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Evaluation of Phosphorus Status of Some Soils Under Estate Rubber (*Hevea Brasiliensis Muel. Argo.*) Trees in Southern Cross River State

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ABSTRACT

The phosphorus status of 100 composite soil samples representing 3 of the 5 divisions found in Pamol rubber plantations were evaluated by determining the available P extracted by the methods Bray P –1, Bray P-2, Mehlich, Olsen, Morgan and the various P forms. Total P varied widely in the soils and tended to be related to the nature of the parent materials (Shale and Sandstone). It ranged from 51.5 to 158 $mgkg^{-1}$ with a mean of 94.5$mgkg^{-1}$ for surface soils while for subsurface soils it ranged from 44.7 to 143$mgkg^{-1}$ with a mean of 70.7$mgkg^{-1}$. As a fraction of total P, organic P obtained was higher (40.4 to 52%) in surface soils than in the subsurface (25.9 to 43.1%). The C/P ratios were generally higher than 200 indicating the relative difficulty in the release of substantial amount of P in available form for most of the rubber trees in the plantations. Available P extracted by the 5 methods were positively correlated with all the active P forms with Al-P and Organic P having the highest and lowest correlation coefficient respectively. Phosphorus concentrations for leaf P and root mat P at the sites were all low. Leaf P correlation with the extractant were negative while only the Olsen extractant had a positive correlation coefficient (0.425**) with root mat P. The study revealed that the rubber growing soils of the estate studied were deficient in total P and active P forms but moderate in the amount of available P. This was confirmed by rubber leaf P and root mat P analysis.

KEY WORDS: Rubber tree, Phosphorus uptake, Soil P, leaf P and Root Mat P.

INTRODUCTION

The rubber tree (Hevea brasilinesis Muel. Argo.) is one of the major tree crops grown in the rain forest areas of Nigeria. Rubber is cultivated primarily for its fresh liquid exudate; latex or natural rubber obtained upon cutting through the bark of the tree. The latex is used in the manufacture of a wide range of industrial and domestic products (Grilli, et. al., 1980) It is known that nearly all parts of the tree, the seed, the stem (wood) and the leaves can be applied to numerous uses for mankind (Enabor, 1986). At present the total land area in Nigeria planted with rubber trees is estimated at between 205,800 and 501,000 hectares out of which over 41,000 hectares are under estate rubber plantations (about 32) and over 170,000 hectares under small holder rubber (Amalu, 1991).

Tropical soils are known to suffer from multiple nutrient deficiencies particularly that involving P. The availability to plants of P in soils is usually linked with the relative abundance of the various chemical forms of the element. Factors such as content of hydrous oxides and hydroxides of Fe and Al, pH, drainage conditions of the soil, types and amount of clay minerals and the degree of soil development are key determinants of the relative amounts of the various forms of P (Udo and Dambo, 1979; Lorganathan and Sutton, 1987). The various forms of soil P are usually determined by the fractionation method of with various modifications (Peterson and Corey, 1966). The supply of phosphorus to plants is particularly governed by the content of active inorganic and organic phosphorus fractions. Organic P fractions contribute substantially to available P reserves following mineralization in tropical soils (Sare and Udo, 1988). This study was designed to evaluate phosphorus forms and status in soils under the large estates owned by PAMOL rubber plantations in Cross River State and established any relationships among the various phosphorus fractions and between these fractions and leaf phosphorus.

MATERIALS AND METHODS

One hundred composite soil samples taken from surface (0-20cm) and subsurface (20-40cm) soil layers of 3 of the 5 divisions located within the PAMOL (Nigeria) limited rubber estate in Calabar (Fig. 1) were evaluated. PAMOL (Nigeria) limited is located about 15km of Calabar, the capital of Cross River State, lat. 4° 8' North to 4° 47' and long. 8° 17' E to 8° 22'. The area has annual rainfall values of 2000 - 3000mm. The rain starts in February or March but last till November. The mean annual temperature is between 21° and 30°C while the relative humidity ranges from 75-80%. The soils are derived from the parent materials namely sandstone and shale, soil colour fluctuates between brown and strong brown in the 0-40cm depth. The soil is loamy sand, has weak medium crumb structure, moist friable (wet) non-sticky plastic consistence, many fine to medium fibrous woody roots and many interstitial pores (Bulk-trade, 1989). The plot studied had varying topographic features and were selected to represent some major rubber clones; namely GT 1, PB 5/51, PB 28/ 59, PR 107, PR 600, RRIM 513, RRIM 600 and RRIM 628. (Fig. 2.)

