Jl. Rubb. Res. Inst. Sri Lanka (1977) 54, 270—283

NUTRITION AND FERTILISER USE IN *HEVEA* AND ASSOCIATED COVERS IN PENINSULAR MALAYSIA - A REVIEW

E. PUSHPARAJAH
(*Rubber Research Institute of Malaysia, Kuala Lumpur, Malaysia*)

SUMMARY

The paper reviews some of the latest findings on nutrition of Hevea *and effects of fertilizer on latex properties. It also considers work on increased efficiency in use of fertilisers. The latter includes studies on effect of fertilisers on soil properties and availability of fertiliser residues.*

The use of appropriate covers and their management to increase their efficiency is considered. Additionally, the influence of the covers on the nitrogen nutrition of Hevea *is discussed. The information available indicates that the applications of inorganic N fertilisers could be avoided for up to 8 — 10 years of tapping, with consequent economic benefits.*

INTRODUCTION

Until the early 1960s, it was generally accepted that fertilisers were essential for immature rubber, whereas for mature rubber, fertiliser applications were given on an insurance basis. The large variability in yield responses observed Anon (1967) was a major contributing factor in the reluctance to use fertilisers on mature rubber. Subsequently, it was demonstrated (Pushparajah & Guha, 1968) that the pattern of responses varied according to soil types and soil nutrient status. They also indicated that the limited experimental data could be related to agronomic parameters such as soil, soil and leaf nutrient content, manuring history, and existing ground conditions, as such data could then be interpolated to provide discriminatory fertiliser recommendations for mature rubber which in all cases, would give economic benefits. Guha *et al.* (1971) then demonstrated the method of application of such an approach, while Chan (1972) provided a more detailed description on the approach to discriminatory use of fertilisers. Thus from the late 1960s, with the above developments, fertiliser use in mature rubber came to be a regular practice. This entailed the need for refinements on investigation of soil/plant interactions, adequacy of rates of fertilisers used, a better understanding of factors affecting leaf nutrient levels, influence of exploitation systems and stock/scion on nutrient needs of rubber. The early findings on these have been reviewed (Pushparajah, 1973). This paper reviews subsequent findings on nutrition and on more efficient management of nutrition of *Hevea*.

Storage of nutrients in the tree

Shorrocks (1965) showed that large reserves of nutrients were stored in trees and indicated the adequacy or otherwise of the then existing fertiliser programme. Subsequently, Pushparajah *et al.* (1972) showed that even assuming the same amount of nutrients immobilised as ascertained by Shorrocks (1965) modern clones like RRIM 600 were being supplied with nutrients far short of their requirements; the extra nutrients being required just to compensate the nutrients drained in latex yield. However, the nutrients immobilised in clones like RRIM 600, are much larger (Lim, 1976) than observed in the earlier study (Shorrocks, 1965), thus implying that the newer clones are relatively more vigorous than older clones like RRIM 501. Additionally, the newer clones also drain more nutrients in the latex removed from the tree system (Pushparajah *et al.*, 1972; Sivanadyan *et al.*, 1972).

About 70% of the nutrients immobilised are locked up in the branches, (Pushparajah *et al.*, 1972) green twigs and the bark. Though at any one time, the nutrients in these parts are considered as immobilised, these can be considered also as storage reserves (Tan, 1975a).

At the time of onset of annual refoliation, the concentration of nutrients in the bark and wood drops to about 15 — 20% and thereafter, it re-stabilised at the initial higher level. The depletion in bark and wood tissue is followed concurrently with high concentration of nutrients in green shoots and leaves, showing a movement of nutrients from the reserve to actively growing tissue.

Generally, the concentration of respective nutrients in bark or wood tissue is higher in well manured trees, compared to trees inadequately manured (Pushparajah, 1966 ; Tan, 1975b). The build up of nutrients in bark and wood during leaf senescence and depletion at refoliation, confirmed that these tissues act as storage organs. This explains the time lag between fertiliser application and response in yield. Such time lag varying from a few months to over 3 years. The shorter time interval is normally the time interval to obtain responses to fertilisers in areas with poor nutrition and hence low storage.

In addition to this, a considerable amount of nutrients are also stored in the leaves (Tan, 1975b) (Table 1). These are returned to the soil during the annual refoliation cycle, but the rate of release was also relatively slow particularly for nitrogen and phosphorus (Table 2). Thus the current years supply through leaf fall may only be available in the following year.

