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ROLE OF ROCK PHOSPHATES IN THE NUTRITION OF IMMATURE AND MATURE *HEVEA*

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ABSTRACT

Commercially available Eppawela rock phosphate (ERP) was evaluated as a source of P for young rubber plants throughout the period of their immaturity. The effects of rock phosphate on yield and nutrient composition of leaves and soil were also studied on mature rubber. The efficiency of ERP in relation to growth of young plants was similar to that of Imported Rock Phosphate (IRP) and Triple Super Phosphate (TSP) when used in soils with a P status less than 37.00 kg of soils and with a soil pH range of 3.6 to 4.2. In these situations it appears that the currently recommended rate of P is unlikely to be sufficient to meet the plant P demand. It is therefore possible to use ERP as a source of P for immature rubber plants growing in areas which are considered low in P for rubber. In contrast, application of rock phosphates did not influence the productivity of the mature rubber tree. Plants were able to maintain adequate levels of P in leaves even under no P fertilizer conditions suggesting the effect of residual P in soil that received IRP during the immature phase.

INTRODUCTION

Phosphorus is one of the important nutrients for crop growth and production for rubber. Adequate P fertilization is therefore essential. The importance of P fertilizers both for immature and mature rubber is well established (Yogaratnam and Mel, 1985). Due to certain limitations in the use of more soluble P fertilizers, rock phosphate fertilizers are normally recommended for rubber (RRISL, 1980). Rock phosphates, imported from foreign countries, are used as the only source of P to meet the P requirements of immature rubber during the unproductive period (about 5-6 years). The quantities of rock phosphates are in the region of 2 000 - 3 000 MT per year. As these are very costly, cheaper alternatives will have to be identified. Locally available ERP deposit discovered in 1971 appear to be a promising substitute. At present it is used only at the mature stage of the crop.

Although, ERP is used in the perennial crop sector (Sivasubramaniam *et al*, 1981, Yogaratnam, 1988 and Jayasekera, 1989), it is known to behave in a complex manner in the soil mainly due to the heterogenic nature of its mineralogy (Dissanayake, 1992). Nevertheless, greater dissolution observed with increased time (Dissanayake, *et al*, 1993) makes it possible to use this material successfully on long term perennial crops. In addition to fertilizer and soil factors (Khasawneh and Dall, 1978, Smyth and Sanchez, 1982), it has generally been recognized that P availability from rock phosphates is governed by plant factors also (Bekele, *et al*, 1983 and Dissanayake *et al*, 1992) and therefore age, productivity and P demand of the rubber plant could be expected to influence the agronomic efficiency of rock phosphate fertilizers. As studies carried out earlier (Yogaratnam, 1977) to evaluate the effectiveness of ERP as a source of P for immature as well as mature rubber growing in the field, have not given conclusive results, another study was undertaken to re-examine this subject.

MATERIALS AND METHODS

Experiments

Immature rubber

This experiment compares the effects of three sources of P *viz* ERP,IRP and TSP at three levels; zero, normal (250g/plant/year) and double the recommended level (500g/plant/year) of P, on the performance of *Hevea* during the immature period. The P contents of the fertilizers are given in Table 1.

Table 1. *Phosphorus contents of fertilizers*

Fertilizer	Total P_2O_5 content %	Citric acid soluble P%	Water soluble P %*
ERP	32.30	2.65	0.010
IRP	28.50	3.59	0.003
TSP	47.85	27.50	0.070

* Expressed as a percentage of the total P content

The experimental trees were planted in June/July 1987 in *Boralu* series soils, some physico-chemical characteristics of which are given in Table 2.

Treatments were allocated to 25 effective trees in a randomized block design with three replicates. All plants received uniform applications of Urea, Muriate of Potash, Kieserite and Dolomite during the experimental period (RRISL, 1980).

Table 2. *Some physico-chemical characteristics and P fractions of the experimental soil*

Texture	Organic C%	p^H	AER-P (mg/kg)	AER+CER-P (mg/kg)	NH_4F+HCl-P (mg/kg)	AAE-Ca (mg/kg)
Gravelly	1.20	3.65	4.21	5.50	6.50	10.50

AER-P - Anion exchangeable Resin P
(AER+CER)-P - Anion and cation exchangeable Resin P
AAE-Ca - Acetic acid extractable P

Mature rubber

A field experiment started in 1976 (Yogaratnam, 1977) on *Boralu* series soils, some physico-chemical characteristics of which are given in Table 3. Two levels of P, 50 and 100 g per plant, using ERP and IRP (Egyption origin) as the sources of P were tested as experimental treatments with no P fertilizer treatment as the control. Treatments were allocated according to a randomized block design with 4 replicates, using 9 effective trees as plot size. Soil and leaf samples were collected 4 times over a period of one year from Sept'90 to August '91.

