Effectiveness of Different Phosphorus Fertilizers as a Basal Dressing in Young Budding Nurseries of Rubber (*Hevea brasiliensis*).

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ABSTRACT

The currently recommended basal application method is labor intensive and hardly practiced in large scale young budding nurseries. Further, the performance of the locally available phosphorus source such as high grade eppawala rock phosphate has so far not been evaluated in these nurseries. Therefore, this study was undertaken to determine the agronomic effectiveness of different phosphorus sources in *Hevea* nurseries raised by young budding technique. Two different rock phosphate fertilizers (imported rock phosphate and high grade Eppawala Rock Phosphate 50g per bag) and a liquid phosphorus fertilizer (di-ammonium phosphate at rates of 2 and 4g per bag) were applied to both sub and top soil, two weeks before planting. Seedling diameter was measured three and four months after planting where as leaf phosphorus concentration and available phosphorus content in soil were measured four months after planting.

Plants grown on top soil did not respond to basal phosphorus application. However, plants raised on sub soil responded positively to basal phosphorus application where plant diameter was significantly higher in rock phosphate added treatments compared to di-ammonium phosphate added treatments. Although a revision to the basal P application method can not be justified from this study, it appears that high grade Eppawala Rock Phosphate application is as agronomically effective as imported rock phosphate for young budded plants raised in sub soil.

KEYWORDS: Rubber, *Hevea brasiliensis*, P Fertilizers, Young Budding, High Grade Eppawala Rock Phosphate

INTRODUCTION

Rubber industry plays an important role in both social and economic terms in Sri Lanka while contributing to the environment protection. However, in the global context, the production of natural rubber in Sri Lanka secures only the 10th place (IRSG, 2004). During the last decade the demand for natural rubber has increased. In order to get maximum benefits from this growing demand, the rubber production in Sri Lanka has to be increased. The average land productivity of rubber in Sri Lanka is about 900 kg/ha/year which is not only far below the potential yields (2500-3000kg/ha/year) but also far below the productivity level of other countries. Nugawela (2002) identified that planting poor quality planting material, inadequate use of fertilizers, neglecting of soil conservation practices and poor disease control methods as the main reasons for the low productivity in rubber plantations in Sri Lanka. Recognizing many advantages over other planting materials, the Rubber Research Institute of Sri Lanka (RRISL) is now recommending only young budded plants as planting materials with the intention of increasing the land productivity.

Young budding involves grafting a small bud slip on to a very young seedling of 3-4 months raised in poly bags (Leong *et al.*, 1985). Vigorous and faster growths of plants are maintained by the continuous application of proper manuring schedule before and after bud grafting (Dharmakeerthi *et al.*, 1997). In turn, this will shorten the nursery time. Saving of nursery and establishment cost, suitability under local conditions well, ease and flexibility of handling and transport because of the small size of the bags, high establishment rate, uniform growth in the field, and reduction of the immature period are the important advantages of young budding (Senawiratna, 1995).

However, Nugawela (2002) reported that if correct nursery practices are not adopted the resulting planting materials will also be of poor quality. One of the most important nursery practices is the adequate use of fertilizers. Yogaratnam and Karunaratna (1972) showed that application of N P K and Mg in the form of inorganic fertilizer is essential for the growth of the seedling plant. Phosphorus is an essential plant nutrient for *Hevea brasiliensis*. Yogaratnam and Karunaratna (1972) observed that young *Hevea* seedlings are likely to benefit from relatively high levels of phosphate fertilizers. The significance of applying N P K and Mg artificially for poly bags becomes more important as fertile top soil is not always available in the vicinity of large scale nurseries (Dharmakeerthi *et al.*, 1997).

Under the current fertilizer program for young budding, imported rock phosphate (IRP) is used as a basal dressing (50g per bag) at bag filling stage in addition to the application of di-ammonium phosphate (DAP) in soluble form at every two weeks intervals. The locally available P sources such as high grade Eppawala rock phosphate (HERP) which is believed to have comparable levels of available P (Sewwandi, 2005), have not been evaluated in young budding nurseries. Utilization of locally available P sources at nursery stage will contribute to cut down part of the foreign exchange on importing P fertilizers. In addition, basal P application is hardly practiced in large scale rubber nurseries as it is time consuming and labor intensive. Therefore, there is growing demand to evaluate an alternate method of basal P application as well. It is hypothized that application of DAP in liquid form could be a practical alternative for this and it is agronomically effective. Therefore this study was carried out to determine the agronomic effectiveness of different P sources in *Hevea* nurseries raised by young budding technique.