Soil samples were taken from 50 augering points at two depths (0-20cm and 20-40cm). Samples were air-dried, crushed with porcelain mortar and pestle 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 a 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 Walkley and Black (1934). Exchangeable K and Na were determined using an EEL flame photometer while Ca and Mg were estimated using the EDTA Versenate titration method. Exchangeable acidity was determined using IN KCL extraction procedure as outlined by Mclean (1965). Effective Cation Exchange Capacity of the soils was computed by summing up the ammonium acetate-

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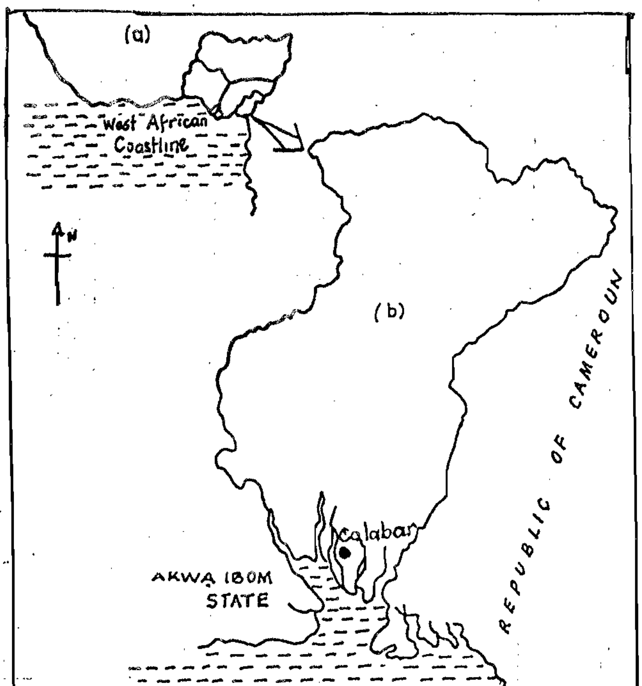

Fig 1: Map of West African Coastline showing (a) Nigeria's Cross River State and (b) Enlarged Cross River State showing Calabar the Study Location

extracted bases and exchangeable acidity and finally the Base Saturation was obtained by expressing the sum of the exchangeable bases as percentages of the effective cation exchange capacity. Total phosphorus was extracted by the perchloric acid digestion method (Jackson, 1964) and the organic form by the ignition method as described by Legg and Black (1955). Inorganic P was sequentially fractionated using the procedure outlined by Chang and Jackson (1957). Available P was determined by extraction with acid fluoride using the Bray P-1 and Bray P-2 methods (Bray and Kurtz, 1945). Olsen's $NaHCO_3$ (Olsen et al), Morgan's NaOAc (Morgan, 1937) and Mehlich 1 (M-1) H_2So_4 (Mehlich, 1978).

To determine the P nutritional status of the rubber leaves and root mat, where the soils were collected, 50 leaf samples were collected between the young and mature leaves, this portion is known to have maximum concentration of nutrients in leaves (Bowen, 1978), with one leaf sample each per tree from the 50 plots sampled and 50 root mat samples were collected by up-rooting at the various soil auger points after the soil on the roots have been shaken- off. Thereafter the leaf samples were oven dried at 70-80°C for 6-8 hours while the root samples were washed thoroughly to remove all the attached soil particles; oven dried at 80-100°C for 8-10 hours and milled (using warring commercial laboratory blender, model 35 BL 59) to pass through 1.0mm sieve. 0.2g of milled leaves and roots were digested in 50ml of acid mixture, 5ml of digest was used for the colour development and P-in the extract was determined by the phosphov- anado-molybdate yellow colour method using the spectrophotometer at 400mm wavelength to read the absorbence.

RESULTS AND DISCUSSION

Some physical and chemical properties of the soils are shown in table 1. Particle size analysis showed the plantation soils to be mainly loamy sand and sandy loam. Most of the soils had sand separates in excess of 70%, the upper limit of textural criteria defined by Chan et al. (1975) for rubber

Table 1: Some Physical and Chemical Properties of the Soils Supporting Rubber at Pamol Plantations, Calabar.