TABLE 1 : NUTRIENTS STORED IN LEAVES AND RETURNED AS LITTER [(a)]

Treatment	Dry weight leaf litter (kg/ha/yr)	Nutrients in litter (kg/ha/yr)				
		N	P	K	Mg	Ca
Nil fertiliser	2360	42	1·6	7·1	5·5	26
NPKMg fertiliser	2860	53	2·1	10·2	7·0	33

(a) After Tan, K.H. (1975)

TABLE 2 : CHANGES IN DRY WEIGHT AND NUTRIENT RELEASE FROM DECOMPOSING *HEVEA* LITTER [(a)]

Time from leaf fall (months)	Dry Weight (as % of original)	Proportion (%) of nutrient released from litter N	P	K	Mg	Ca
0	100	0	0	0	0	0
2	42	59	41	90	60	61
4	32	65	62	94	81	74
8	26	75	77	96	93	87

(a) After Tan, K. H. (1975)

Influence on latex concentration and properties

Major nutrients N, P, K and Mg have been shown to improve growth of bark anatomy (Samsidar *et al.*, 1975), yield and in some cases, bark renewal (Pushparajah, 1969). However, their role in latex flow and properties has been generally overlooked.

Early investigation (Shorrocks, 1961) showed that applications of ammonium sulphate, rock phosphate, potassium chloride and manganese sulphate increase respectively the N, P, K and Mn contents of latex. The application of ammonium sulphate in addition to increasing the N content, also increased the Mg content and reduced total solids and drc (Collier & Lowe, 1969). On the other hand, rock phosphate was shown to increase the P content and reduce the Mg content. They also showed that ammonium sulphate increased VFA content and KOH number and thus reduced stability of concentrated latex. Simultaneous applications of rock phosphate reduced this adverse effect. They (Collier & Lowe, 1969) thus considered that the adverse effect of ammonium sulphate could be due to the increase in Mg content and the beneficial effect of rock phosphate could be due to the increase in P and reduction in Mg contents of latex with a consequent reduction in the P and Mg ratio.

Philpott & Westgarth (1953) found that application of phosphate improved stability and they indicated that application of potassium also seemed to have an influence on improving stability of concentrated latex, while nitrogen fertiliser on its own tends to reduce stability. The positive effect of the P/K combination was described by them to be due to a more balanced P/Mg ratio in the latex. Pushparajah (1969) found that applications of potassium in addition to increasing K content in latex, increased the P and reduced the Mg content. Thus potassium having a direct influence on the P/Mg ratio. Rambeaux & Danjard (1963) had suggested that application of K based fertilisers could be used for narrowing the Mg/P ratio and this could not be substantiated in field trials (Anon, 1966).

Effect on nutrient balance

With these in mind, the influence of various fertilisers on latex flow and properties were considered in some detail (Pushparajah *et al.*, 1975a) and are discussed below.

Applications of ammonium sulphate generally increased the N, K and Mg contents and the Mg/P ratio in latex. Phosphate applied as rock phosphate, increased P and Ca contents and reduced the Mg/P ratio. The effect of concurrent applications of ammonium sulphate and rock phosphate was intermediate to their individual application. Potassium applied as potassium chloride generally increased K and P contents, but reduced Ca, Mg and consequently the P/Mg ratio. The applications of Mg on the other hand, resulted in increase in Mg and decrease in K content in latex, with the consequent decrease in the K/Mg ratio and an increase in the Mg/P ratio.

Effect on flow

Generally, when the nutrients were applied without causing any imbalance to the other major nutrient content in the leaf tissue, there was an increase in yield. However, where excessive amounts of P or Mg in particular were applied, they reduced yields (Table 3). Potassium generally had the largest effect on latex flow both in terms of flow rate and yield. Nitrogen while increasing yield and time of flow, did not affect the average rate of flow. Where excessive rates of P or Mg were applied, the flow rates were also reduced.

TABLE 3 : INFLUENCE OF FERTILISERS ON LATEX FLOW AND NUTRIENT CONTENT [(a)]