MATERIALS AND METHODS

The field experiment related to this study was carried out in the government rubber nursery at Welikadamulla located in the low country wet zone of Sri Lanka in 2005. Laboratory analysis was conducted at the Rubber Research Institute of Sri Lanka (RRISL), Agalawatta. A young budding nursery was established using boralu series soil belonging to the Red Yellow Podsolic great soil group (Ultisol) for bag filling. The experiment was a factorial experiment with two factors; soil types and different phosphorus fertilizer sources as the basal application. Soil types were top soil and sub soil. Phosphorus fertilizer sources were IRP, HERP, DAP. The details of the basal P application are given in the Table 1. These P sources were applied to both top and sub soil.

Table 1. Details of the basal P application treatments used in the experiment.

Phosphorus sources	Quantity g/plant	Method of application
IRP	50	Thoroughly mixed with soil at bag filling
HERP	50	Thoroughly mixed with soil at bag filling
DAP	4	Dissolved in water and applied at bag filling.
DAP	2	Dissolved in water and applied at bag filling.
0 P	-	-

Each treatment consisted of 100 bags and one germinated seedling per bag was planted fourteen days after bag filling and treatment application. General field practices and fertilizer application, except basal P were carried out according to the RRISL recommendations (Senawiratna, 2001). Treatments were arranged in a complete randomized design (CRD).

Measurements

Composite samples from sub soil and top soil used for bag filling were taken to the laboratory, air-dried and sieved through 2-mm sieve. Soils were then characterized for important soil properties such as texture, using the pipette method (RRIM, 1971), organic carbon using the Walkley and Black method (Walckley and black, 1934), pH (1:2 water) (RRIM, 1971) and ammonium acetate extractable cations using atomic absorption spectrophotometer, (RRIM, 1971) and available P using the Bray 2 method (Bray and Kurtz, 1945).

Diameters of randomly selected 50 plants in each treatment were measured at 1cm above the soil level at three months and four months after planting. Six plants from each treatment were randomly selected four months after planting to determine the P concentration in the leaves (RRIM, 1971) and the available P concentration in soils. Data were analyzed using proc GLM procedure of the SAS statistical package (SAS Institute Inc. 1996).

RESULTS AND DISCUSSION

The effect of different sources of P fertilizers on seedling growth will be the focus on this paper. Root stock diameter is considered as a convenient parameter for assessing the seedling growth (Jayasekara and Senanayaka, 1971) and evidence from the literature has indicated a good correlation between diameter and the dry matter content (Dissanayaka and Mitrasena, 1986). Total leaf P, available P in the soil at four month after planting and data on the percentage of dead plants were used to describe the agronomic effectiveness of P sources

a) *Soil Properties*

Some important physical and chemical properties of sub soil and top soil prior to the commencement of experiment are given in Table 2. Very high clay content (62.5 %) and low organic carbon content (0.08 %) were observed in sub soil compared to that in top soil. The sand content (54.9 %) was high in top soil than that in sub soil (27.7 %) while the silt content of both soils was similar (7.5 %). Concentration of exchangeable cations was high in top soil, where as the available P content and pH in sub and top soils were comparable. Low nutrient levels and organic carbon contents indicate the poor fertility in the sub soil used in the experiment.

Table 2. Some important physical and chemical properties of sub soil and top soil used in the experiment.

Property	Sub soil	Top soil
Organic carbon (%)	0.08	2.54
Sand (%)	27.7	54.9
Clay (%)	62.5	37.5
Silt (%)	7.5	7.5
pH (1:2 water)	5.5	5.5
Exchangeable K (ppm)	13.0	62.7
Exchangeable Ca (ppm)	15.5	51.0
Exchangeable Mg (ppm)	15.2	31.3
Available P (ppm)	28.2	20.2

b) *Available Phosphorus Content of Soil in Poly Bags*

Application of P fertilizers has significantly increased the P availability in soil as measured after four months of application (Table 3). Applied fertilizer as HERP at 50 g showed highest available P concentration in sub soil and top soil, (982.2 ppm and 565.4 ppm in top soil and sub soil respectively). Available P concentration values in top soil were always higher than the respective sub soil values except in DAP added soils. Application of DAP at both 2 and 4 g significantly increased the available P in sub soil than in top soil. The availability of P in DAP added soils was lower than that in IRP and HERP added soils. This in part could be related to fact that the total P added is high in rock phosphate treatments compared to DAP. DAP is a water soluble fertilizer which has high P content (46 %) and almost all P are available (Tisdale *et al.*, 1993) whereas IRP and HERP are phosphate rock fertilizers which are not water soluble. When P in water soluble forms is added to the soil, concentration of readily available P forms ($H_2PO_4^-$ and HPO_4^{2-}) increased in soil solution. Therefore, a higher available P content is resulted at the time of P applied to the soil. Then these readily available forms are gradually fixed with time, decreasing their availability in the soil. P can be fixed by adsorbing to the clay minerals or precipitating P as $Ca_3(PO_4)_2$ in high Ca containing soils. However, water insoluble fertilizers such as IRP and HERP are not fixed as fast as water soluble fertilizers. Therefore, the available P in IRP and HERP added soils could be high at four months after application. The low P availability in sub soil compared to top soil in phosphate rock added treatments would be mainly due to high clay % in sub soil (Table 2). It appears that to increase available P content in soil to the levels comparable with phosphate rock treatments the DAP dosage has to increased beyond 4 g per bag.

