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EFFECT OF FERTILIZERS ON LEAF COMPOSITION OF NPK IN SOME *HEVEA* CULTIVARS

by

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SUMMARY

Application of N, P and K fertilizers in the form of urea, muriate of potash and rock phosphate at the rate of 310 kg N, 160kg P and 310 kg K per hectare during the 7 year unproductive period significantly increased the respective leaf N, P and K concentrations in immature *Hevea* cultivars, PB 86, RRIC 100, RRIC 101 and RRIC 102. These responses have been due to each nutrient acting singly. Increases up to a maximum of 47.0%, 14.7% and 46.7% over no fertilizer control have been obtained for N, P and K respectively. However, the lag between fertilizer application and changes in their respective leaf nutrient concentration was longer for P than N and K. Urea applications decreased the K concentration in leaves and similar depressive effect of K fertilizers on leaf Mg was also recorded.

INTRODUCTION

Rubber under current plantation practices requires a period of about 6 to 9 years to reach an arbitrary tappable standard of a girth of 50 cm. This immature period amounts to about 20% to 33% of the tree's life cycle. The drag of this unproductive period is governed mainly by the inherent clonal characteristics, the soil and the method of management.

Efforts to reduce the period of immaturity by better horticultural practices (Yoon 1972; Zeid, 1976) nursery management (Yogaratnam, 1975; Yoon et *al*, 1976) and improvements in nutrition disease and weed control (Ng et *al*, 1972; Sivanadyan et *al* 1973 Tan, et *al* 1976) have been made but the gains have been variable and insufficient. Nevertheless, the economic benefits of such reductions have been amply demonstrated (Barlow et *al* 1966; Lim et *al* 1973). As with other crops (Bould, 1966, Yogaratnam, 1975; Fremond 1977; Ng, 1977) leaf analysis is valuable as a method for confirming visual diagnosis by symptoms (Chapman, 1941; Bolle Jones; 1956) for assessing the nutritional status of individual stand of rubber trees (Shorrock, 1961; Yogaratnam and Silva, 1977) and their response to fertilizer applications (Yogaratnam and Perera, 1981, Yogaratnam and Weerasuriya 1984).

The present paper describes a series of fertilizer trials on immature *Hevea* and shows the effects of fertilizer treatments on the nutritional status of the trees as indicated by the mineral composition of leaf samples. Since, virtually no work had been done on the effectiveness of urea in immature *Hevea* in spite of it being a cheap source of nitrogen, this fertilizer was also included.

MATERIALS AND METHODS

Three out of a series of five field experiments were started in 1969 on the more common soils under rubber, with constrasting physicochemical properties. Only clones of good vigour and high yields were compared with clone PB 86, a cultivar currently grown in approximately 80 to 90% of the rubber growing areas in Sri Lanka. The experimental design was a split plot with two replicates where the different cultivars were in the main plots and fertilizer treatments in the sub-plots.

Each sub-plot consisted of 25 to 30 measuring trees surrounded on all sides by one row of guard trees. The fertilizers were forked into the soil at depths varying from 5 to 10 cm as urea was the source of nitrogen (Yogaratnam and Perera 1981) in all the experiments.

EXPERIMENT 1

This experiment was designed to compare the effects of three levels of N and K applied at; 0, 310 and 620 kg per ha of the element in the form of urea and potassium chloride, during the full experimental period of 7 years, on growth of four cultivars viz. PB 86, RRIC 100[a], RRIC 101[b] and RRIC 102[c]* The experimental trees were planted in June/July 1976 at 6X5m and grown with a mixed leguminous cover of *Pueraria phaseoloides* and *Desmodium ovlifolium* in an area receiving an average annual rainfall of 3125-3750 mm. All plants received uniform applicatons of 160 kg per ha as rock phosphate and 65 kg mg/ha as kieserite during the full immature period.

Rubber was grown on *Homagama* series soils (Silva 1964) which are moderately deep, gravelly loam in texture and strong brown to reddish brown in colour. They are characterised by an abundance of quartz gravel, originating form the highly quartzitic parent rock, fragments of which occur throughout the soil mass.

EXPERIMENT 2

Effects of three levels of N, as in Experiments 1 and P applied at 0,160 and 320 kg per ha of the element in the form of rock phosphate on growth of cultivars PB 86, RRIC 101 and RRIC 102 were studied in this experiment. The ground covers consisted of a mixed growth of naturals and legumes and the annual average rainfall varied from 3750—5000 mm. All trees received uniform applications of 310 kg N/ha as urea and 65 Mg/ha as kieserite during the experimental period.