Clone	Plot/ Year of Planting	No. of Profiles	Depth (cm)	pH (H_2O)	Organic Carbon %	EA (H^++Al^{3+}) $Cmolkg^{-1}$	Effective C. E. C $Cmolkg^{-1}$	Base Saturation %	Sand	Silt %	Clay	Silt/ silt + clay ratio	Textural/ class
			0 - 20	4.8	1.43	1.80	5.83	69.1	84.6	5.4	10.1	0.35	L.S
GT 1	1969	2	20 – 40	5.1	0.69	0.88	5.69	83.0	78.7	2.7	18.6	0.13	S.L
	1970	2	0 - 20	4.7	1.41	1.28	3.18	71.1	78.3	7.3	14.5	0.33	L.S
			20 – 40	4.7	0.57	0.64	2.13	81.1	78.8	5.1	16.1	0.24	L.S
PB 5/51	1964	4	0 - 20	5.1	1.26	1.66	4.96	66.3	82.3	5.3	12.4	0.30	L.S
			20 – 40	5.2	0.65	1.44	4.75	69.3	80.8	2.9	16.3	0.15	S.L
	1966	6	0 - 20	4.8	1.50	1.48	4.08	64.2	82.9	4.2	12.9	0.25	L.S
			20 – 40	5.1	0.67	0.91	4.76	79.8	79.3	4.8	15.9	0.23	L.S
PB 28/59	1969	2	0 - 20	5.1	1.51	1.40	5.21	73.2	85.8	3.1	11.1	0.22	L.S
			20 – 40	5.1	0.82	1.64	5.82	73.4	84.1	5.0	11.0	0.31	L.S
	1970	2	0 - 20	4.9	1.42	0.80	3.57	77.5	85.0	4.6	10.5	0.30	L.S
			20 – 40	4.5	0.60	0.08	3.75	79.4	80.3	4.3	15.5	0.22	S.L
PR 107	1966	4	0 - 20	4.8	1.49	1.58	4.07	61.1	73.6	6.6	19.8	0.25	S.L
			20 – 40	5.2	0.70	1.35	4.11	62.9	64.0	6.4	29.7	0.18	S.C.L
	1970	2	0 - 20	4.7	1.51	1.52	6.00	74.1	80.0	7.3	12.0	0.38	L.S
			20 – 40	5.0	0.79	1.08	4.85	78.4	68.8	6.4	24.8	0.21	S.C.L
	1975	2	0 - 20	4.5	1.70	1.20	4.13	63.5	83.2	4.1	12.7	0.24	L.S
			20 – 40	4.8	0.68	0.68	3.47	79.3	80.8	3.4	15.8	0.18	L.S
PR 600	1969	2	0 - 20	4.9	1.19	1.60	5.19	69.1	80.5	8.1	11.4	0.42	L.S
			20 – 40	4.9	0.71	1.12	4.74	75.9	82.8	3.0	14.3	0.17	S.L
RRIM 513	1964	2	0 - 20	3.9	1.29	2.08	2.08	65.9	83.1	5.0	12.0	0.29	L.S
			20 – 40	4.8	0.63	1.68	1.68	70.2	75.8	7.8	16.4	0.32	S.L
RRIM 600	1965	2	0 - 20	5.0	1.35	1.20	3.86	68.1	83.0	3.3	13.8	0.19	L.S
			20 – 40	5.1	0.62	1.00	3.61	71.1	80.8	3.3	16.0	0.17	S.C.L
	1967	6	0 - 20	5.0	1.46	1.51	5.03	68.7	75.8	9.7	14.5	0.40	L.S
			20 – 40	4.8	0.62	1.09	4.61	75.7	72.8	5.7	21.9	0.21	S.C.L
	1969	6	0 - 20	4.9	1.32	1.52	4.99	67.8	81.1	6.6	12.3	0.35	L.S
			20 – 40	5.2	0.74	1.19	5.03	75.4	74.2	4.5	21.3	0.18	S.C.L
RRIM 628	1966	4	0 – 20	5.0	1.24	1.58	4.23	60.4	75.6	9.3	15.1	0.38	S.L
			20 - 40	5.1	0.58	1.08	3.43	68.3	67.6	6.3	26.2	0.19	S.C.L
	1969	2	0 - 20	4.7	1.24	1.56	4.23	60.4	88.4	3.1	8.5	0.29	L.S
			20 - 40	4.9	0.58	1.08	3.48	68.3	82.4	1.4	16.2	0.17	S.C.L