Fertiliser & Levels	Yield (ml/tree/ tapping)	Rate of flow (ml/min)	Nutrient (% on Total Solids)					
			N	P	K	Mg	Ca (ppm)	Mg/P
Ammonium Sulphate								
Nil	73	1·00	0·74	0·199	0·57	0·182	—	0·91
Level 1	96	1·01	0·82	0·198	0·64	0·202	—	1·02
Level 2	90	0·97	0·85	0·195	0·65	0·213	—	1·09
Kieserite								
Nil	92	1·01	0·81	0·200	0·65	0·169	—	0·85
Level 1	86	1·01	0·79	0·190	0·60	0·198	—	1·04
Level 2	82	0·97	0·80	0·202	0·60	0·230	—	1·14
s.e.$\pm$	96	—	0·012	0·008	0·012	0·006	—	—
($P < 0·05$)	29	—	0·04	0·025	0·04	0·018	—	—
Rock Phosphate								
Nil	187	0·80	0·68	0·158	0·57	0·043	22	0·27
Level 1	186	0·84	0·70	0·198	0·59	0·044	23	0·23
Level 2	171	0·79	0·69	0·199	0·59	0·043	27	0·22
Potassium Chloride								
Nil	169	0·75	0·69	0·179	0·57	0·054	26	0·30
Level 1	187	0·80	0·70	0·188	0·60	0·041	24	0·22
Level 2	190	0·88	0·67	0·187	0·58	0·035	22	0·19
s.e.$\pm$	19	0·058	0·006	0·0022	0·007	0·0001	0·9	0·005
($P < 0·05$)	57	0·18	0·02	0·007	0·02	0·003	2·6	0·014

(a) After Pushparajah *et al.*, 1975

Effect on latex

N fertilisers generally increased the KOH number of fresh latex but on storage, the differences in KOH of latices from manured and unmanured trees were reduced (Table 4).

TABLE 4 : INFLUENCE OF FERTILISERS ON VFA AND KOH [(a)]

Treatment	VFA		KOH Number	
	Fresh	10 days	Fresh	10 days
Legumes — Nil N	0·02	0·05	0·64	0·71
Legumes — high N	0·01	0·13	0·72	0·73
Grass — Nil N	0·03	0·12	0·68	0·72
Grass — high N	0·02	0·10	0·82	0·76
Nil P	0·01	0·15	0·83	0·84
Phosphate	0·01	0·04	0·66	0·63

(a) After Pushparajah *et al.*, 1975

Additionally, nitrogen increased VFA content. Normally, the high levels of N fertilisers are not applied to rubber in areas where good legume covers are maintained. Thus the use of legume covers seems preferable for obtaining better quality latex. Phosphate on the other hand, reduced KOH number in both fresh and stored latex and KOH in stored latex.

Both N and P gave higher PRI of auto-coagulated rubber and led to lower reduction in PRI on storage of coagula (Table 5).

TABLE 5 : EFFECT OF FERTILISERS ON PRI [(a)]

Treatment	PRI		
	Fresh	10 days	20 days
Legume Cover			
Nil N	81	58	22
High N	88	53	38
Grass Cover			
Nil N	88	55	28
High N	92	63	47
Phosphate			
Nil P	80	38	31
Phosphate	92	67	59

(a) After Pushparajah *et al.*, 1975

The effect of P on PRI was larger than that due to nitrogen applications. This clearly indicates that the major nutrients particularly N, P and K in addition to giving better performance in growth and yield, also affected the quality of the latex produced. Generally, both phosphate and potassium seem to beneficially influence the stability of the latex. Phosphate additionally also seems to influence the technological properties *e.g.* PRI. Thus adequate and optimum manuring particularly in the use of P and K, in addition to giving higher yields and returns, could also enable the elimination of additives to prevent loss in stability or reduction of PRI. This gives a greater emphasis for the need of optimum and discriminatory manuring of rubber.

However, as the cost of fertiliser is generally showing an increasing trend, it is of paramount importance to optimise the use of fertilisers. Such increased efficiency could be brought in by a better understanding of the effect of fertilisers on soil. Further, the use of legumes to fix atmospheric nitrogen and return to the soil has been known to be a method of obtaining nitrogen in an inexpensive manner. These therefore are discussed in some detail in the subsequent section.

Efficient use of fertilizers

Leaching losses : It is generally an accepted practice that fertilisers should be applied to the root zone of the crop. For rubber during the initial stages after establishment, the roots are confined to a small circle around the plant (Anon, 1958). Thereafter the roots extend well into the mid-point of the interrow (Soong, 1970). The distribution of the active feeder roots in mature trees increases from about 60 cm away from the tree to the peak at a point about 300 cm from the tree and thereafter this declines (Soong *et al.*, 1971). Thus fertiliser applications have to be confined to this zone.

During the first year of field budding, the fertilisers are applied in a small circle 30 — 40 cm in diameter. This amounts to about 270 kg/ha of NPKMg fertiliser. Thus the effective zone of application is only 0·006 ha and the effective rate amounts to 40 tonnes per ha. Thus, one dressing of 170 g per tree would amount to 13 tonnes per ha containing about 5 tonnes of ammonium sulphate. A considerable proportion of this fertiliser at these rates could be lost by leaching (Pushparajah *et al.*, 1973) (Table 6). More than twice as much nitrogen and potassium is lost from sandy to sandy loam soils than from clay to clay loam soils, when an average rainfall of about 1 cm is experienced. However, if 2 - 5 cm of rain per day is experienced, then even on the clay to clay loam soils, up to 50% or more of the fertilisers is lost by leaching within 10 - 15 days of fertiliser application. The split application of fertilisers at greater frequency than hitherto practised becomes of paramount importance.