Leaf sampling and analysis

Leaf samples were taken for analysis annually in July/August, from a low shade position. Each sample consisted of 6 leaves collected at random, oven dried for 24 h at 85° C and ground. Determinations were made on Kjeldahl digests and expressed on a dry weight basis. N and P were measured colurimetrically, K and Ca by flame emission spectroscopy and Mg by atomic absorption spectroscopy.

Analytical data were subjected to analysis of variance as angular transformations where necessary, but only the untransformed values are presented in Tables. Where it is not possible to give the standard error of the differences (SED) statistical evaluation is indicated by *, ** and *** denoting that the treatments are significantly different from the control at $P<0.05$, 0.01 and 0.001 respectively.

RESULTS

Routine analyses done to characterise the soil (Table 1) appear to indicate that the pH and total N at all sites were satisfactory, but 'available' P, K and Mg status varied between experiments (Yogaratnam and Weerasuriya, 1984).

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* [a]parentage, RRIC 52 x PB 86
[b]parentage, Ch 26 x RRIC 7
[c]parentage, RRIC 52 x RRIC 7

Table 1. *Routine soil analyses*

Experiment - Soil - Sampling depth

Characteristics	Experiment 1 Homagama (quartzitic)		Experiment 2 Agalawatta (granatic)		Experiment 3 Boralu (cabook)	
	0-15 - 15-30 (cm)		0-15 - 15-30 (cm)		0-15 - 15-30 (cm)	
pH (water)	4.15	4.20	4.30	4.15	4.70	4.50
C (%)	1.86	0.97	2.22	1.24	2.12	0.76
N (%)	0.24	0.18	0.25	0.16	0.24	0.13
Total - P (ppm)	353	273	337	202	248	183
Available - P (ppm)	17.0	2.0	42.5	4.5	13.3	2.0
Total - K (me/100g)	3.33	3.21	3.01	3.33	3.43	3.46
Total - Mg (me/100g)	5.99	6.61	5.12	5.26	3.51	4.23
Exchangeable - K (me/100g)	0.12	0.04	0.07	0.05	0.07	0.02
Exchangeable - Mg (me/100g)	0.15	0.03	0.16	0.05	0.15	0.05
CEC (me/100g)	5.67	4.64	5.95	4.26	4.99	3.66

Total P by perchloric/sulphuric acid; available P by NH_4F/HCl; total K and Mg by 6N HCl and exchangeable K and Mg and CEC by ammonium acetate at pH 7.

Nitrogen

Leaf nitrogen and potassium concentrations for different levels of applied nitrogen in Experiment 1 and 2 are presented in Tables 2 and 3.

Table 2. *Effect of three levels of nitrogen on leaf N and K content-Experiment 1*

Treatments	1978	1980	1981	1982	1983
		Nitrogen (%)			
N_0	3.02	3.03	3.59	3.19	2.82
N_1	3.11	3.24*	3.66*	3.14	2.92
N_2	3.16*	3.31*	3.74*	3.21	2.88
		Potassium (%)			
N_0	0.892	0.797	0.769	0.793	1.123
N_1	0.680*	0.775	0.681*	0.751	1.022
N_2	0.587**	0.747	0.702*	0.761	1.107

Table 3. *Effects of three levels of nitrogen on leaf N and K content-Experiment 2*

Treatments	1978	1980	1981	1982	1983
			Nitrogen (%)		
N_0	2.60	3.05	2.01	3.09	2.69
N_1	2.83	3.22	2.76	3.25	2.91
N_2	2.94**	3.34**	2.97***	3.33*	2.99*
			Potassium (%)		
N_0	0.738	0.996	0.948	0.959	0.874
N_1	0.728	0.975	0.878	0.872	0.862
N_2	0.598*	0.803*	0.859*	0.852*	0.858

In Experiment 1 nitrogen fertilization at levels 1 and 2 significantly increased ($P<0.005$) the N concentration in leaves over the control until 1981. Thereafter the response declined sharply. In Experiment 2, however, the increase in N content was fairly consistant ($P<0.05$) throughout the immature period at both N_1 and N_2 levels with maximum increases for N_2 level.

The K concentration in the leaves, on the other hand, were depressed by applications cf N even at level 1, in 1978 and 1981 ($P<0.05$) and a similar tendency in other years, in Experiment 1. Similar effects were observed in Experiment 2 also.

Applications of nitrogen did not affect the leaf P and Mg concentrations in both experiments.

Phosphorus

Application of phosphorus at level 1 increased ($P<0.05$) the P concentration in leaves in Experiment 2 (Table 4) from 1980. No further increase was obtained with P_2 level, except at the end of the immature period when the P concentration in leaves was increased further by 0.012% P which amounted to 44% increase over level 1.