Table 3. *Some physico - chemical characteristics of experimental soil*

Texture	Organic C%	pH	AER-P (mg/kg)	NH_4F+HCl P(mg/kg)
Gravelly loam	1.19	4.07	1.05	14.50

Growth, leaf and Soil assessments

Girth of immature rubber plants was measured annually at a height of 90cm from the point of bud union, and leaf and soil samples were also taken for analysis in the usual manner. After drying, the soil was sifted to obtain samples of not greater than 2 mm size. Soil pH in 0.01 M $CaCl_2$, anion - exchangeable resin P (AER-P) and NH_4F+HCl extractable P were determined by colorimetry.

Healthy leaves found on branches situated in the middle third of the canopy were sampled from each tree (Yogaratnam, 1983); and one composite sample was made for each treatment plot. Samples were dried in an oven at 70-80°C for 48 hrs. then ground and digested, and P contents were measured colorimetrically.

Yield assessments

Yield assessments were made fortnightly by tapping and latex was collected form each tree and its volume was measured. After mixing latex collected from 9 trees, a representative sample of 50ml. was taken, dried in an oven at 80°C and dry weight recorded. This was used to determine the dry rubber content of the individual tree and used to calculate the monthly average dry rubber yield per tree for each treatment.

RESULTS

Immature rubber

Crop response to different rates of phosphate application

No significant differences were observed in plant girth between the recommended level (L_1) and zero level (L_0) of applied P during the period of 6 years. But, a significant increase ($P<0.05$) in girth was recorded from the end of second year when the rate of application of P was increased to double the recommended level (L_2). This amounted to an annual increase of 4.9%, 6.9%, 4.6%, 7.4% and 4.8% over the currently recommended rate of P up to the age of 6 yrs (Table 4).

Table 4. *Effect of different levels of P on plant girth (cm)*

P level	Age (years after planting)					
	1	2	3	4	5	6
L0	9.20^{A}	14.43^{B}	24.43^{B}	31.56^{B}	36.87^{B}	41.27^{B}
L1	8.93^{A}	14.80^{B}	24.90^{B}	32.93^{B}	37.00^{B}	41.85^{B}
L2	9.37^{A}	15.50^{A}	26.62^{A}	34.45^{A}	39.73^{A}	43.86^{A}

(Means with the same letters are not significantly different at 5% level)

Crop response to different phosphatic sources

Although there had been significant increases in girth to application of phosphate (Table 4), yet different sources of P did not show any significant differences on the performance of rubber plants throughout the immature period. All the sources behaved in a similar manner showing that the effect of ERP was similar to that of IRP and TSP on plant girthing in phosphate deficient soils (Table 5).

Table 5. *Effect of different sources of P on plant girth (cm)*

Source	Age (yrs)					
	1	2	3	4	5	6
IRP	9.18^{A}	14.90^{A}	25.27^{A}	33.29^{A}	38.72^{A}	42.78^{A}
ERP	9.27^{A}	14.74^{A}	24.76^{A}	32.17^{A}	37.16^{A}	41.71^{A}
TSP	9.02^{A}	15.12^{A}	25.94^{A}	33.49^{A}	37.72^{A}	42.48^{A}

(Means with the same letters are not significantly different at 5% level)

Changes in leaf P content

Although there were no marked effects on leaf P content due to different sources and levels of phosphate at the early stages, a significant interaction ($P<0.05$) between sources and levels of P was observed at the age of 5 years. Application of

TSP at higher rate increased the leaf P content although the rock phosphate sources of P failed to increase the P content even at the highest level of P. IRP on the other hand was able to increase the leaf P content ($P<0.05$) at the recommended level of P application (Table 6).

Table 6. *Effect of different sources and levels of P on leaf P content (%)*

P source	Level of P			
	L0	L1	L2	LSD[1]
IRP	0.187	0.203	0.189	0.021
ERP	0.185	0.172	0.198	0.031
TSP	0.175	0.182	0.199	0.016
LSD[2]	0.015	0.016	0.040	

LSD[1] - For fertilizer levels (Source of fertilizers fixed)
LSD[2] - For source of fertilizers (Levels of Fertilizer fixed)

Economics of P fertilization

A calculation was made on the use of imported and locally available rock phosphate as sources of P during the immature period in an extent of 1 ha for economic comparison between the two sources of P (Table 7).