TABLE 6 : LEACHING LOSS OF N AND K (a)
(LOSS IN 20 RAINY DAYS AS % OF THAT ADDED)

Soil and Rainfall	N	K
Sandy Clay Loam (Rengam Series)		
1·05 cm per alternate day	80	20
2·10 cm per alternate day	100	45
Clay Loam (Munchong Series)		
1·05 cm per alternate day	22	3
2·10 cm per alternate day	62	14

(a) After Pushparajah *et al.*, (1973)

Timing : In addition, correct timing of application is a pre-requisite. During the early stages of growth, the application of fertilisers should be at closer frequencies and as far as possible, being in relation to the active flushing of leaves which is continuously taking place. In mature rubber, uptake of nitrogen is active at the commencement of refoliation (Shorrocks, 1964 ; Pushparajah & Tan, 1972), and the uptake diminishes after 4 - 5 months.

Slow release fertilisers : Ideally, a slow release fertiliser with controlled release of nutrients would satisfy both these requirements. However, the commercially available slow release fertilisers are either cost prohibitive or are not satisfactory in tropical soils. However, recent work (Soong *et al.*, 1976) has shown that NR latex encapsulated fertilisers have considerable promise (Table 7).

TABLE 7 : EFFECT OF NR ENCAPSULATION ON NUTRIENT RELEASE

Fertiliser	Cumulative amounts released (%)					
	Nitrogen			Potassium		
	2 weeks	6 weeks	10 weeks	2 weeks	6 weeks	10 weeks
Uncoated	35	76	81	38	89	100
Encapsulated						
1 coating	8	86	95	3	74	98
3 coatings	2	45	65	3	27	62

Effect on soil : Use of fertilisers would also influence the properties of the soil. Generally, the continued use of ammonium sulphate reduces pH and the amount of exchangeable bases in the soil. It also tends to adversely affect soil aggregation (Pushparajah *et al.*, 1975b). Application of rock phosphate increased pH, calcium and improved soil aggregation. Thus to minimise long term adverse effects of ammonium sulphate, concurrent applications of ammonium sulphate and rock phosphate may be essential.

The continued use of phosphates led to considerable build up of P in both surface soils and soils in lower depths (Table 8).

TABLE 8 : AVAILABILITY OF RESIDUAL P

Treatment	Total	Soil P	NH_4F Extractable P		P uptake by cropping (mg/pot)
	ppm	mg/pot	ppm	mg/pot	
P_0	498	299	13	8	7
P_1	1149	689	246	148	70
P_2	1511	900	395	237	95

P recovery at P_1 (*i.e.* $P_1 - P_0$) : as % of total P = 16
as % of NH_4F extractable P = 45

P recovery at P_2 (*i.e.* $P_2 - P_0$) : as % of total P = 15
as % of NH_4F extractable P = 38

A considerable proportion of the P was present as calcium phosphate, while that fixed as aluminium and iron phosphate was lower (Lau *et al.*, 1973). Exhaustive cropping showed that a large proportion of the residual P in the iron and aluminium fraction was available to plants (Pushparajah, 1966 ; Pushparajah *et al.*, 1975b). Further, field investigations have shown that these are also available and gave satisfactory performance to the rubber replanted in the same area (Table 9).

TABLE 9 : EFFECT OF RESIDUAL P ON RUBBER

Treatment	Mean Girth (cm at 150 cm from union)
Nil P	44·8
P applied to previous stand (P^1)	49·0
P applied to current stand (P)	50·5
N only	48·4
N + P_1	52·6
N + P_1 + P	52·5

Fairly large increases in exchangeable acid extractable K were found in soils with 2:1 clays and micas, indicating fixation of potassium. Investigations have also shown that in these soils, even ammonia is fixed in some soils (Tan, 1976). The availability of such fixed nutrients *viz.* ammonia, K and Mg needs to be investigated in order to utilise the residual effects and thus optimise on use of fertilisers.

