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Status of Macro-elements in Latex, Bark and Leaf of Clone RRIM 901, Panel BO-1, *in Relation to Gaseous Stimulation*

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The effect of different methods of latex extraction (T) and stimulation (S) on the status of nutrient present in the latex, bark and leaf of clone RRIM 901, Panel BO-1 *was studied to establish a relationship between the status of nutrient in tissue and tree productivity. The results showed no consistent pattern on the influence of the interaction effect of T × S on the drainage of elements from the latex and removal of nutrient from the bark. The influence of T × S interaction on N and Mg was observed both in the latex and the bark, while for P and K, the influence was confined solely in the latex or the bark. The study indicated that nutritional stress possibly caused the declining yield response as obtained from gaseous stimulation on young* Hevea *trees of clone RRIM 901,* Panel BO-1. *Therefore, to achieve sustainable crop production, it is essential to have a balanced situation between the amount of crop harvested and the ability of the tree to replenish, not only the crop harvested but also the amount of elements lost in the latex and bark after completion of tapping.*

Key words: latex; stimulation; nutrients; status; stress; bark; leaf; RRIM 901; productivity; drainage; P; K; N; Mg; Ca; puncture tapping; yield; mineral content; REACTORRIM

The nutritional requirements of plant tissue or the source-sink relationship determine the direction of transport of mineral nutrient in the phloem[1]. The translocation of mineral nutrient in the bark of *Hevea* trees is considered as a short-distance transport; there is a possibility that the movement of nutrient in the bark is facilitated by the concentration gradient, created by the mobilisation of water and accumulation of nutrient in the bark[2]. The partitioning of photosynthate, the source-sink relationship and its controlling mechanism can be limited by the supply of assimilate (source limitation) and by the limited capacity of the sink itself (sink limitation).

The yield profile of the REACTORRIM stimulated $^{1}/_{2}$S d/3 system[3] is similar to the yield trends observed earlier[4] where the declining yield trend was made evident by the lack of yield response to stimulation. The application of yield stimulant increased the yield of *Hevea* trees resulting in net loss of nutrients because of the greater volume of latex being removed from the tree.

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In a study[5], it was observed that trees tapped with intensive tapping systems, suffered high removal of nutrients, particularly N and K in ethephon stimulated trees. The amount of nutrient outflow was influenced mainly by the amount of latex harvested per unit area (kg/ha), over a period of time. Mixed views have been recorded on the effect of tapping intensity on nutrient drainage from *Hevea* trees. It has been reported[6] that there was no consistent pattern in the effect of tapping intensity on nutrient drainage, while in another study[7] no marked clonal difference was observed, in terms of the amount of nutrients in latex being removed through the tapping operation.

This study was proposed to establish the effect of different methods of latex extraction and stimulation on the status of nutrients in the latex, bark and leaf of clone RRIM 901, *Panel BO-1* and to establish a relationship between the status of nutrients in these tissues and the tree productivity obtained.

MATERIALS AND METHODS

The study was conducted in Field 19 of the Rubber Research Institute of Malaysia Experimental Station, Sg. Buloh, Selangor, on five year old trees of clone RRIM 901, *Panel BO-1*, newly opened for tapping. The latex from selected trees in each plot were pooled together and analysed for determination of the status of elements in latex. A total of 27 samples were collected per recording. The frequency of sampling was monthly, and this was for over a period of 12 months from June 1996 to May 1997. Sampling of latex was carried out during latex collection, usually from 1000 hours to 1130 hours.

Latex samples were sent to the analytical laboratory of the Malaysian Rubber Board immediately after the samples had been coded for determination of nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), copper (Cu), manganese (Mn), iron (Fe), and zinc (Zn). Bark sampling was carried out simultaneously with the sampling of latex. For tapped trees, bark samples were taken from bark shavings of two trees from each replicate. Bark samples for the puncture tapping system were taken from the puncture groove at the end of each month, by tapping off the bark from each section of the groove, using a tapping knife. The bark samples were then placed in coded petri dishes for oven drying at 100ºC until they were completely dry. Dry weight of the samples were determined before the bark samples were analysed.