It is very clear that the use of ERP even at the rate of double the recommended level is more profitable than the use of IRP at the currently recommended rate, amounting to savings of 3.8 – 3.9 % during the different stages of the immature period. Moreover, if the amount of P has to be increased as indicated in this study (Table 3) and if the source of P is imported rock phosphate, the cost would be very much higher than with the use of ERP at the same rate of P. Therefore, the use of ERP instead of using IRP at the increased rate would be much more economical as the annual net saving would be more than 50%. This would amount to a saving of over 300% during the entire immature period.

Table 7. *Economic evaluation of P fertilization*

Year	Cost (Rs)			% Saving	
	IRP L-1	IRP L-2	ERP L-2	ERP L-2 vs IRP L-1	ERP L-2 vs IRP L-2
1	656.25	1312.50	631.60	3.86	51.89
2	687.50	1325.00	660.96	3.87	51.90
3	1000.00	2000.00	961.40	3.90	51.90
4	1000.00	2000.00	961.40	3.90	51.90
5	1375.00	2750.00	1321.00	3.90	51.90
6	1375.00	2750.00	1321.00	3.90	51.90
Total savings during the immature period				23.33	311.39

Mature rubber

Crop response to added rock phosphates

Application of rock phosphate fertilizers did not show any effect on leaf nutrient content during a period of one year from September 1990 to August 1991. Although, leaf P contents were significantly different between two levels of ERP ($P<0.001$) and IRP ($P<0.001$) at the very early stage, no further response to rock phosphate application was observed (Table 8).

Table 8. *Effect of rock phosphate fertilizers on leaf P content (%)*

P source	Leaf P%			
	Sep.'90	Jan.'91	Apr.'91	Jul.'91
Nil	0.226	0.205	0.240	0.255
IRP - Level 1	0.236	0.243	0.244	0.287
IRP - Level 2	0.286	0.210	0.251	0.290
ERP - Level 1	0.234	0.212	0.243	0.278
ERP - Level 2	0.280	0.248	0.246	0.259

Plants were able to maintain their leaf P contents around 0.20 - 0.29% irrespective of the fertilizer treatments. Also, leaf P contents were fairly high even in plants that did not receive any phosphate for a period of one year.

The yield of rubber measured as average dry rubber content in relation to the treatments during a period of one year is shown in Fig 1.

Generally, yields were higher during the period December/January, thereafter it decreased until March and then increased again. Normally rubber tree sheds it's leaves once a year in January - February, and new flush of leaves are produced thereafter and this characteristic feature appears to be closely linked to the pattern of change in rubber yield. The above pattern of latex production were however not influenced by the either rate or the sources of P used in this study.

P availability in soil

There was no effect of rock phosphate application on phosphate availability in soil as estimated by anion - exchangeable resin. No significant differences were observed between the control and P fertilizer treatments. Soil P contents at both depths, 0–15 cm and 15 - 30 cm, decreased with increasing time (Table 9) but did not correlate with leaf P values. Generally, the available P content of the soil was increased when rock phosphate fertilizers were applied at double the recommended level in comparison with the recommended level.

Table 9. *Effect of fertilizers on soil phosphate availability.*

P Source	AER - P (mg/kg)							
	0 - 15 cm				15 - 30 cm			
	Sep. '90	Jan. '91	Apr. '91	Jul. '91	Sep. '90	Jan. '91	Apr. '91	Jul. '91
Nil	27.89	2.63	3.13	1.57	8.73	1.37	1.29	1.36
IRP–level 1	37.68	4.81	6.64	3.50	22.10	1.42	1.32	2.48
IRP–level 2	24.32	6.56	31.39	14.86	20.84	2.05	8.84	7.20
ERP–level 1	51.89	4.16	10.00	7.64	42.73	1.68	3.05	5.87
ERP–level 2	37.26	9.95	12.68	9.68	11.57	2.68	10.33	6.10

