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THE EFFICIENT USE OF PHOSPHATIC FERTILIZER IN RELATION TO THE PHOSPHORUS FIXING CAPACITIES OF THE RUBBER SOILS

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INTRODUCTION

Rubber (*Hevea brasiliensis*) is grown extensively in the South Western part of Sri Lanka. The soils of this region have a pH range of 4·5 to 5·5 and contain appreciable amounts of iron and aluminium as oxides. These rubber lands have received large quantities of fertilizer over the years. The source of fertilizer phosphorus has been exclusively the import rock phosphate. About 150 kg per ha is recommended for use annually. The phosphorus fixing capacities of these soils have been estimated to be high. The present study attempts a quantitative evaluation of the phosphorus fixing capacities of the important soil series and their relationships with a few significant physical and chemical properties, in order that meaningful recommendations may be made on the use of rock phosphate in supplying the phosphorus requirements of *Hevea.* The significance of this work to the Rubber Industry has been increased, as a result of the availability in Sri Lanka of a large deposit of Apatite. The use of Apatite as a source of phosphorus for the nutrition of rubber is also discussed.

MATERIALS AND METHODS

Five important soil series on which rubber is extensively grown were selected for this study. They are the Agalawatte, Homagama, Boralu, Parambe and Ratnapura soil series. The amounts of phosphorus fixed was calculated by subtracting the amount of phosphorus in soil solution from the amount of phosphorus in the original solution, before mixing with the soil. The chemical and physical properties were determined using the conventional methods.

RESULTS AND DISCUSSION

Maximum Phosphorus fixing capacity

The process of phosphorus fixation has been found to obey the Langmuir equation (Kardos, 1964). This implies that the curve plotted between the concentrations of added and the extracted P will have a point when it changes from a convex to a concave position. This is the stage at which the phosphate fixing capacity of the soil is nearly satisfied. This inflection point at which there is an abrupt increase in extracted P, has been defined as the maximum P fixing capacity. The concentrations of added P are plotted against that of extracted P and shown in Fig. 1. It is seen that for Parambe, Agalawatta, Homagama and Ratnapura soil series this abrupt increase in extracted P occurs at a point when the concentration of added P is 50 ppm. The maximum P fixing capacity of these soils therefore occurs when the concentration of the added P is 50 ppm. With respect to the Boralu soil there is no particular concentration at which the P fixation is at a maximum. Therefore, for all the soils studied a 50 ppm solution of added P was used to determine the relationships between P fixing capacities and soil physical and chemical properties.

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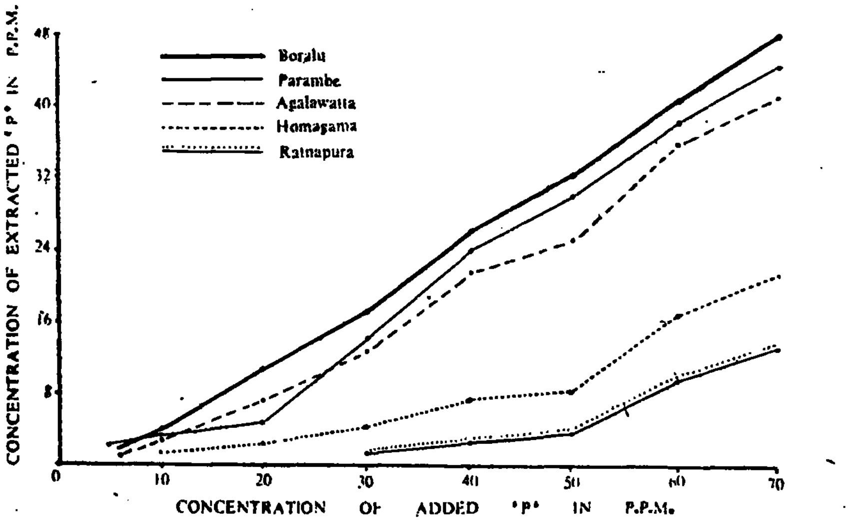
FIG. I — EFFECT OF CHANGE IN 'P' CONCENTRATION ON 'P' EXTRACTED AFTER FIXATION