Legume Covers

Nitrogen is one of the most important major nutrient both for growth and yield of *Hevea*. The use of legume covers to supply the considerable amounts of nitrogen needed and thus enhance the vigour and performance of *Hevea* has been discussed in detail (Mainstone, 1961 ; Watson, 1961 ; Pushparajah & Chellapah, 1969 ; Pushparajah & Tan, 1976). Generally, in addition to nitrogen, levels of phosphorus in leaves of *Hevea* were enhanced by legume covers. The role of legume covers in enhancing soil organic matter (Pushparajah & Chellapah, 1969 ; Watson *et al.*, 1964), and in improving soil physical properties and hence rooting (Mainstone, 1961 ; Watson, 1961) has also been discussed. Thus influence of legumes on productivity of rubber has been shown to be not only through its nitrogen return, but also through its influence on the physical and chemical properties of the soil. However, there has also been controversy over the economic value of the initial expenditure on establishment and maintenance of a stand of pure legumes. With the existing vagaries in the price and availability of nitrogenous fertilisers, the greater use of legume covers becomes essential.

The results of long term trials carried out at the RRIM showed that, to give yields similar to that obtained in legume cover areas, additional fertilisers had to be applied to trees in non-legume areas (Pushparajah & Tan, 1976) (Table 10). In one of the trials evaluating residual effects of covers where yield recording was done for thirteen years, trees in grass plots needed extra applications of at least 737 kg of N (Table 10). Trees under natural cover required even more nitrogen than those under grass (over 900 kg, *i.e.* treatment r_2n_2).

TABLE 10 : RESIDUAL EFFECTS OF COVERS ON CUMULATIVE YIELD (kg/ha) [a]
(TRIAL 2 ON MUNCHONG SERIES SOIL WITH GG_2 SEEDLINGS)

Cover	Fertiliser treatment [b]			
	r_1n_0	r_1n_1	r_2n_0	r_2n_2
Legumes	18,226	18,707	18,341	18,877
Grass	15,535	18,319	16,015	19,149
Naturals	16,044	16,079	16,799	18,851
N applied (kg/ha)	22·8	22·8 + 737	195	195 + 737

[a] From August 1962 to December 1975

[b] r_1 = NPKMg fertiliser in first 18 months ; r_2 = NPKMg fertiliser up to August 1962 ;

n_0 = no nitrogen from tapping ; n_1 = nitrogen from tapping.

r_2 received additional 183 kg P_2O_5 ; 55 kg K_2O/ha.

The extra fertilisers needed for the grass cover and naturals imply that the nitrogen returns from conventional creeping legumes could be much more than the 200 — 300 kg per ha estimated (Watson, 1961) ; such estimates being done by periodic sampling of only the above ground vegetative matter and litter. The extra fertiliser needed is equivalent to 3·5 — 4·3 tonnes of ammonium sulphate per ha costing M$ 980 — M$ 1200. Against this, the cost of establishing and maintaining a pure legume cover amounting to about M$ 400 — M$ 500 per ha could be set off. However, in these two trials, up to 1970 *i.e.* the first eight years of tapping, a detailed financial analysis (Ti Teow Chuan *et al.*, 1971) indicated that legumes gave the highest discounted returns. This was particularly enhanced by the earlier tapping of trees under legume cover.

TABLE 11(a) : EFFECT OF COVER AND NITROGEN ON YIELD OF RUBBER (KG/HA) (b)
(TRIAL 2 SEEDLINGS ON JERANGAU SERIES SOIL)

Cover and Fertiliser treatment [a]	May-Dec 1966	Jan-Dec 1968	Jan-Dec 1969	Jan-Dec 1970	Jan-Dec 1971	Jan-Dec 1972	Jan-Dec 1973	Jan-Dec 1974	Jan-Dec 1975	Total
Legumes — Nil N	1 210	1 124	1 910	1 610	1 620	1 240	1 074	1 338	1 553	12 676
— Level 1 N	1 320	1 023	1 917	1 640	1 600	1 190	1 027	1 558	1 827	13 102
Grass — Nil N	672	912	1 503	1 380	1 460	1 260	1 016	1 214	1 349	10 766
— Level 2 N	1 245	982	1 751	1 530	1 610	1 420	1 095	1 456	1 631	12 720
— Level 3 N	1 284	1 095	2 068	1 650	1 680	1 490	1 215	1 547	1 846	13 875

NOTE : [a] Nil N = 17 kg N during first 12 months, uniform PKMg

Level 1 N = 468 kg of N/ha + uniform PKMg

Level 2 N = 836 kg of N/ha + uniform PKMg

Level 3 N = 1404 kg of N/ha + uniform PKMg

(b) After Pushparajah & Tan (1976)

In a trial where compensatory nitrogen was applied to trees under grass cover from the early period of planting, yields similar to that in legume cover was obtained (Table 11). An addition of about 836 kg of N was needed over a period up to nine years of tapping. However, the amount of compensatory N required is again found to be much more than that estimated (Watson, 1961) to be returned by the legume covers. The cost of the extra fertilisers amounts to M$ 1110 — M$ 1435 per hectare. Another interesting feature in this trial is that up to the eighth year of tapping, there was no response to nitrogen applications to trees in legume cover. This confirms suggestions from the earlier trials that though the conventional legumes are shaded out by the time of closure of the canopy, the residual effects on nitrogen would be continued for at least seven to eight years of tapping.