The leaves were sampled at half-yearly intervals, during the moderate and high yielding periods. The first set of samples were taken in the month of June, followed by December in 1996 and 1997. No sampling was carried out during the wintering period. Leaves at the lower level of the canopy, also known as lower shade, were sampled and sent for analysis. Bark and latex samples were analysed at monthly intervals.

Determination of Elements

Nitrogen was determined by Kjeldhal digestion method while P was determined by Bray's method and both were quantified by a calorimetric autoanalyser[8,9]. K was determined by using a flame photometer while Mg, Mn, Cu, Fe, Zn and Ca were determined by using an absorption spectrometer for specific wavelengths. The atomic absorption wavelengths for Mn, Cu, Fe and Zn were 2794 Aº, 3247 Aº, 2483 Aº and 2138 Aº while the wavelengths required for determination of Mg and Ca were 2025 Aº and 4226 Aº, respectively.

RESULTS

With the exception of Ca, the status of other elements in the leaf was not affected by tapping (T), and stimulation (S) and by the interaction (T × S) effect (*Table 1*).

Similar observations were made on P, K and Ca content in latex. N and Mg in the latex, and N, P, K and Mg in the bark were affected significantly by the T × S interaction effect. The study established a pattern of elements in the leaf, bark and latex (*Table 2*).

N, P, K and Mg were abundant in the leaf while Ca was highest in the latex. The effect of gaseous stimulation employed was markedly observed in the study (*Figures 1*, *2*, *3*, *4* and *5*). It was more apparent in the bark, followed by latex and the least was in the leaf.

Mineral Content in the Leaf

The content of elements in the leaf was significantly ($p<0.001$) higher than in the latex and bark, except for Ca content in the latex. The N content in the leaf ranged from 3.63% to 3.95% which was five to nine times higher than the contents of latex and bark. Although it was not influenced by T × S interaction, the N content in the leaf of the unstimulated puncture tapping system was significantly lower than in other treatments with larger tapped surface area *viz*. $^1/_8$S and $^1/_2$S, irrespective of the methods of stimulation employed (*Table 3*). The same pattern was observed when it was compared with the stimulated puncture tapping system.

The P content was lower compared to N, ranging from 0.25% to 0.29% which was 135% and 300% of P in the latex and in the bark. P in the leaf was not significantly different

TABLE 1. INTERACTION (T × S) EFFECT OF NUTRIENT DRAINAGE IN LATEX, BARK AND LEAF[a]

Elements	Latex	Bark	Leaf
Nitrogen	0.0067*	0.0082*	NS
Phosphorus	NS	0.0035**	NS
Potassium	NS	0.0160*	NS
Magnesium	0.0002***	0.0024*	NS
Calcium	NS	NS	0.18***

[a]Clone RRIM 901, *Panel BO-1*, Field 19, Rubber Research Institute Experiment Station, Sg. Buloh
NS = Not Significant; *Significant at $p<0.05$; **Significant at $p<0.01$; ***Significant at $p<0.001$

TABLE 2. STATUS OF ELEMENTS IN LEAF, BARK AND LATEX[a]

Status of Elements		Range		
		Leaf	Bark	Latex
Nitrogen	Leaf > Bark > Latex	3.63 – 3.95	0.69 – 1.12	0.42 – 0.50
Phosphorus	Leaf > Latex > Bark	0.25 – 0.29	0.05 – 0.12	0.12 – 0.26
Potassium	Leaf > Bark > Latex	0.97 – 1.14	0.61 – 1.21	0.35 – 0.50
Magnesium	Leaf > Bark > Latex	0.23 – 0.32	0.09 – 0.16	0.04 – 0.09
Calcium	Latex > Bark > Leaf	1.06 – 1.70	1.27 – 2.05	12.85 – 21.79

[a]Clone RRIM 901, *Panel BO-1*, Field 19, Rubber Research Institute Experiment Station, Sg. Buloh