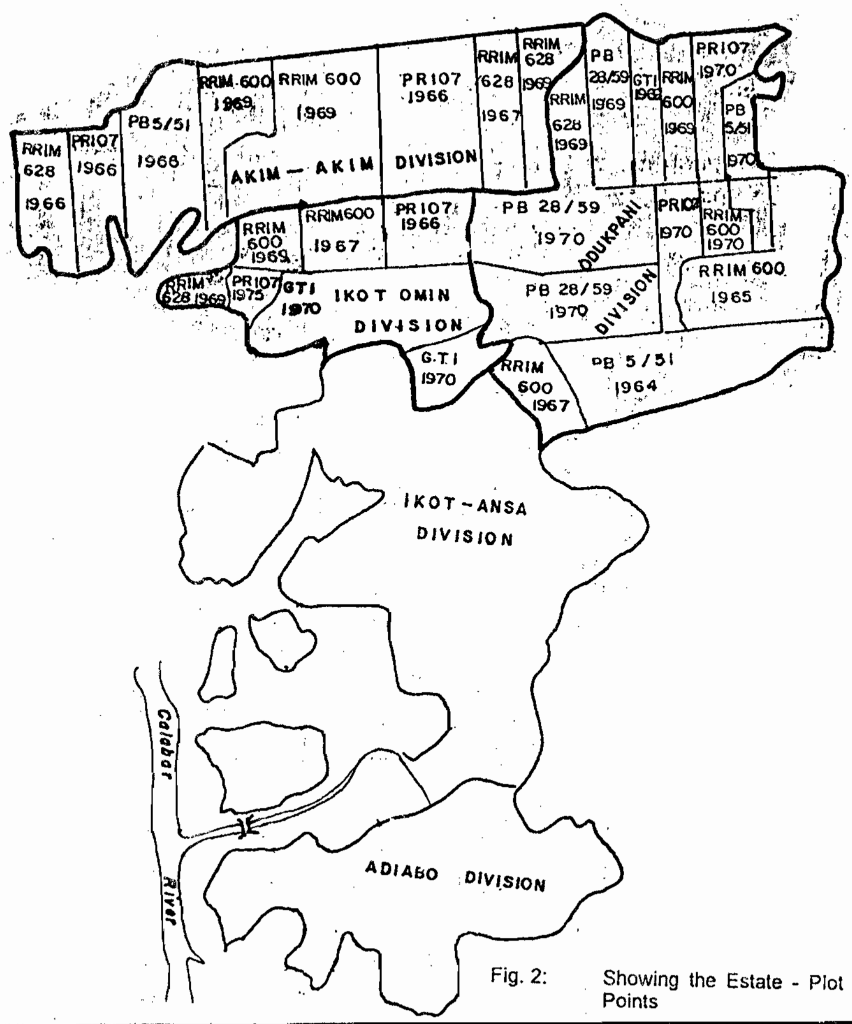

Fig. 2: Showing the Estate - Plot Lay-out and the Sampling Points

soils. Rather it indicates that the soils were too loose to provide sufficient mechanical support for the trees and prone to heavy leaching of nutrients and severe gully erosion both of which are major agents of soil degradation caused by rainfall (Okigbo, 1985). The desirable range of texture for rubber soils has been established at 50-70% sand and "almost proportionate amount of sand and silt plus clay" in the rooting zone of rubber trees (RRIM, 1977). The poor physical conditions of the soils may be attributed to old age or advanced degrees of weathering caused by rainfall. This deduction is largely because the silt/silt + Clay ratios (table 1) which according to Stewart et al (1970) reflect the degree of weathering of soils, were very low (Silt/Silt + Clay < 1.0). All values regardless of depth were less than 1.0; further emphasizing advanced stages of mechanical disintegration, especially of a large proportion of the silt into clay fractions (Amalu, 1992).

With just one exception, all the soils were generally very acidic to moderately acidic as pH values ranged from 3.9 to 5.1 (with a mean value of 4.8) for surface soils and from 4.5 to 5.2 (with a mean value of 5.0) for subsurface soils. 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).