TABLE 11 : EFFECT OF COVERS AND LEVELS OF N ON CUMULATIVE YIELD (kg/ha) (TRIAL 1 WITH RRIM 605)

Cover Levels of N[a]	In 1968	Jan-Dec 1969	Jan-Dec 1970	Jan-Dec 1971	Jan-Dec[b] 1972	Total
Legume						
Nil N	590	1,384	1,440	1,330	800	5,544
Level 1 N	491	1,391	1,400	1,320	790	5,392
Grass						
Nil N	—	736	920	890	580	3,126
Level 2 N	—	998	1,290	1,410	780	4,478
Level 3 N	533	1,370	1,410	1,460	850	5,623

[a]Nil N = 12·6 kg N prior to budding, uniform PKMg throughout
Level N_1 = 359 kg N/ha + uniform PKMg as above
Level N_2 = 718 kg N/ha + uniform PKMg as above
Level N_3 = 1077 kg N/ha + uniform PKMg as above
[b]In September 1972, severe damage to storm made further recording unreliable.

In evaluating the economics of the use of legumes, it would also be necessary to credit the savings in costs in root disease treatment (Pushparajah & Chellapah, 1969) and reduce weeding on planting strips.

The investigations (Pushparajah & Tan, 1976) in the use of mixed creeping and bush legumes clearly demonstrate that especially in sandy soils, bushy legumes are inferior to creeping legumes; the adverse effect of *Stylosanthes* being more severe. The competition has been shown to be for nutrients; but as the chemical properties of the two soils considered were similar, the more severe depression in growth in Holyrood series indicates that there was also competition for moisture. This therefore indicates the possibility of *Stylosanthes* as a cover to be considered for use in soils with poor drainage.

The evidence presented earlier (Pushparajah & Tan, 1976) showed that despite the use of the rather poor cover policies prevailing in the late 1960s, economic benefits from legume covers were large. Recent investigations on increasing efficiency of legumes indicate that the benefits could be further enhanced. The use of P and Ca to increase the effectiveness is an accepted practice and hence rock phosphate has been used to supply both these nutrients. The evidence (Pushparajah & Tan, 1976) showed that by manipulating the application of the rock phosphate, greater efficiency can be obtained. The need for nutrient K and Mg was also indicated. To obtain speedier ground cover and vigour, 'starter doses' are essential. Implementation of chemical weed control in addition to enhancing speedier cover and efficiency of nitrogen return, is likely to reduce cost of legume establishment and maintenance. Other work (Tan, 1976b ; 1976c) has shown that the use of sulphur (as gypsum) and molybdenum (as molybdated rock phosphate coating on seeds) considerably increased the nitrogen returns from *Pueraria.*

The introduction of a shade tolerant legume, *Calopogonium caeruleum* has been shown (Tan *et al.*, 1976) to return about two to three times more nitrogen than the conventional creeping legumes. These have been shown to have considerably more residual effects on *Hevea* (Table 12). Even using the evidence currently available on residual effects and extra fertiliser needed for non-legume areas, the savings on nitrogenous fertilisers can be large.

TABLE 12 : EFFECT OF *CALOPOGONIUM CAERULEUM* ON NITROGEN [(a)]

Cover	N returns		Leaf N (%)
	Period (yr)	kg/ha	in *Hevea* at 11th year
Pueraria phaseoloides + *Centrosema pubescens*	1—5	285	3·41
Calopogonium caeruleum + *Pueraria phaseoloides*	3—8	694	3·75

(a) After Tan *et al.* (1976)

With the implementation of the improved management and cultural practices indicated earlier, and by the use of other more suitable legume covers, the nitrogen economy of rubber cultivation can be considerably enhanced.

CONCLUSIONS

For maximising productivity of rubber, optimal nutrition is essential. The work reviewed shows that not only is the yield affected by proper nutrition, but a balanced nutrition seems to enhance quality of the latex, thus indicating the possibility for elimination of artificial additives during processing. This has been particularly found to be possible in as far as the PRI of autocoagulated rubber is concerned and could have tremendous implication in the smallholder sector. Additionally, more efficient utilisation of fertilisers could result in use of lower amounts of fertilisers or increased returns for the same investment in fertilisers. Continuous cropping with rubber and regular application of fertilisers results in a build up of nutrients, which can be used for subsequent croppings. The knowledge of such build up allows for manipulation and adjustment of fertiliser inputs whereby such applications could be eliminated or reduced during certain periods, particularly when prices of the fertilisers are high or prices of rubber are low.