Table 3. Mean available phosphorus content of soil in poly bags four months after planting

P source	Available P (ppm)[†] Sub soil	Top soil
IRP (50g/plant)	415.7^b_B	723.9^b_A
HERP (50g/plant)	565.4^a_B	982.2^a_A
DAP (4g/plant)	371.8^b_A	284.1^c_B
DAP (2g/plant)	151.8^c_A	120.7^d_B
0 P	27.2^d_B	82.1^e_A

[†]*Letters with the same superscript within the column and subscript across a row are not significantly different at P> 0.05.*

There is a significant difference (P> 0.05) in soil available P in HERP and IRP (Table 3). In both sub soil and top soil HERP 50 g treatment showed higher soil available P than IRP 50 g. This may be due to high total P % (P_2O_5 38 %) and higher available P % (P_2O_5 6 %) in HERP than in IRP (Dissanayaka, 1994).

It is interesting to note that the available P content in top soil is significantly higher than that of sub soil in no basal application treatment. This indicates that subsequent P application in the form of NPK Mg mixtures was able to increase the available P levels in top soils but not in sub soils. The higher P fixing in sub soil could have been the reason for this observation.

c) *Diameter of Plants*

Mean diameter of plants, three and four months after planting, is shown in Table 4. Sources of P fertilizers and soil showed a significant interaction effect (P> 0.05) on plant diameter in both three and four months after planting. Application of P fertilizer has significantly increased the plant diameter in sub soil at both three and four months after planting. In sub soil the response of plant diameter to P sources is greater in phosphate rock treatment compared to DAP treatments. But plants grown in top soil did not respond to P application. Instead, significant decrease in plant diameter was observed in DAP added top soils.

Table 4. Mean diameter (mm) of plants at a given time

	Diameter of plants (mm)[†]			
	Three months		Four months	
P source	Sub soil	Top soil	Sub soil	Top soil
IRP (50g/plant)	4.50^a_A	3.93^b_B	5.66^a_A	5.05^a_B
HERP (50g/plant	4.27^a_A	3.96^b_B	5.44^a_A	4.67^{ab}_B
DAP (4g/plant)	3.83^b_A	3.69^b_A	4.67^b_A	4.49^b_A
DAP (2g/plant)	3.69^b_A	3.86^b_A	4.50^b_A	4.55^b_A
0 P	3.53^b_B	4.11^a_A	4.14^c_B	4.91^a_A

[†]*Letters with the same superscript within the column and subscript across a row within a given time are not significantly different at P> 0.05.*

Plant diameter at four months after planting showed a significant quadratic relationship with the soil available P content. When the soil available P content increased, the plant diameter increased until it reached a maximum. Then with further increase of soil P availability there is a tendency to reduce plant diameter (Figure 1). The maximum plant diameter was observed when the available P content was 567 ppm. In top soil treatments, very high available phosphorus concentrations (Table 3), could have adversely affected the plant growth as indicated by a decline in plant diameter. However, in sub soil, available P concentrations of all treatments were below 567 ppm (Table 3).

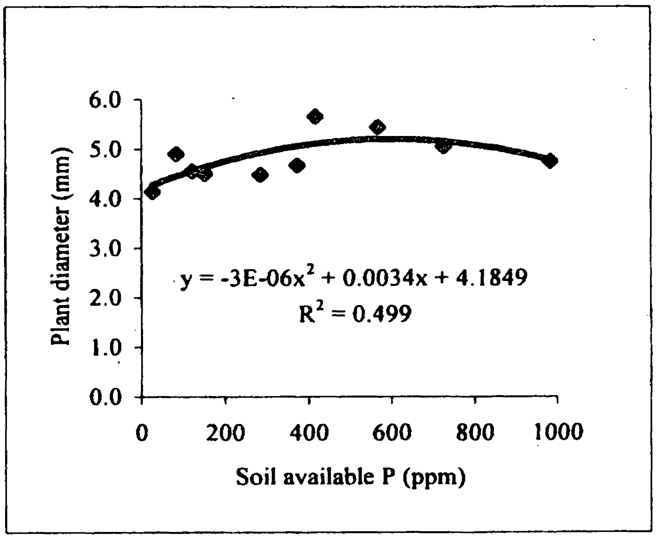

Figure 1. Relationship between soil available P content and plant diameter at four months after planting.