Generally, the organic matter content in the surface soils exceeded the lower critical soil test values (2.0%) while the subsurface soils hardly reached the critical soil test values (Sys, 1975). Thus the surface soils were moderately endowed with organic matter whereas all the subsurface soils were rather low in organic matter. This observation is not uncommon in estate tree-crop soils generally. According to Von Uexhull (1986) the continuously humid, shady and cool conditions in the organic horizon enable roots to thrive in it and large proportions of the nutrients in these plant-soil systems are cycled and recycled between the living and dead organic matter without contact with the mineral soil below. This may probably explain why the present soils have remained fairly very productive and stable, like other tree-crop plant-soil ecosystems.

Effective Cation Exchange Capacity (E.C.E.C.) was generally moderate in all the soils, ranging from 2.08 to 6.0 $cmolkg^{-1}$ and 2.13 to 5.82 $cmolkg^{-1}$ for surface and subsurface soils respectively. Base saturation values for both surface and subsurface soils were high ranging from 60.4 to 77.5% and 62.9 to 83.9% for the two depths.

FORMS AND DISTRIBUTION OF PHOSPHORUS

TOTAL P

As shown in table 2, total P values varied between the soils. Soils under clones RRIM 600 (1965) and RRIM 513 (1964) had the lowest and highest values ranging from 51.5 to $158mgkg^{-1}$ with a mean of 94.5 $mgkg^{-1}$ for surface soils. For the subsurface soils, soils under clones PB 5/51 (1966) and

Table 2: Profile Distribution of Various Forms of Phosphorus in the Soils Supporting Rubber at Pamol Plantations, Calabar.

Clone	Plot / Year of planting	No. of Profile	Depth (cm)	Occluded P	Fe-P	Al-P	Ca-P	Residual P	Inorg. P	Org. P	Total P	Org.P (% of total P)	Org.C (%)	Org.C / Org.P
				←			mgkg^{-1}				→			
GT I	1969	2	0 – 20	2.8	12.2	8.0	11.9	1.3	36.3	31.5	67.8	46.5	1.4	444
			20 – 40	3.6	14.5	10.6	11.7	1.8	42.2	24.9	67.1	37.1	0.7	281
	1970	2	0 – 20	4.8	25.2	21.7	23.3	1.0	75.9	60.6	36.5	44.4	1.4	231
			20 - 40	3.8	17.1	13.7	15.4	1.1	51.2	38.7	89.9	43.1	0.6	155
PB 5/51	1964	4	0 – 20	2.0	12.8	8.1	10.1	0.8	33.8	33.0	66.7	49.9	1.3	394
			20 – 40	1.6	10.4	7.4	8.3	0.7	29.7	21.4	51.2	41.8	0.7	327
	1966	6	0 – 20	3.5	15.3	12.1	11.7	1.2	43.8	32.7	76.9	42.5	1.5	459
			20 – 40	1.7	9.4	7.0	7.8	0.5	26.3	18.4	44.7	41.2	0.7	380
PB 28/59	1969	2	0 – 20	6.1	16.8	11.9	14.5	2.7	52.0	35.3	87.3	40.4	1.5	425
			20 – 40	2.2	12.6	8.8	9.9	1.4	34.8	25.6	60.4	42.4	0.8	313
	1970	2	0 – 20	2.3	13.8	10.8	10.6	1.0	38.4	27.7	66.1	41.9	1.4	505
			20 – 40	2.0	11.9	7.8	9.5	1.0	32.1	23.5	55.6	42.3	0.6	255
	1966	4	0 – 20	2.6	14.6	7.3	11.3	1.4	37.2	30.7	67.9	45.2	1.5	489
			20 – 40	1.6	11.0	6.9	8.3	0.8	28.7	21.6	50.7	42.6	0.7	324
PR 107	1970	2	0 – 20	2.2	14.4	10.8	12.6	0.8	40.8	34.1	74.9	45.5	1.5	440
			20 – 40	2.9	9.4	7.3	8.2	1.4	29.1	20.5	49.6	41.3	0.8	390
	1975	2	0 – 20	5.1	22.5	18.2	19.5	2.8	68.0	56.5	124.6	45.3	1.7	301
			20 – 40	2.2	13.4	9.8	10.7	1.4	37.3	26.8	64.1	41.8	0.7	261
PR 600	1969	2	0 – 20	3.1	20.3	15.4	16.3	1.6	56.5	40.7	97.2	41.8	1.2	295
			20 – 40	2.2	14.7	10.1	12.8	0.6	40.3	27.7	67.9	40.8	0.7	253
RRIM 513	1964	2	0 – 20	6.0	27.3	19.3	21.6	2.0	76.2	82.5	158.7	52.0	1.3	158
			20 – 40	4.4	34.6	25.5	23.0	1.6	89.5	53.7	143.2	37.5	0.6	112
	1965	2	0 – 20	1.2	10.4	6.7	8.1	0.4	26.8	24.7	51.5	48.0	1.4	567
			20 – 40	2.9	18.3	13.4	15.3	1.5	51.4	17.9	69.2	25.9	0.6	335
RRIM 600	1967	6	0 – 20	3.3	27.2	20.2	22.1	1.5	74.8	56.2	131.0	42.9	1.5	267
			20 – 40	3.2	23.9	16.3	19.2	1.2	63.7	40.1	103.8	38.6	0.6	150
	1969	6	0 – 20	4.5	22.9	22.9	18.4	2.1	65.3	47.0	112.3	41.9	1.3	277
			20 – 40	2.6	13.1	9.6	11.1	1.2	37.7	24.6	62.2	39.5	0.7	285
RRIM 628	1966	4	0 – 20	3.5	21.0	21.0	18.4	1.8	60.1	45.4	105.5	43.0	1.5	330
			20 - 40	2.4	15.1	10.8	12.3	1.2	42.2	31.2	73.4	42.5	0.8	256
	1969	2	0 – 20	3.8	15.7	15.7	12.9	1.4	46.3	40.0	86.3	46.3	1.2	300
			20 - 40	4.5	17.1	11.7	12.5	1.6	47.4	31.2	78.6	39.7	0.6	192

