt fractions were not uniformly distributed in the profiles, the surface soils had high values than the subsurface soils with the soils of Nko being the only exception and had the lowest values ranging

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from 2.6 to 17.3%. Although the soils posses favourable physical characteristics such as friable (moist) consistence, effective depths of more than 100cm and moderate internal drainage and erodibility classes or workability of the soils (Russell, 1973), they hardly meet the desirable criterian of "almost proportionate amount of sand and silt plus clay" in the rotting zone of rubber trees proposed by Chan et al (1975). Rather it indicates that the soils were too loose to provide sufficient mechanical support for the rubber trees and prone to heavy leaching of nutrients and severe gully erosion both of which are major agents of soil degradation (Okigbo, 1985). The poor physical conditions of the soils may be attributed to old age or advanced degrees of weathering. This deduction is largely because the silt/silt + clay ratios which according to Stewart et al. (1970) reflect the degree of weathering of soils, were very low. All values, regardless of soil location and depth were less than 1.0, (table 1) further emphasizing advanced stages of mechanical disintegration, especially of a large proportion of the silt into clay fractions.

The chemical properties of the soils are shown in Table 2. The soils were generally acidic to moderately acidic as pH values ranged from 4.7 to 4.9 (0-15cm), 4.5 to 5.2 (15 – 30cm) and 4.9 to 5.3 (30 – 45cm).

The acid reaction of these soils are typical characteristics of most upland soils within the "acid sand" areas of Southern Nigeria, the levels of acidity seems to agree with the critical range of 4.3 to 4.6 which Chan et al (1975) considered as the desirable pH limits for optimal growth and performance of rubber in tropical soils. Rubber trees had been reported to thrive well in acid sand conditions (Anon, 1960) where soil pH is not less than 4.0, as the resultant lack of calcium reduces flow of latex (William, 1979). According to Aslander (1952) such acid tolerant crops usually assess higher feeding capabilities than those which grow in near neutral to alkaline soils and therefore better utilize the small amount of readily soluble plant nutrients present in acid soils. The soils varied appreciably in their contents of organic carbon, total nitrogen and available phosphorus, ranging from 0.51 to 1.51%, 0.04 to 0.19% and 3.51 to 8.07 mgkg^{-1} respectively with the surface soils values expectedly being higher than those of subsoils. Generally, the present values are low, surface soils organic carbon values hardly reached the 1.5% estimated as lower critical organic carbon level in similar rubber growing soils of Malaysia (Sys, 1982); with the exception of the surface soils of Nko, (1.51%), total nitrogen and available phosphorus contents for most of the soils were below the critical soil test values (0.15% N and 8.00 mgkg^{-1} P) for these properties in soils supporting most crops in Nigeria (Enwezor, et al, 1987)

Wide variations were also observed in the values of exchangeable cations. The ranges over the soils were 0.08 to 0.14 cmolkg^{-1} for sodium 0.06 to 0.12 cmolkg^{-1} for potassium; 1.0 to 2.60 cmolkg^{-1} for calcium; and 0.60 to 1.73 cmolkg^{-1} for magnesium. The present values are below the critical values of 5.0 cmolkg^{-1} and almost all the soils had values above 1.0 cmolkg^{-1} proposed for calcium and magnesium in similar tropical soils of New Zealand (Taylor and Pohlen, 1970). Critical value for neutral normal NH_4OAc extractable potassium in the acid sands" had been estimated at 0.20 cmol (Enwezor, et al, 1981) below which symptoms of potassium deficiency and hence responses to potassium could be expected. Potassium data (Table 2) shows all the soils to be deficient in exchangeable potassium. On the other hand the present soils were considered to contain moderate amounts of sodium. According to Russell (1975) most soils contain enough sodium for crop growth and responses to sodium fertilizers are confined to crops with definite sodium requirements such as sugar-beets, mangolds, etc. Rubber species have been reported to have definite need for sodium. In addition, Tinker (1967) reported that even for sugar beets responses to sodium fertilizers are possible only if the soil contain less than 0.05 cmol of readily exchangeable sodium. For these reasons, the present sodium values are sufficient for good performances of rubber.

Of the four soils involved in this study, those of Nko, Oban and Uyanga, plantations appeared much more endowed with essential nutrient than Odukpani plantation. In terms of distribution within the soils, lower levels were generally found in subsoils. A noticeable feature is the extremely low levels of exchangeable bases in the subsurface (15 – 45 cm) soil depths, similar to those obtained in "acid sands" of mid-Western Nigeria (Amalu, 1992). The result of this is that the subsurface soils had remarkably high base saturation values (range, 71.0 – 96.8%) compared with the surface soils. The relatively high levels of essential nutrients of surface soils perhaps reflects the extent of organic matter accumulation and high nutrient contents associated with rubber leaf litter.

The results obtained in the study have demonstrated that the physical and chemical properties of the soils were fairly suitable for growing rubber trees. This probably explains the occurrence of some symptoms of nutrient deficiencies (Shorrocks, 1964). Poor growth and low yield of rubber trees resulting from poor soil conditions were not entirely unexpected in the surveyed soils. Similar reports of poor soil physical and chemical characteristics have been made for most soils within the "acid sand" zone of Southern Nigeria (Babalola and Obi, 1981, Amalu; 1992 and, Attoe and Amalu, 2005), and have been attributed mainly to their underlying parent materials which are loose, unconsolidated sandstone sediments (Ojanuga, et al, 1981), and the rapid mineralization of organic matter under isohyperthermic soil temperature regimes (Eshiett, 1987), denitrification and volatilization processes involving nitrogen (Ahmad, 1985), their high phosphate fixation capacity (Udo and Uzu, 1972) and excessive leaching of nutrients resulting from prevailing high rainfall amounts (Yayock, et al, 1988)