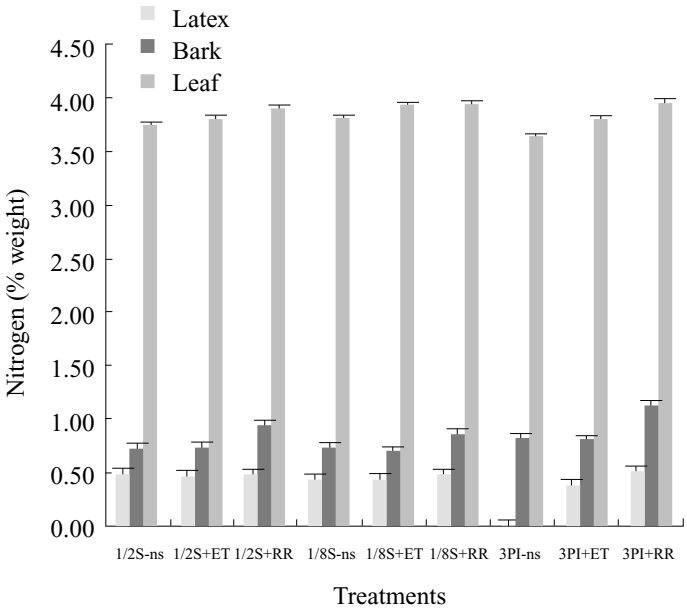

Figure 1. Nitrogen content in latex, bark and leaf of clone RRIM 901, Panel BO-1.

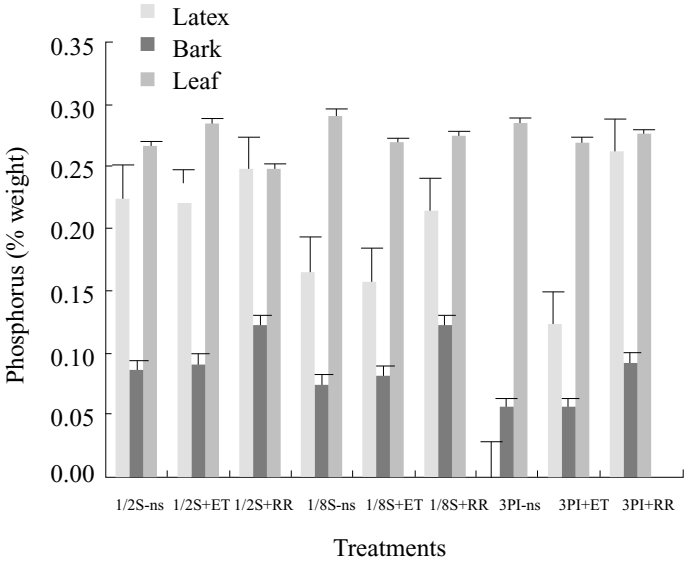

Figure 2. Phosphorus content in latex, bark and leaf of clone RRIM 901, Panel BO-1.

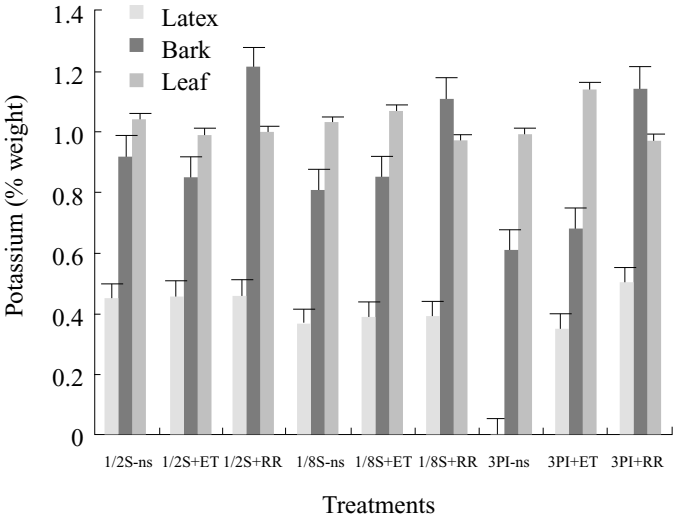

Figure 3. Potassium content in latex, bark and leaf of clone RRIM 901, Panel BO-1.