RRIM 513 (1964) had the lowest and the highest values ranging from 44.7 to 143.2 mgkg^{-1} with a mean of 70.7 mgkg^{-1} Total Phosphorus for the soils in the three divisions studied are comparable to those reported for Nigerian soils (Ibia and Udo, 1993; Udo and Dambo, 1979; Udo and Ogunwale 1977; Enwezor, 1977) and for soils from other West African counrties (Halm and Bampoe – Addo, 1972). The relatively low contents of total P for both surface and subsurface soils indicate low phosphorus reserves in these soils. Comparatively low phosphorus level in parent materials, great age of the soils and the intense weathering to which they have been subjected have probably all contributed to these low total phosphorus values.

ORGANIC PHOSPHORUS

...Organic P content in these soils varied from 17.9 to 82.5mgkg^{-1} for both the surface and subsurface soils. There was a general decrease of organic P with depth in line with the trend in organic carbon distribution. As a fraction of total P, organic P varied from

40.4 to 52% with a mean of 44.8% of total P for surface soils and from 25.9 to 43.1% with a mean of 39.9% of total P for subsurface soils. The higher organic phosphorus values for the surface layers of the soils are related to their higher organic matter content that results from the more luxuriant vegetation they carry. The supply of phosphorus to plants in soils is particularly governed by the content of active inorganic P and organic P fractions. Organic P fractions contribute substantially to available phosphorus reserves following mineralization in tropical soils (Sare and Udo, 1988). This phenomenon is governed by C/P ratios and the established critical limit for tropical soils is 200 (Tisdale and Nelson, 1975). The C/P ratios in the studied soils were generally high (>200) in most of the soils with the exception of the soils to which the clone RRIM 513 (1964) was planted; suggesting relative difficulty in the release of substantial amount of P in available forms to most of the rubber trees in the plantations (**Table 2**).

INORGANIC PHOSPHORUS

Total inorganic phosphorus is divided into active and inactive forms, the former consists of Fe-P, Al-P and Ca-P and the latter, occluded P, reductant soluble P and residual P (Chang and Jackson, 1957). The active forms are the fractions most available to plants, with the degree of availability increasing in the order Ca-P, Fe-P and Al-P in the upland conditions (Thomas and Peaslee, 1973), in the flooded soils Fe-P is the form most available (Uzu, *et al*, 1975). The order of abundance of the active inorganic P fractions was Fe-P > Al-P > Ca-P in all the soils formed from shale and sandstone. The relatively low values of inactive P in these soils generally indicate that the soils are likely to be formed from quartz sand with practically no iron-oxide (Enwezor, 1977).