During the experiment period the polybag nursery was affected by drought and plants have not irrigated adequately. As a result some plants were severely affected by moisture stress. Percentages of dead plants in IRP and HERP added plants in the top soil were very high (43 % and 53 % respectively) while dead plant percentages of other treatments were less than 15 % (Table 5). Due to the low water availability in soil, soil solution P concentration could also have increased up to toxic levels. This could have resulted in more dead plant percentages in rock phosphate added top soils where available P content is very high.

Yoon *et al.* (1987) showed that application of solid fertilizer has often resulted in die-back of scion shoots. They have also observed dead feeder roots, possibly as a result of plasmolysis due to too concentrated fertilizer. Dharmakeerthi *et al.* (1997) showed that the solid fertilizers could effectively be used in young budding only when they are applied at lower concentration.

Table 5. Percentages of dead plants at four months after planting.

	Plant dead Percentages	
P source	**Sub soil**	**Top soil**
IRP (50g/plant)	4	53
HERP (50g/plant)	6	43
DAP (4g/plant)	10	15
DAP (2g/plant)	9	7
0 P	5	10

Although the available P concentration in soil is significantly different in HERP and IRP at 50 g level, plant growth data did not show significant difference between the two P sources. Therefore, HERP could be substituted for IRP when sub soil is used for bag filling. Dissanayaka *et al.* (1994) showed 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 level during the immature period of *Hevea*. HERP is manufactured by minimizing the contamination with soil and clay particle already mixed with appatite particles. Although the production of phosphate fertilizer in this nature at eppawala is currently limited and costly (Dissanayaka *et al.*, 1996), the use of HERP would still save countries foreign exchange. Because of the poor response of plants grown in top soil to basal P application, the current practice of IRP application need to be revised, at least for the soil types used in this study.

Application of DAP at 2 g and 4 g in liquid form did not increase the plant diameter as in the case of HERP and IRP in sub soil. This may be mainly due to the low availability of P in soil as result of high P fixation in this clay rich sub soil. Therefore further studies are needed to test DAP with high dosages. However, care should be taken to select a suitable DAP dose as there is evidence of seedling toxicity to ammonia gas in high pH situation (Tisdale, *et al.*, 1993).

d) *Phosphorus Content of the Leaf*

Different P sources did not influence leaf P content. It ranged from 0.229 to 0.255 % (Table 6). The leaf P concentrations observed in our study fell well within the optimum range for young rubber trees which is usually 0.16 % to 0.28 % of the dry matter (Shorrocks, 1964).

According to Yogaratnam and Mel (1985) the absence of significant increase in leaf P content due to application of phosphate fertilizer may not be surprising as the lag period between the first application of P and leaf P response is longer, possibly due to higher levels of available P in the soil prior to the commencement of experiment. Soil used for experiment also had a some what high value of available P (Table 2). Moreover P is known to be highly mobile and is probably continuously circulated within the plant, a given P atoms may make several complete circuits of a plant within a day (Biddalph, 1954). The vital role of P in respiration, photosynthesis and the synthesis of starch, nucleic acid, fat and protein (Guach,1972) means that P is being incorporated and released continuously at various points within the young actively grown seedlings, where any of these processes can take place. Dissanayaka *et al.*, (1994) also showed that plant were able to maintain adequate level of P in leaves under no P fertilizer condition and that plants did not respond to P application during the very young stage. Although Weerasuriya and Yogaratnam (1989) stated that leaf nutrient content is known to be a reliable indicator of the plant nutrient status, Yogaratnam *et al.*, (1984) showed that it may not be applicable to rubber plants at young stage.

Table 6. Mean phosphorus content of leaf four months after planting.

	Leaf P %	
P source	**Sub soil**	**Top soil**
IRP (50g/plant)	$0.233^{a}{}_{A}$	$0.255^{a}{}_{A}$
HERP (50g/plant)	$0.234^{a}{}_{A}$	$0.242^{a}{}_{A}$
DAP (4g/plant)	$0.229^{a}{}_{A}$	$0.240^{a}{}_{A}$
DAP (2g/plant)	$0.244^{a}{}_{A}$	$0.225^{a}{}_{A}$
0 P	$0.251^{a}{}_{A}$	$0.243^{a}{}_{A}$

[T]*Letters with the same superscript within the column and subscript across a row are not significantly different at P> 0.05.*

CONCLUSIONS

This study demonstrated that the application of basal P, either as rock phosphate or as DAP, is not agronomically effective when seedlings are grown in top soil of boralu series soils. However, when the sub soil is used for bag filling there is a significant plant response for basal P application. The sub soil contained very high clay content which in turn could have caused high P fixation. The application of DAP at 2 or 4 g per bag is not as effective as 50 g of rock phosphate. Therefore further studies are needed with different dosages of DAP. The local rock phosphate source, HERP, is as equally effective as IRP or even better in sub soil suggesting a possible cost effective substitution for IRP in young budding nurseries.

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