The use of legume covers and the possible introduction of more shade tolerant legume covers seem to indicate possible long term savings in inputs of nitrogenous fertilisers. Thus a more concerted action is necessary for ensuring that trees are maintained at optimum nutrition at minimum costs.

ACKNOWLEDGEMENT

I wish to thank the Director and Board of the Rubber Research Institute of Malaysia for permission to present this paper.

REFERENCES

ANON (1958). Rooting habit. *Plrs'. Bull. Rubb. Res. Inst. Malaya No.* **39,** 120.

ANON (1966). *Rapp. a Inst. Rech. Caoutch. Cambodge* 1965, 61.

ANON (1967). Economic use of fertilisers in mature rubber. *Plrs'. Bull. Rubb. Res. Inst. Malaya No.* **93,** 300.

CHAN, H. Y. (1972). Soil and leaf nutrient surveys for discriminatory fertiliser use in West Malaysian rubber holdings. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf. Kuala Lumpur*, 1971, 201.

COLLIER, H. M. AND LOWE, J. H. (1969). Effect of fertiliser application on latex properties. *J. Rubb. Res. Inst. Malaya* **21** (2), 181.

GUHA, M. M., SINGH, M. M. AND CHAN, H. Y. (1971). Use of appropriate fertilisers for rubber based on soil and leaf nutrient survey. *Q. Jl. Rubb. Res. Inst. Ceylon*, **48,** 160.

LAU, C. H., PUSHPARAJAH, E. AND YAP, W. C. (1973). Evaluation of various soil P indices for *Hevea. Proc. Fert. Chem. Trop. Soils Conf., Malaysian Soil Sc. Soc., Kuala Lumpur* 1973 (in press).

LIM, T. S. (1976). Private communication.

MAINSTONE, B. J. (1961). Effects of ground cover and continuity of nitrogenous fertiliser treatment upon growth to tappable maturity of *Hevea brasiliensis. Proc. Nat. Rubb. Res. Conf., Kuala Lumpur*, 1960, 362.

PHILPOTT, M. W. AND WESTGARTH, D. R. (1953). Stability and mineral composition of *Hevea* latex. *J. Rubb. Res. Inst. Malaya* **14,** 133.

PUSHPARAJAH, E. (1966). Studies on the effect of rock phosphate on growth and yield of *Hevea brasiliensis. Thesis submitted for the degree of Master of Agricultural Science, University of Malaysia.*

PUSHPARAJAH, E. (1969). Response on growth and yield of *Hevea brasiliensis* to fertiliser application on Rengam series soil. *J. Rubb. Res. Inst. Malaya* **21** (2), 165.

PUSHPARAJAH, E. (1973). Recent developments in the nutrition of *Hevea* in West Malaysia. *Q. Jl. Rubb. Res. Inst. Sri Lanka* **50,** 68.

PUSHPARAJAH, E. AND CHELLAPAH, K. (1969). Manuring of rubber in relation to covers. *J. Rubb. Res. Inst. Malaya* **21** (2), 126.

PUSHPARAJAH, E. AND GUHA, M. M. (1968). Fertiliser response in *Hevea brasiliensis* in relation to soil type and soil and leaf nutrient status. *Proc. 9th Int. Congr. Soil Sci., Adelaide, 1968,* **4,** 85.

PUSHPARAJAH, E., NG, S. K. AND RATNASINGAM, K. (1973). Leaching losses of nitrogen, potassium and magnesium on Peninsular Malaysian soils. *Proc. Malaysian Soil Sc. Soc. Conf. Kuala Lumpur 1973,* (in press).

PUSHPARAJAH, E., SIVANADYAN, K., P'NG TAT CHIN AND NG, E. K. (1972). Nutritional requirements of *Hevea brasiliensis* in relation to stimulation. *Proc. Rubb. Res. Inst. Malaya, Plrs'. Conf., Kuala Lumpur*, 1971, 189.