AVAILABLE PHOSPHORUS

The level of available P extracted by various extractants showed variability in the efficiency of extractants as well as variability among the different soils (Table 3). Of the five methods Bray P-2 removed the highest amount ranging from 3.5 to 10.2mgkg^{-1} and

Morgan removed the lowest amount of available P ranging from 1.1 to 4.2mgkg^{-1}. The dilute acid fluoride extractants of Bray and Kurtz (1945) and the Mehlich extractant stand out as good extractants of available phosphorus in the soils. This was as expected since the soils studied were generally very acidic and the dominant species of inorganic P were mainly Fe-P and Al-P. The Mehlich extractant combines the advantage of double acid action since relatively greater amounts of Fe-P could be dissolved in the mixed acid solution compared to HCl alone. The dilute acid extractant of phosphate by Morgan's

Table 3: Mean Values of Different Methods of Available P in the Soils of Pamol Rubber Plantations, Calabar

Clone	Plot/ year of planting	No. of Profile	Depth (cm)	Bray P-1	Bray P-2	Mehlich	Olsen	Morgan
				←		$mgkg^{-1}$		→
	1969	2	0 – 20	2.82	5.36	2.58	2.72	2.46
GT 1			20 – 40	1.80	3.82	1.48	1.03	1.54
	1970	2	0 – 20	5.27	7.34	3.44	3.46	2.46
			20 – 40	3.19	5.18	1.78	1.55	1.96
	1964	4	0 – 20	2.21	4.39	0.80	1.24	1.87
PB 5/51			20 – 40	3.31	3.53	1.47	0.98	1.08
	1966	6	0 – 20	4.46	6.12	2.33	2.40	2.03
			20 – 40	2.96	3.59	0.96	1.48	1.52
	1969	2	0 – 20	4.47	6.03	1.90	2.57	2.08
PB 28/59			20 – 40	3.74	4.98	2.21	1.83	1.78
	1970	2	0 – 20	6.44	6.81	5.92	3.42	2.14
			20 – 40	3.74	4.70	2.21	1.38	1.78
	1966	4	0 – 20	5.15	5.89	2.27	2.13	2.88
			20 – 40	2.97	3.78	2.18	1.57	1.69
PR 107	1970	2	0 – 20	4.18	4.92	2.33	0.97	1.66
			20 – 40	2.21	3.51	1.04	1.04	1.29
	1975	2	0 – 20	8.03	10.2	1.72	2.15	2.33
			20 – 40	2.84	4.62	1.54	1.18	1.35
PR 600	1969	2	0 – 20	5.58	7.02	2.70	1.72	2.21
			20 – 40	2.21	4.02	0.92	1.29	1.54
RRIM 513	1964	2	0 – 20	6.56	9.12	1.78	5.56	3.37
			20 – 40	8.46	11.76	6.05	5.39	7.11
	1965	2	0 – 20	3.62	5.67	3.01	1.42	1.90
			20 – 40	6.13	6.41	3.19	1.09	1.60
RRIM 600	1967	6	0 – 20	7.82	8.61	5.76	3.73	4.23
			20 – 40	4.40	5.27	2.66	1.90	1.60
	1969	6	0 – 20	7.02	8.07	3.68	2.25	2.33
			20 – 40	3.62	4.24	1.82	1.19	1.64
	1966	4	0 – 20	6.04	6.67	4.60	2.02	1.41
RRIM 628			20 – 40	4.75	5.30	2.85	1.82	2.02
	1969	2	0 – 20	2.64	4.75	1.84	2.09	2.02
			20 – 40	3.68	4.90	2.06	1.98	1.81

reagent is the least in this capacity and this could be due to low rates of displacement of phosphates as well as low level of acid dissolution of calcium phosphate in the soils (Ibia, 1998).

Table 4: Correlation Coefficients between Available P and P Fractions for Surface and Subsurface Soils

Available P	Total P	Organic P	Al – P	Fe – P	Ca- P
		Surface			
Bray P –1	0.608**	0.476**	0.685**	0.656**	0.592**
Bray P –2	0.570**	0.459**	0.615**	0.601**	0.523**
Mehlich	0.408**	0.337*	0.483**	0.450**	0.378**
Olsen	0.473**	0.413**	0.490**	0.508**	0.410**
Morgan	0.431**	0.400**	0.412**	0.472**	0.401**
		Subsurface			
Bray P –1	0.546**	0.428**	0.658**	0.590**	0.532**
Bray P –2	0.607**	0.529**	0.639**	0.629**	0.549**
Mehlich	0.512**	0.398**	0.572**	0.559**	0.490**
Olsen	0.671**	0.641**	0.610**	0.629**	0.577**
Morgan	0.506**	0.486**	0.605**	0.536**	0.436**