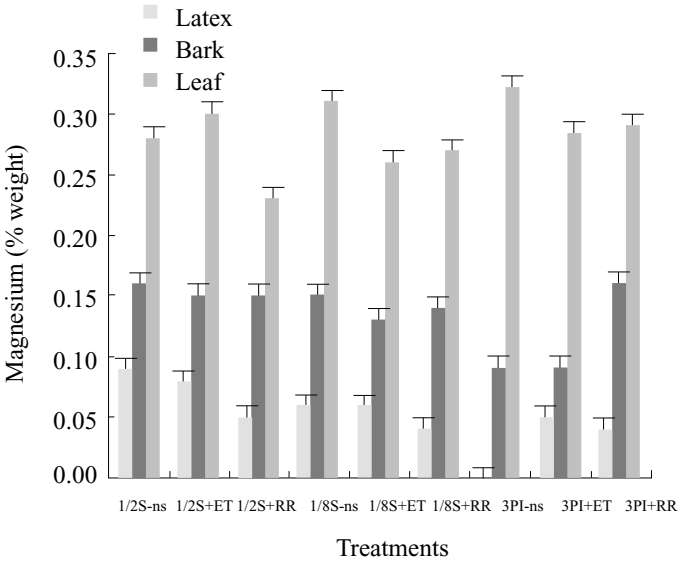

Figure 4. Magnesium content in latex, bark and leaf of clone RRIM 901, Panel BO-1.

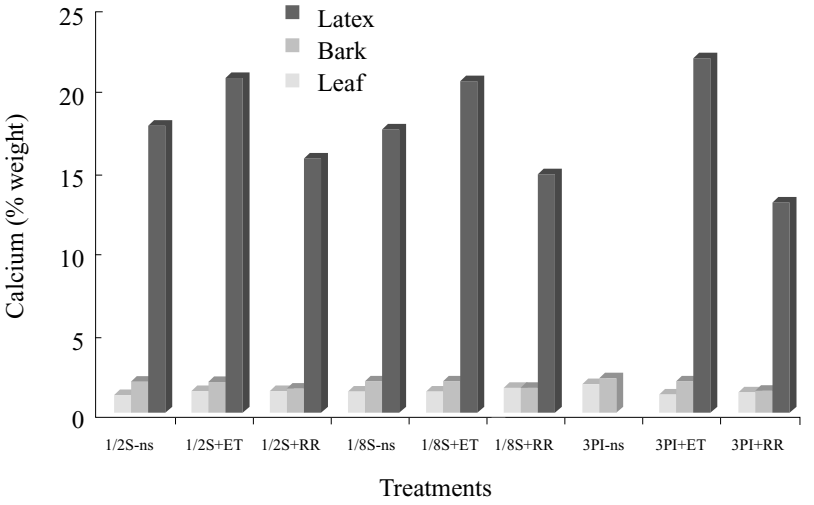

Figure 5. Calcium content in latex, bark and leaf of clone RRIM 901, Panel BO-1.

(*Table 3*), indicating that it was not influenced by the methods of latex extraction and methods of stimulation.

The K content in the leaf was higher than that of P but lower than that of N ranging from 0.97% to 1.14% with no influence of T × S interaction. However, the K content in the leaf of the unstimulated puncture tapping system was significantly lower when compared to $^{1}/_{2}$S, $^{1}/_{8}$S and ethephon stimulated puncture tapping systems. The analysis also showed that K in the leaf of the ethephon stimulated puncture tapping system was significantly lower than in the ethephon stimulated $^{1}/_{2}$S d/3 system.

The average Mg content in the leaf was 0.28% which was 206% of Mg content in the bark and 475% of Mg drained from the latex of young *Hevea* trees, clone RRIM 901, used in this study. The non-stimulated puncture tapping system and the REACTORRIM stimulated $^{1}/_{2}$S d/3 system had significantly different values of Mg while the difference in Mg of other treatments was not significant.

Ca recorded the least content in the leaf ranging from 1.06% to 1.70% which was 34% to 52% of Ca in the bark and 5% to 9% of Ca in the latex (*Figure 5*). However, Ca content in the leaf of the non-stimulated puncture tapping system was significantly higher when compared with other treatments (*Table 3*). The trend was the opposite of N in the leaf.

Mineral Content in Latex

The N, K and Mg content in the latex was influenced by the T × S interaction (*Table 1*), while the P content in the latex was influenced by the main effect, namely methods of latex extraction which is a manifestation of the tapped surface area. The content of elements in the unstimulated puncture tapping system was not available because the latex samples were too little, thick and prone towards coagulation, thus not suitable for the analysis.