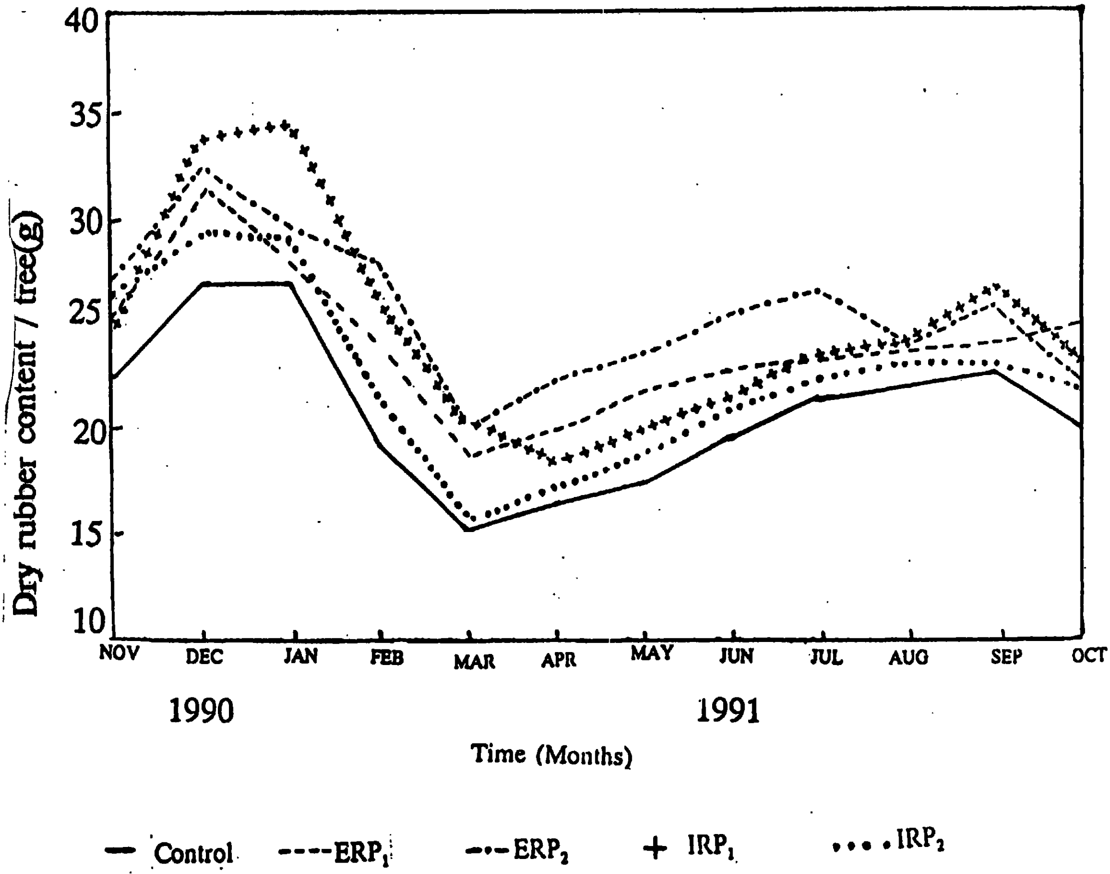

Fig. 1. Effect of rock phosphates on average monthly dry rubber content of the tree

DISCUSSION

Immature rubber

Although plants did not responded to P application during the very young age, they responded to P fertilization with the increasing age and this showed that phosphorus is indeed limiting the growth of immature rubber plants confirming the previous findings (Yogaratnam, *et al* 1977, Dissanayake, *et al*, 1992). Results of this study clearly indicate that the existing normal recommended rates are not sufficient to meet the P requirements of plants under some situations and also when phosphate has not been applied in the plant hole, and therefore the amount has to be increased further in such cases. However, Yogaratnam (1980) reported that increased level of P did not have any beneficial effect as plant growth in comparison with the recommended rates. Plant response to increased level of P in this experiment may have been due to the depletion of the phosphate reserves in the soil and/or due to the fact that phosphate was not applied in the planting hole prior to planting in this study. It is known that fertilizer consumption in all the crop sectors have dropped in the recent past (NFS, 1992), which may have been mainly due to higher fertilizer prices. In addition, the fertilizer recommendations made on the basis of leaf analysis by the RRISL during the last 20 years indicates that application of P as rock phosphates have been curtailed in most of the fields as the leaf P levels were satisfactory for the normal performance of the plants. This possibly would have lowered the soil P content. On the other hand, the current recommendation of the RRI is that phosphate should be applied in the planting hole prior to planting. If this had been done in this experiment, the phosphate requirements of the plant during the early stages would have been partly supplied by this application and therefore under such situations, the results would perhaps have been different.

Both P sources were equally effective on girthing of plants throughout the immature period, although ERP reported to be inferior to IRP as a source of P for immature rubber by Yogaratnam (1977), who obtained a 15% increase in growth with IRP as against only a 3% increase with ERP in comparison with the no P treatment, after 4 yrs of planting.

Being a water – soluble fertilizer, P availability from TSP is expected to depend on the fixation (McLaughlin & Syers, 1978) and therefore it is possible that it lost it's efficiency in rubber growing soils, which are high in Fe and Al (Silva, *et al*, 1978). On the other hand both rock phosphates were equally efficient in providing the P requirement of plants, although earlier studies showed that the ERP behaves in a complex manner in the soil (Dissanayake, *et al*, 1993). This indicates that ERP could be used for slow growing perennials like rubber as a source of P.