* P significant at 0.05
** P significant at 0.01

The correlation coefficients were highest for Al-P and lowest for Ca-P and Organic P. **(table 4)**
Of the extractants, Bray P-1 and Bray P-2 had high correlation coefficient with Al-P indicating that these acidic extractants removed mainly Al-P. Values for Bray P-1 and Bray P-2 extractants stand out as the best soil test for available

Table 5: Values of Leaf P and Root Mat P for the Clones and Under Growth in Pamol Rubber Plantations, Calabar.

Clone	Year	No. of Plot	Leaf P	Root Mat P
			← $mgkg^{-1}$	→
GT 1	1969	2	0.53	0.57
	1970	2	0.54	0.48
PB 5/51	1964	4	0.62	0.47
	1966	6	0.54	0.50
PB 28/59	1969	2	0.60	0.58
	1970	2	0.57	0.48
PR 107	1966	4	0.41	0.45
	1970	2	0.46	0.42
	1975	2	0.57	0.47
PR 600	1969	2	0.58	0.58
RRIM 513	1964	2	0.60	0.55
RRIM 600	1965	2	0.53	0.50
	1967	6	0.53	0.54
	1969	6	0.50	0.47
RRIM 628	1966	4	0.43	0.41
	1969	2	0.53	0.54

phosphorus, though most of the soils had moderate amount of available P (3-7mgkg^{-1}). This confirms the findings of Uzu and Onuwaje, (1980) who worked on major rubber soils in Nigeria and confirmed Bray P-1 as the best extractant for predicting responses of rubber seedling to P in terms of dry matter yield and P uptake and Bray P-2 was also confirmed from the findings of Ibia (1998) as the best extractant for routine test for soils in South-Eastern Nigeria. The results showed that soils supporting rubber in the plantations were generally deficient in total and active P and had moderate amount of available P in most of the soils except the soils on which the clones PR 107 (1975) and RRIM 513 (1964) were planted. Hence the soils were only marginally suitable for growing rubber trees.

Values for leaf P of the rubber trees in the plantations ranged from 0.41 to 0.62mgkg^{-1} with a mean of 0.53 mgkg^{-1} while that of root P ranged from 04.1 to 0.58 mgkg^{-1} with a mean of 0.51 mgkg^{-1}. (Table 5)

The correlation coefficients of leaf P and root mat P concentrations with soil P showed negative correlation with leaf P while the root mat P showed no correlations with soil P. The only exception was Olsen extractant that showed a correlation of 0.425** (Table 6).

Table 6: Correlation Coefficients between leaf P /Root Mat P and Soil P for Surface Soils

Soil Properties	Leaf P	Root Mat P
Olsen	0.022	0.425**
Bray P – 1	-0.231	0.042
Bray P – 2	-0.140	0.091
Total P	-0.033	0.125
Organic P	-0.015	0.090
Al – P	-0.011	0.130
Fe – P	-0.081	0.0139
Ca – P	-0.083	0.113

** P Significant at 0.01.

The results showed that the amount of root P did not vary much from the leaf P compared to the amounts of available P that were present in the soils. These variations in general, may be attributed to the complex mechanisms of uptake of nutrients from soil supply, which varies from element to element, and in relation to the nature of plant species, their rooting systems (tap-root and extensive lateral roots) and seasons of the year. (Leaf, 1973, Munson and Nelson, 1973). It was interesting to note that Olsen extractant correlated with root mat P at 0.01 significant level indicating that the root mat was helpful in the retention of available P for rubber trees.

In conclusion, the results of the study showed that soils supporting rubber in the plantations were generally deficient in total and active P and had moderate amount of available P in most of the soils except the soils on which the Clones PR107 (1975) and RRIM 513 (1964) were planted. Hence the studied soils were only marginally suitable for growing rubber trees and as such it is recommended that 40kg of rock phosphate, in a mixture of 42kg ammonium sulphate, 10kg of potassium chloride and 6kg of magnesium sulphate fertilizers (R.R.I.N., 1971) be applied for the healthy growth of the rubber trees in the plantations to increase latex yield.

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