Irrespective of the methods of stimulation employed, the N content in the latex of trees

TABLE 3. CONTRAST (P<0.05) FOR N, P, K, MG AND CA IN THE LEAF[a]

Contrast	N	P	K	Mg	Ca
1/2S–ns *vs* 1/2S+ET	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/2S+RR	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/8S-ns	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/8S+RR	NS	NS	NS	NS	–0.30*
1/2S–ns *vs* 3PI-ns	0.15*	NS	0.39*	NS	–0.56*
1/2S–ns *vs* 3PI+ET	NS	NS	NS	NS	NS
1/2S–ns *vs* 3PI+RR	NS	NS	NS	NS	NS
1/2S+ET *vs* 1/2S+RR	NS	NS	NS	NS	NS
1/2S+ET *vs* 1/8S-ns	NS	NS	NS	NS	NS
1/2S+ET *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/2S+ET *vs* 1/8S+RR	NS	NS	NS	NS	NS
1/2S+ET *vs* 3PI-ns	0.12*	NS	NS	NS	–0.38*
1/2S+ET *vs* 3PI+ET	NS	NS	0.110*	NS	0.26
1/2S+ET *vs* 3PI+RR	NS	NS	NS	NS	NS
1/2S+RR *vs* 1/8S-ns	NS	NS	NS	NS	NS
1/2S+RR *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/2S+RR *vs* 1/8S+RR	NS	NS	NS	NS	NS
1/2S+RR *vs* 3PI-ns	0.14*	NS	NS	–0.09*	–0.40*
1/2S+RR *vs* 3PI+ET	NS	NS	NS	NS	0.24*
1/2S+RR *vs* 3PI+RR	NS	NS	NS	NS	NS
1/8S-ns *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/8S-ns *vs* 1/8S+RR	NS	NS	NS	NS	NS
1/8S-ns *vs* 3PI-ns	0.08*	NS	0.37*	NS	–0.48*
1/8S-ns *vs* 3PI+ET	NS	NS	NS	NS	NS
1/8S-ns *vs* 3PI+RR	–0.12*	NS	NS	NS	NS
1/8S+ET *vs* 1/8S+RR	NS	NS	NS	NS	NS
1/8S+ET *vs* 3PI-ns	0.10*	NS	0.42*	NS	–0.44*
1/8S+ET *vs* 3PI+ET	NS	NS	NS	NS	NS
1/8S+ET *vs* 3PI+RR	–0.10*	NS	NS	NS	NS
1/8S+RR *vs* 3PI-ns	0.14*	NS	NS	NS	–0.25*
1/8S+RR *vs* 3PI+ET	NS	NS	NS	NS	0.38*
1/8S+RR *vs* 3PI+RR	NS	NS	NS	NS	0.24*
3PI-ns *vs* 3PI+ET	–0.08*	NS	–0.17*	NS	0.64*
3PI-ns *vs*3PI+RR	–0.20*	NS	NS	NS	0.49*
3PI+ET *vs* 3PI+RR	–0.12*	NS	NS	NS	NS

[a]Clone RRIM 901, *Panel BO-1*, Field 19, Rubber Research Institute Experiment Station, Sg. Buloh
NS = Not Significant; *Significant at p<0.05

tapped with 1/2S d/3 system was comparable with an average of 0.48% of the weight of the oven dried sample, but declined to 0.42% when the surface area was reduced to a 1/8S cut without the REACTORRIM method of stimulation. The N content in the REACTORRIM stimulated 3PI (45 cm) d/3 system was significantly ($p<0.05$) higher than N content in the non-REACTORRIM stimulated 1/8S d/3 and 3PI (45 cm) d/3 systems (*Table 4*). A similar trend was shown by P. The use of the REACTORRIM technique increased the P content marginally; 14% higher than P content in the latex of the non-REACTORRIM stimulated 1/2S d/3 system.

The effect of stimulation on K content was observed only in treatments with reduced surface area, namely 1/8S d/3 and 3PI (45 cm) d/3 systems, but the results were not consistent. The K content in the latex of the REACTORRIM stimulated 1/8S d/3 and puncture tapping systems was significantly ($p<0.05$) higher than the K content in the latex of the non-stimulated treatments. Latex of trees tapped with 3PI (45 cm) d/3 + REACTORRIM drained the highest K, with 0.50% or 9% to 43% higher than the K drained from 1/2S d/3, 1/8S d/3 and the non-REACTORRIM puncture tapping systems.