Table 4. *Effect of three levels of phosphorus on leaf P content–Experiment 2*

Treatment	1978	1980	1981	1982	1983
P_0	0.152	0.161	0.156	0.200	0.254
P_1	0.157	0.171	0.170*	0.208*	0.277**
P_2	0.160	0.178	0.179*	0.209*	0.289**

There were no effects of applied phosphorus on N, K and Mg concentration in leaves.

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Potassium

In Experiment I, application of K at level I increased (Table 5) the K concentration in leaves consistantly from 1978 ($P<0.05$ in 1978, 1980 and 1981 and $P<0.001$ in 1982 and 1983). No further significant increases were obtained when K was increased to level 2.

Table 5. *Effect of three levels of potassium on leaf K and Mg content-Experiment I*

Treatment	1978	1980	1981	1982	1983
			Potassium (%)		
K_0	0.809	0.689	0.659	0.627	0.801
K_1	0.944*	0.818***	0.774*	0.805***	1.255***
K_2	0.979*	0.812**	0.747*	0.873***	1.312***
			Magnesium (%)		
K_0	0.255	0.272	0.309	0.221	0.341
K_1	0.218	0.241	0.293	0.324	0.307
K_2	0.209	0.206*	0.277*	0.291*	0.292

Similar, but more marked increases in K concentration of leaves were obtained in Experiment 3 (Table 6), with application of K fertilizers even at level I ($P<0.001$ in 1978, $P<0.05$ in 1981 and $P<0.01$ in 1980, 1982 and 1983). Increasing the level of applied potassium to K_2 gave additional increases in K concentration in 1978 and 1980.

Table 6. *Effect of three levels of potassium on leaf K and Mg–Experiment 3*

Treatment	1978	1980	1981	1982	1983
			Potassium (%)		
K_0	0.490	0.676	0.542	0.487	0.579
K_1	0.620***	0.793**	0.724*	0.684**	0.830**
K_2	0.719***	0.952**	0.768*	0.689**	0.746**
			Magnesium (%)		
K_0	0.289	0.291	0.308	0.299	0.389
K_1	0.214***	0.243*	0.287	0.232*	0.360
K_2	0.195***	0.209*	0.274	0.206*	0.357

Potassium fertilizers depressed the leaf Mg concentrations in both Experiment I and 3, the effect being more marked in Experiment 3. This effect appeared to persist throughout the immature period ($P<0.001$ in 1978 and $P<0.05$ in 1980, 1982 and 1983) in Experiment 3.

Applications of K fertilizers did not affect the leaf N and P concentrations throughout the study.

Cultivars

There being no significant interaction between different cultivars and levels of N, P and K fertilizers, the leaf composition data from these factorial experiments collected at the end of the immature period are presented in Table 7 as the means for the main effects of the different cultivars. This illustrates the extent to which the cultivar treatments influenced the nutrient status of the trees. However, it should be noted that the means for the individual treatments should be considered separately, to enable the absolute concentrations of the different mineral constituents of the leaf to be related to growth and yield of different cultivars.

Table 7. *Leaf nutrient content of PB 86, RRIC 100, RRIC 101 and RRIC 102 at the end of the immature period* (1983)

Clones	N	P	K (%)	Mg
EXPERIMENT 1				
PB 86	2.77	0.296	1.288	0.346
RRIC 100	2.78	0.274	0.985	0.306
RRIC 101	2.88	0.304	0.930	0.318
RRIC 102	3.11	0.312	1.308	0.271
EXPERIMENT 2				
PB 86	2.85	0.306	0.940	0.232
RRIC 101	2.75	0.273	0.190	0.189
RRIC 102	2.64	0.253	0.951	0.285
EXPERIMENT 3				
PB 86	2.67	0.250	0.965	0.319
RRIC 100	2.61	0.219	0.705**	0.290*
RRIC 101	2.75	0.234	0.752**	0.263*

Although leaf N and P concentrations appeared to vary between sites, with the concentration in Experiment 1 being comparatively higher than in Experiment 3, there was no marked effects on leaf N and P due to different cultivars in each experiment, except for leaf P concentration which showed a tendency to be low in RRIC 100 in Experiment 1 and 3.

On the other hand there were not only differences between experiments, but between clones in leaf K and Mg levels. In Experiment 2 K and Mg concentration in leaves was significantly lower in RRIC 100 and 101 than in PB 86 ($P<0.01$ for K and $P<0.05$ for Mg) and similar tendencies were seen in other experiments. A closer scrutiny of the data, within the factorial matrix, for absolute concentrations (not presented) and based on tentative sufficiency criteria formulated by Yogaratnam and Silva (1977), in general, the leaf N and K concentrations appeared to be very low to low with values below 3.20% and 1.30% for N and K, respectively, and leaf P and Mg very high with values greater than 0.02%.