Table 1: Mean Values of the Physical Properties of Soils grown to Rubber in the four Locations

Location	Number of blocks	Soil Depth (cm)	Particle size fraction sand	silt (%)	clay	silt / silt + clay ratio	Textural class	Consistency Dry	Moist	Effective soil Depth (cm)	Internal Drainage(a)	Erodibility (b)
		0-15	82.2	10.3	7.5	0.58	ls		Non sticky	>100	Class D.	Class 2
Nko	6	15-30	73.2	10.3	16.5	0.38	sl				Well-	moderately
		30-45	36.6	13.2	50.2	0.21	c	soft	friable		Drained	Eroded
		0-15	73.0	17.3	9.8	0.64	sl	Slightly		>100	Class D	Class 2
Oban	6	15.30	63.0	15.9	21.1	0.43	scl	Hard	Friable		well drained	moderately
		30.15	37.0	6.3	56.8	0.59	c					Eroded
		0-15	86.2	4.6	9.2	0.33	sl			>100	Class D	Class 1
Odukpani	6	15.30	78.2	2.6	19.2	0.12	sl		Non-plastic.		well brained	slightly eroded
		30.45	72.2	3.6	24.2	0.13	scl		Non-sticky			
		0-15	70.6	14.9	14.5	0.51	sl		Slightly	>100	Class C	Class 2
Uyanga	6	15-30	64 0	6.9	29.1	0.19	scl		friable		moderately	moderately
		30-45	54.6	5.2	40.	0.11	sc.				well drained	eroded

a - Considered depth to hardpan or to permanent water table

b - Based on the definitions of USDA (1960), ls = loamy sand, sl = sandy loam, scl = sandy clay loam, sc = sandy clay, c = clay

Table 2: Mean values of some chemical properties of soils grown to rubber in the four locations

Location	Number of blocks	Soil Depth (cm)	Soil Ph	Organic carbon (%)	Total N (%)	Avail. P $mgkg^{-1}$	Exchangeable cations ($cmol\ kg^{-1}$) Na	K	Ca	Mg	$H^{+}+Al^{3+}$	Effective CEC ($cmol\ kg^{-1}$)	Base saturation (%)
		0-15	4.7	1.51	0.19	4.92	0.14	0.12	2.60	1.60	1.52	5.98	74.6
Nko	6	15-30	4.7	0.79	0.08	3.51	0.14	0.11	1.80	0.80	1.08	3.93	92.6
		30-45	5.0	0.60	0.07	3.51	0.14	0.10	1.80	0.60	1.08	3.72	71.0
		0-15	4.7	1.41	0.14	7.34	0.11	0.09	1.60	1.40	1.28	4.48	71.4
Oban	6	15-30	4.7	0.57	0.06	5.18	0.10	0.07	1.40	1.20	0.64	3.48	81.6
		45-15	5.0	0.51	0.05	5.20	0.10	0.08	1.00	1.02	0.62	2.80	77.9
		0-15	4.9	1.42	0.17	6.81	0.09	0.08	1.20	1.40	0.80	3.57	77.6
Odukpani	6	15-30	4.5	0.60	0.08	4.70	0.08	0.07	1.40	1.40	0.80	3.03	73.6
		30-45	5.3	0.60	0.04	4.80	0.08	0.06	1.08	1.20	0.06	2.48	96.8
		0-15	4.9	1.32	0.14	8.07	0.10	0.11	2.07	1.20	1.52	5.00	69.6
Uyanga	6	15-30	5.2	0.74	0.19	4.25	0.08	0.10	1.93	1.73	1.19	5.13	76.8
		30-45	5.2	0.70	0.08	4.64	0.08	0.12	1.96	1.76	1.18	5.10	76.9

Table 3: Data on critical soil nutrient requirement for rubber

pH	4.3-4.6
Organic Carbon	1.5%
Total N	0.15%
Available P	8.0 mgkg^{-1}
Magnesium	1.0 cmol kg^{-1}
Calcium	5.0 cmol kg^{-1}
Potassium	0.20 cmol kg^{-1}
Sodium	0.05 cmol kg^{-1}

Nevertheless, the "acid sand" soils of Southern Nigeria will continually be used for most tree-crop farming and moreso now that the hectarage of land under rubber needs to be expanded to meet the increasing demand for natural rubber and its products. For these reasons, it is recommended that for the present as well as similar soils under rubber in the rainforest areas of Nigeria the common practice of applying lime to reduce acidity would be appropriated. The acid conditions should be sustained but not below the lower critical limit of pH for rubber soils. As much as possible, the fertility of the surface soil should be improved upon by maximum conservation of decomposing debris into organic matter.

From the study, it is recommended that proper manuring with inorganic fertilizers is necessary for achieving higher productivity of the present and similar soils under rubber. A typical mix of 42kg/ha, ammonium sulphate, 40kg/ha rock phosphate, 10kg/ha potassium chloride and 6kg/ha magnesium sulphate is recommended and this will supply 8.8%N, 13.5% P_2O_5, 6.0% K_2O and 2.1% Mgo to the rubber trees growing in the field (RRIM 1971). Also leguminous covers may not be immediately beneficial in terms of soil fertility improvement as work in Malaysia and Nigeria suggests but their long term beneficial effects on soil fertility under both rubber and oil palm seem established and there is an overall advantage in planting leguminous covers in rubber and oil palm plantations whose economic life span over twenty years. Further investigation is required to determine the optimum rates of the suggested amendments and other cultural practices that would assist in the increase of productivity for soils under rubber.

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