Generally, the release of phosphate from a phosphate rock can be represented simplistically as follows.

$$Ca_{10}(PO_4)_6F + 12H^+ \text{ ----> } 10Ca^{++} + 6H_2PO_4 + F^-$$

This indicates that the solubility of rock phosphate could increase with decreasing pH. The soil pH in the experimental areas were low and ranged from 3.6 to 4.2 (data not presented) which may have helped to increase the dissolution of low soluble ERP.

In addition, it is known that the rock phosphate solubility is strongly influenced by the activities of reaction products (Chien, 1977, Weir *et al*, 1971; Mackay and Syres, 1986). Phosphate ions added by the dissolution of rock phosphate is known to be removed through chemical and biological fixation in addition to plant uptake, and these processes create a low level – P situation which helps in the dissolution of rock phosphates. This would have taken place under the experimental conditions as soil P was low and ranged from 3.50 to 37.00 mg/kg through out the period of 6 years (Data not presented). Higher rates of P fixation in rubber soils may also have created low – P situation and therefore, greater dissolution of low soluble ERP may have taken place. On the other hand, results showed that rubber plants required more P for their growth during the immature phase which may also have resulted in lowering the soil P status. It is therefore possible to expect a considerable dissolution of ERP in the soils low in phosphate although it has been reported to be a low solubility product, and therefore a low grade phosphate source.

Rubber soils can be categorized into 3 groups according to the P status (Pushparajah *et al*, 1983). Generally, *Boralu, Agalawatta* and *Homagama* soils are of medium P status, where their P content is in the range of 14.00 to 21.00 per kg soil. Higher agronomic value of ERP could therefore be expected in these soils as indicated in this study. This would be profitable as IRP is the only source currently recommended for immature rubber which involves a considerable amount of foreign exchange. Nevertheless, inorder to make a general recommendation on the use of ERP which will be applicable to all immature plantings, more experiments are required. Such studies would be of benefit to the rubber industry of Sri Lanka, as currently IRP is used as the only source of P. However, based on the results of this study, a tentative recommendation could be made to provide 50% of the plants requirement with ERP at the currently recommended level of P.

Mature rubber

The lack of response by mature rubber trees to added rock phosphate fertilizers indicates that P is not a limiting factor for activities of the plant at this stage. Even under no – P fertilizer conditions plants were able to maintain the normal growth and production levels. Foliar survey programme of the RRISL also suggested this and therefore application of rock phosphate fertilizer was curtailed in most of the areas under mature rubber (Yogaratnam and Mel, 1985).

Being a tree crop, the root system of the rubber tree is well established and plants are therefore able to absorb P already present in the soil efficiently to meet the tree's demand. Also recycling of phosphorous within the mature rubber tree could be expected as it was reported that the internal recycling of phosphorus taken place due to accumulation of P in the terminal region of other trees when trees age (Mouth, 1968; Dighton and Harisson,1983).

Generally due to slow solubilization of rock phosphates, the total quantity of P added is released gradually providing a stable source over a period of time (Gillespie and Pope, 1990). A very similar situation has been reported by Yogaratnam *et al* (1984), also in relation to rubber, who have concluded that the P fertilization with rock phosphate during the immature period is likely to be sufficient to sustain the rubber trees at least during the early productive period. In this experimental area also, the rubber plants would have been fertilized with rock phosphates for a longer period, and therefore, may have built up enough P reserves in the soil. This may have prevented the effective dissolution of rock phosphates that were added to soil. Even if rock phosphates dissolved up to a certain extent, the released P may not be easily available to the plant root system as phosphate fixing capacity of this particular rubber growing soil is reported to be fairly high due to: low pH (3.9 - 4.5), high amount of Fe, Al, and clay content. This was confirmed in this study where the available soil P decreased during the period of one year but this was not correlated with the plant P content suggesting that the decrease in the soil P content could have been predominantly due to chemical fixation. Also it was reported that leaching losses of P is very low in soil which have high sorption capacity (Kanabo and Gilkes, 1978) and therefore, the long term availability of added P from the rubber soils could be expected. It is therefore not surprising that the rubber yield was not influenced by application of ERP and IRP in the mature stage. This indicates that mature rubber plants could possibly meet their P requirements from these native phosphate reserves and this would be beneficial as it implies that they have the ability to grow satisfactorily with low phosphate inputs.

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