DISCUSSION

The leaf analysis provide abundant evidence of the uptake of N, P and K from applied nitrogen, phosphate and potassium fertilizers, respectively. The absence of any interaction effects, even known N-K interaction (Pushparajah, 1969), indicates that such responses are all due to each nutrient applied singly, which included urea. As recognised nutrient deficiencies were absent on the sites of the experiments, initial decrease in the leaf nutrient concentrations were not expected and were not shown.

The results show that the increase in leaf nutrient concentration due to fertilizer application, varying from 0.02 to 0.28% and 0.22 to 0.96% in response to nitrogen with urea in Experiments 1 and 2 respectively, 0.008 to 0.023% to phosphorus and from 0.12 to 0.25 and 0.20 to 0.28% to potassium in Experiments 1 and 3, respectively, can in general be considered large by Malaysian (Pushparajah, 1969) and Liberian (Guha, 1975) standards. Relative to no fertilizer application, this means a percentage increase of 0.6 to 9.0 in Experiment 1 and 7.3 to 47.0 in Experiment 2 for nitrogen, 4.5 to 14.7 for phosphorus and 13.4 to 39.2 and 40.1 to 46.7 for potassium in Experiments 1 and 3. respectively. In the absence of significant interactions between cultivars and levels of N, P and K, changes in the mechanism of nutrient uptake and consequently the leaf nutrient concentrations in different cultivars were not expected and were not recorded, unlike previous findings (Pushparajah *et al* 1972.).

Leaf N concentration increased within 18 months of commencement of urea fertilizer treatment in both Experiments 1 and 2 although this effect had not been maintained and was less marked in Experiment 1. Such reduction in responses was probably a reflection of the better agronomic management inputs the trees had received since planting. In Experiment 1, a pure legume cover policy had been adopted during the immature period in contrast to the mixed growth of naturals and legume in Experiment 2. The merits of maintaining legumes and their beneficial residual effects have been adequately discussed (Yogaratnam *et al* 1976). Retarding effects of high levels of N on nitrogen contribution by legumes (Sosulski and Buchan, 1978; Bhangoo and Albritton, 1976) and enhanced leaching losses from the gravelly loam textured soils (Bolton, 1968; Soong, 1973) may have also contributed to the poor response to applied nitrogen in Experiment 1.

Although application of phosphate at both levels has increased the P status of the tree, as shown by higher leaf P concentrations, the lag period between first application of phosphate and increase in leaf P was longer than for leaf N and K, possibly due to high levels of available P in the soil prior to commencement of the experiment. More soluable forms of phosphate such as super phosphate may have improved this effect, but at the same time in granite derived acid soils a cosiderable portion of P may have been fixed as calcium, aluminium and iron phosphate (Lan *et al* 1973) although a large portion of this residual P in the iron and aluminium fractions may be available to plants subsequently (Pushparajah *et al* 1975). Moreover, P is known to be highly mobile and is probably continuously circulated within the plant: a given P atom may make several complete circuits of a plant within a day (Biddalph, 1959). The vital role of P in respiration, photosynthesis and starch, nuclic acid, fat and protein syntheses (Guach, 1972) means that P is being incorporated and released continuously at the various points within the young actively growing trees, where any of these processes take place.

Efficiency of potassium uptake by immature plants appears to have been influenced, as expected, by the level of applied K and by the pre-treatment K content of the soils. Boralu soils in Experiment 3 with a very low exchangeable K of 0.07m. equiv/100g, exhibited enhanced uptake than in the Homagama soils in Experiment 1, where the exchangeable K value was 0.12m. equiv./100g. It is therefore possible to eliminate or at least minimise the depressive effect of applied N on K concentration in leaves by increased application of K fertilizers. However, this has to be done with caution as higher levels of applied K can suppress Mg uptake as indicated by low leaf Mg concentrations in Experiments 1 and 3, supporting earlier reports (Yogaratnam and Weerasuriya 1984) and emphasizing the vital importance of balanced nutrition (Yogaratnam and Weerasuriya, 1984).

Although the experimental design was such that statistically significant differences in the nutrient concentration in different clones planted in the main plot were not expected yet, the K and Mg concentrations in clones RRIC 100 and 101 were significantly lower than PB 86 in Experiment 3, possibly an inherent clonal characteristic. As the magnitude of these differences were not sufficiently large and consistant further studies on other sites and for different years are required before this clonal difference can be fully substantiated. Until such differences are found under more widely varying conditions, common values may be used.

The effects of the applied fertilizers on growth and getting a tappable stand of trees more rapidly will depend on the changes in the nutritional condition of the tree following fertilizer application (Yogaratnam, N. Silva, F. P. W. and Weerasuriya, S. M. 1985).

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