PUSHPARAJAH, E., SIVANADYAN, K., SUBRAMANIAM, A. AND TAN, K. T. (1975). Influence of fertilisers on nutrient content, flow and properties of *Hevea* latex. *Rubb. Res. Inst. Malaysia Int. Rubb. Conf., Kuala Lumpur, 1975.*

PUSHPARAJAH, E., SOONG, N. K., YEW, F. K. AND ZAINOL, EUSOF (1975). Effect of fertilisers on soils under *Hevea*. *Rubb. Res. Inst. Malaysia Inst. Rubb. Conf., Kuala Lumpur, 1975.*

PUSHPARAJAH, E. AND TAN, K. T. (1972). Factors affecting leaf nutrient levels in rubber. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf., Kuala Lumpur, 1972*, 97.

PUSHPARAJAH, E. AND TAN, K. H. (1976). Legumes in nitrogen economy in rubber cultivation. *Proc. Seminar on Soil Microbiology and Plant Nutrition, Kuala Lumpur, Aug. 1976.*

RAMBEAUX, J. AND DANJARD, J. C. (1963). Tene rouge basaltique et nutrition de l'hevea dans les conditions ecologiques du Cambodge Opusc. *Techq. Inst. Res. Caoutch. Cambodge* No. 2/63.

SAMSIDAR, ABDUL AZIZ MAHMOOD, SIVANADYAN, K. AND FOMEZ, J. B. (1975). Effect of mineral deficiencies on bark anatomy of *Hevea brasiliensis*. *Rubb. Res. Inst. Malaysia Int. Rubb. Conf., Kuala Lumpur, 1975* (Preprint).

SHORROCKS, V. M. (1961). Some effects of fertiliser application on the nutrient composition of leaves and latex of *Hevea brasiliensis*. *Proc. Nat. Rubb. Res. Conf., Kuala Lumpur 1960.*

SHORROCKS, V. M. (1964). Effect of time of fertiliser application on leaf nutrient composition. *J. Rubb. Res. Inst. Malaya*, **18** (5), 276.

SHORROCKS, V. M. (1965). Mineral nutrition, growth and nutrient cycle of *Hevea*. *I.* Growth and nutrient content. *J. Rubb. Res. Inst. Malaya* **19,** 32.

SIVANADYAN, K., P'NG TAT CHIN AND PUSHPARAJAH, E. (1972). Nutrition of *Hevea* in relation to Ethrel stimulation. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf., Kuala Lumpur*, 1972, 83.

SOONG, N. K. (1970). A study of the root distribution of *Hevea brasiliensis* in relation to its nutrition and growth on some typical Malayan soils. *Thesis submitted for the degree of Master of Agricultural Science, University of Malaya.*

SOONG. N. K., PUSHPARAJAH, E., SINGHE, M. M. AND TALIBUDEEN, O. (1971). Determination of active root distribution of *Hevea brasiliensis* using radioactive phosphorus. *Proc. Int. Symp. Soil Fert. Evaln. New Delhi*, 309.

SOONG, N. K., YEOH, C. S., CHIN, S. L. AND HARIDAS, G. (1976). Natural rubber encapsulated fertilisers for controlled nutrient release. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf.*, 1976 (Preprint).

TAN, K. T. (1975). Seasonal changes in the concentration of nutrients in mature *Hevea*. *Rubb. Res. Inst. Malaysia Int. Rubb. Conf., Kuala Lumpur, 1975* (Preprint).

TAN, K. T. (1975). Unpublished data. Rubber Research Institute of Malaya.

TAN, K. H. (1975). *Hevea* leaf litter fall and chemical changes during litter decomposition. *3rd ASEAN Soil Conf., Kuala Lumpur, Dec. 1975.* (Preprint).

TAN, K. H. (1976). Private communication.

TAN, K. H. (1976). Studies on response of some leguminous creepers to sulphur applied as Gypsum. *3rd ASEAN Soil Conf., Kuala Lumpur*, 1976.

TAN, K. H. (1976). Effect of peletting as seed treatment on the nodulation and growth of *Pueraria*. *National Seed Symp. Serdang 1976.*

TI TEOW CHUAN, PEE TECK YEW AND PUSHPARAJAH, E. (1971). Economic analyses of cover policies and fertiliser use in rubber cultivation. *Proc. Rubb. Res. Inst. Malaya Plrs', Conf., Kuala Lumpur, 214.*

WATSON, G. A. (1961). Cover plants and soil nutrient cycle in *Hevea* cultivation. *Proc. Nat. Rubb. Res. Conf., Kuala Lumpur, 1960, 352.*

WATSON, G. A., WONG, P. W. AND NARAYANAN, R. (1964). Effects of cover plants on soil nutrient status and on growth of *Hevea*. V. Loss of nitrate nitrogen and of cations under bare soil conditions. A progress report on results from a small scale trial. *J. Rubb. Res. Inst. Malaya* **18** (4), 161.