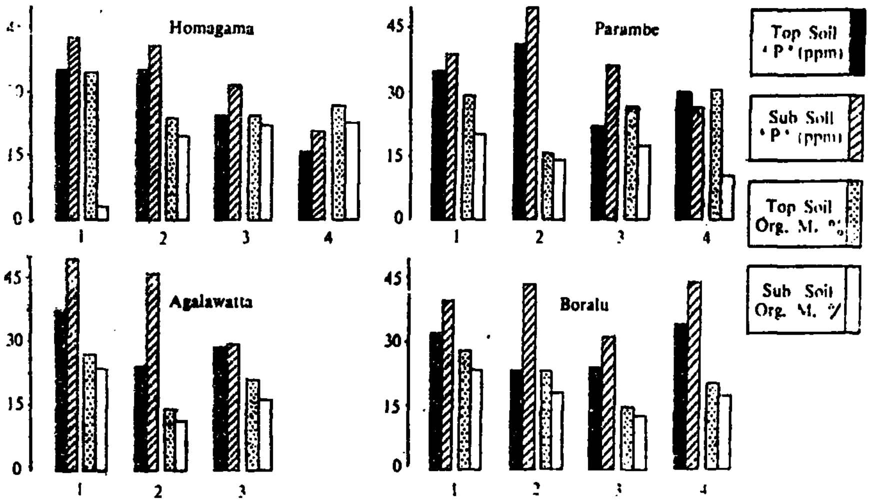
P fixing capacities

The phosphorus fixing capacities of the different soil series show a distinct trend between the two depths in all the soil series. In all of them the amounts of P fixed increases with depth, and this relationship is significant consistently ($P = 0{\cdot}001$).

Organic matter and P fixation

The organic matter contents of the upper layers of the soil is higher than in the sub-surface layers as shown in Fig. 2. This decrease in organic matter content of the soil with depth too is significant consistently ($P = 0{\cdot}001$). Oke (1970) has observed that in Nigerian soils there exists a highly positive correlation between organic matter and the multivalent ions such as Fe, Al and Mn. He attributes this to the fact that these ions could form complexes with the organic matter. It is therefore possible that in our soils also the organic matter forms complexes with the Fe, Al and Mn ions in which our soils are very rich, thus reducing the ability of these soils to fix P, by combining with the organic matter. A negative correlation between organic matter and P fixed is therefore explained. The parent material of these soils being rich in ferro-magnesium minerals this relationship is understandable.

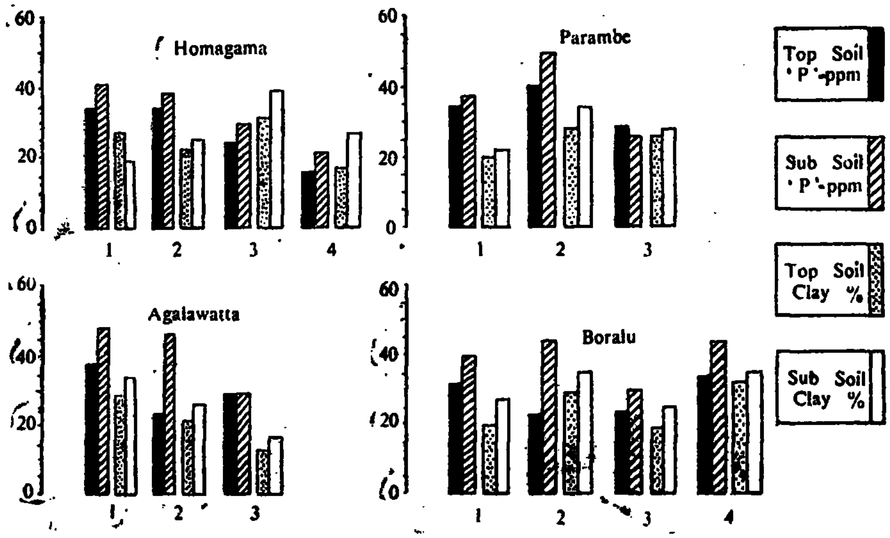
FIG. 2 — RELATIONSHIP BETWEEN P FIXING CAPACITY AND ORGANIC MATTER.



Clay content and P fixation

The clay contents in the sub-surface soils is higher than in the surface soils as shown in Fig. 3. This increase in clay content with depth is significant consistently (P = 0·005). The amount of P fixed also increases with depth. Dhanapalan *et al.* (1975) have shown that the P fixing capacity is dependent more on the type and amounts of sesquioxides than on the actual amounts of clay. The rubber soils are red yellow podzolic or reddish brown earths with a preponderance of Kaolinitic type clays. This relationship appears to be quite significant in the Boralu soil and is understandable because the process of laterization and the formation of Kaolinitic clays in the Boralu soil is expected to be at a maximum.

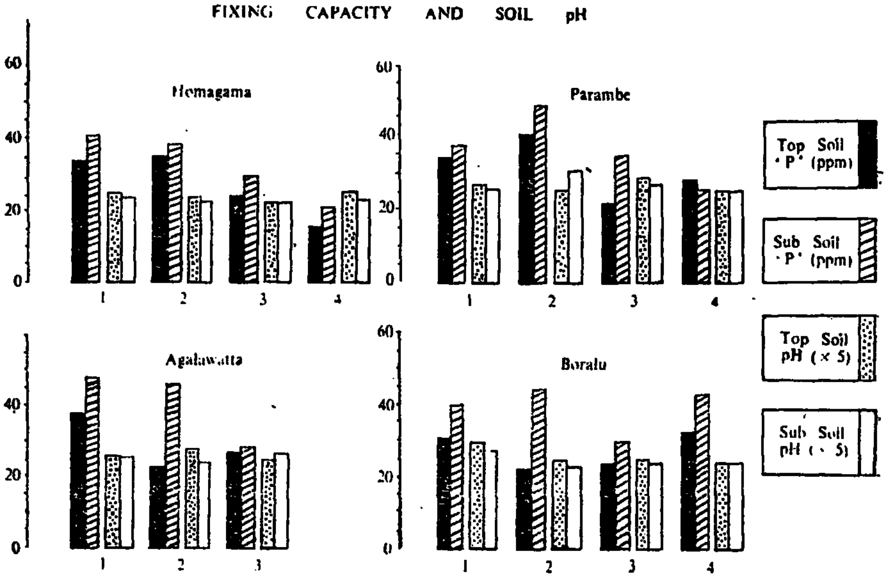
FIG. 3 — RELATIONSHIP BETWEEN P FIXING CAPACITY AND CLAY CONTENT



pH and P fixation

The pH of the soil decreases with depth as shown in Fig. 4, and this is significant (P = 0·02). Deb & Datta (1959) have observed that phosphate absorption in soils decreases with increase of the pH of the reacting medium and attributed it to the higher activity of multivalent ions at lower pH levels causing a higher fixation of P, by the development of a positive charge in the soil colloidal system.

FIG. 4 RELATIONSHIP BETWEEN P FIXING CAPACITY AND SOIL pH



Fe and P fixation

The amounts of available iron is found to increase with depth as shown in Table 1. This relationship is however non-significant probably because of the limited number of sites studied. It is well known that multivalent ions such as Fe enhances P fixation. The availability of Fe will therefore play a major role in P fixation. It is seen that the surface soil in site 1 of the Homagama series has a high available Fe content of 56 ppm. but the P fixed is not exceptionally high. This is because of the high organic matter content of 3·29% which would react with the available Fe thus preventing excessive P fixation. The surface soil in site 1 and the sub-surface soil in site 2 of the Agalawatta series have similar clay contents of 26·6% and 26·3%, respectively. However, the P fixed in the latter soil is 45·00 ppm and is higher than in the former which is 35·50 ppm. This is probably because the available Fe in the sub-surface soil of site 2 is 54·8 and higher than in the other site and shows that available Fe increases P fixation. The pH difference between the two sites also suggests that at lower pH levels the availability of Fe increases thus increasing P fixation.

TABLE 1 : PHOSPHORUS FIXING CAPACITIES AND PROPERTIES OF THE AGALAWATTA AND HOMAGAMA SERIES

Soil Series	Site	'P' Fixed (in ppm)	Clay %	Organic matter %	Available 'Fe' (in ppm)
Agalawatte	1	35·50	26·55	2·58	49·6
		47·30	33·03	2·20	50·2
	2	22·20	20·75	1·27	17·5
		45·00	26·33	1·15	54·8
	3	27·00	12·73	2·05	17·6
		27·25	15·68	1·62	34·3
Homagama	1	33·50	26·00	3·29	56·0
		40·00	18·53	0·39	11·8
	2	33·75	21·80	2·32	15·1
		38·25	24·50	1·84	11·3
	3	23·75	31·03	2·34	9·6
		29·25	37·55	2·06	14·8
	4	15·00	16·23	2·53	7·3
		20·75	26·83	2·25	15·6

Ca and P fixation

The calcium contents decrease with depth. This relationship is however not statistically significant. It is possible that the surface soils because they are richer in organic matter could release the Ca which then get absorbed by the soil colloids thus increasing the exchangeable Ca in the surface soils. Most of the added phosphates forms complexes with Ca and Mandal (1975) has reported that most of these reaction products could be considered as sources of phosphorus for plants.

Soil fertilizer reaction products

Lehr *et al.* (1960) has listed a few of the reaction products of Fe and Al phosphates in acid soils.

1. Strengite $FePO_4 \cdot 2H_2O$: It has been recognised as a supplier of P to the plant.

2. Vivianite $Fe_3(PO_4)_2 \cdot 8H_2O$: It is found in high organic matter soils and likely to contribute to the phosphate pool of the soil.

3. Varisate $AlPO_4 \cdot 2H_2O$: In colloidal form the phosphorus is moderately available to crop plants.

Studies indicate that under different soil conditions different reaction products are formed. Aluminium phosphate regarded as an ineffective source of phosphorus supply has now been recognised as a source of considerable amount of P. Cholitkul (1971) regards iron phosphate as a prime source of labile P in the rice soils of Thailand. Calcium phosphate no doubt is believed to be a major source of phosphate in the soil.

Sources of phosphatic fertilizers

Rock phosphates are used exclusively to supply the phosphorus requirements of *Hevea* and this is imported. In 1973 a fluor Apatite deposit was found in Sri Lanka. Experiments with this material have shown that the growth of budded stumps is in no way retarded when this material is used as the source of P. Table 2 gives the average girth measurements of the plants in this area.

TABLE 2 : GIRTH MEASUREMENTS OF THE DIFFERENT TREATMENTS

Treatment	Average diameter in cm at 6″ above graft union		Average girth measurements in cm at 3′ above graft union
	1973	1974	1975
R 4 : 0 : 3 Mg (Control)	0·89	1·35	11·69
R 4 : 6 : 3 Mg (Apatite)	0·88	1·37	13·40
R 4 : 6 : 3 Mg (Saphos)	0·93	1·38	11·94

The soil and leaf analytical data of the same area are given in Table 3.

TABLE 3 : LEAF AND SOIL PHOSPHORUS LEVELS

Treatment	Leaf nutrient values P%	Soil nutrient values Available P (ppm)
R 4 : 0 : 3 × Mg	0·169	11·13
R 4 : 6 : 3 × Mg-A	0·177	23·83
R 4 : 6 : 3 × Mg-S	0·176	14·7

This data also show that there is no difference between the different treatments. Experiments have also being initiated to test the availability of P from this source using incubation techniques, pot experiments and ^{32}P tracer methodology. These experiments have not yet been concluded. The results are available to date indicate that the locally available Apatite may be used as a source of P for the nutrition of immature *Hevea*.

CONCLUSION

The fact that pH and soil organic matter are negatively correlated with P fixation suggests that by manipulating these soil characteristics, P fixation could be decreased. Liming is an accepted practice of increasing pH. It would be impracticable to implement in rubber plantations and the reported ill effects of Ca in depressing yields prevent us from recommending this approach to reduce fixation of added fertilizer P. The increase of soil organic matter is another method of decreasing P fixation. It is therefore of paramount importance that a well established ground cover be maintained specially during the immature period. The organic matter thus formed would contribute to decreasing the P fixing capacity of the soil during the mature phase also, when a cover may no longer be present. The clay contents and the available iron contents are positively correlated with P fixation. All the five soil series studied have high clay contents. Therefore the amounts of P fixed by these soils is expected to be high. These soils have high iron contents and the present studies indicate that complexes with iron are formed explaining the observed positive correlation. Current thinking however regards these reaction products are suppliers of P in acid soils. An indirect method of reducing this type of P fixation would be to minimise direct contact of fertilizer P with these ions. The use of a sparingly water soluble source of phosphorus *i.e.* a rock phosphate, the placement of fertilizer in bands and the application of crushed rock phosphate instead of finely ground phosphate rock, would contribute to reduced P fixation.

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