Mg was significantly ($p<0.05$) lower in the latex of trees stimulated with the REACTORRIM technique ranging from 0.043% to 0.047% of dry weight, which was 67% to 80% of the Mg content in the non-REACTORRIM stimulated tapping systems. While the non-REACTORRIM stimulated 1/2S d/3 system with the largest tapped surface area showed a higher Mg content, trees tapped with a similar system but stimulated with the REACTORRIM technique and treatments with smaller surface area namely 1/8S d/3 and 3PI (45 cm) d/3 displayed lower drainage of Mg in latex.

Irrespective of the methods of latex extraction used in this study, Ca content in the latex of the ethephon stimulated tree was higher, ranging from 20.38 p.p.m. to 21.80 p.p.m. while trees stimulated with the REACTORRIM technique recorded the lowest Ca content, ranging from 12.85 p.p.m. to 15.65 p.p.m., respectively. The results obtained indicated that tapped surface area was not a critical factor, compared to methods of stimulation in influencing the removal of Ca through latex.

Mineral Content in the Bark

The N content in the bark of trees tapped with the non-REACTORRIM stimulated puncture tapping systems was comparable, with an average of 0.81% of dry weight which was significantly ($p<0.05$) lower than the N content in the bark of trees tapped with the REACTORRIM stimulated puncture tapping system which had 1.12% of the dry weight.

The P content in the bark was markedly lower than the P content in the latex and in the leaf (*Figure 2*) and this was influenced mainly by the methods of stimulation. As observed the N and P contents in the RR stimulated treatments was higher than in the non-REACTORRIM stimulated tapping systems (*Table 5*). The results indicated that the use of mild ethephon stimulation, did not significantly alter the P content in the bark of the 1/2S d/3, 1/8S d/3 and 3PI (45 cm) d/3 systems as observed in the REACTORRIM stimulated treatments.

The influence of the interaction effect of T × S on the status of K was observed in the bark but the pattern displayed was the opposite of the pattern observed in the latex. The results showed that, irrespective of the methods of latex extraction used, the drainage of K from the bark was strongly influenced by the main effect which was the methods of stimulation,

TABLE 4. CONTRAST (P<0.05) FOR N, P, K, MG AND CA IN LATEX[a]

Contrast	N	P	K	Mg	Ca
1/2S–ns *vs* 1/2S+ET	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/2S+RR	NS	NS	NS	0.045*	NS
1/2S–ns *vs* 1/8S-ns	NS	0.053*	NS	0.032*	NS
1/2S–ns *vs* 1/8S+ET	NS	0.063*	NS	0.031*	NS
1/2S–ns *vs* 1/8S+RR	NS	NS	NS	0.043*	NS
1/2S–ns *vs* 3PI-ns	NA	NA	NA	NA	NA
1/2S–ns *vs* 3PI+ET	NS	0.100*	NS	0.041*	NS
1/2S–ns *vs* 3PI+RR	NS	NS	NS	0.049*	NS
1/2S+ET *vs* 1/2S+RR	NS	NS	NS	0.033*	NS
1/2S+ET *vs* 1/8S-ns	NS	0.050*	NS	0.020*	NS
1/2S+ET *vs* 1/8S+ET	NS	0.060*	NS	0.020*	NS
1/2S+ET *vs* 1/8S+RR	NS	NS	NS	0.035*	5.78*
1/2S+ET *vs* 3PI-ns	NA	NA	NA	NA	NA
1/2S+ET *vs* 3PI+ET	NS	0.097*	0.110*	0.030*	NS
1/2S+ET *vs* 3PI+RR	NS	–0.043*	NS	0.037*	7.68*
1/2S+RR *vs* 1/8S-ns	NS	0.080*	NS	NS	NS
1/2S+RR *vs* 1/8S+ET	NS	0.090*	NS	NS	NS
1/2S+RR *vs* 1/8S+RR	NS	NS	NS	NS	NS
1/2S+RR *vs* 3PI-ns	NA	NA	NA	NA	NA
1/2S+RR *vs* 3PI+ET	NS	0.127*	0.110*	NS	–6.15*
1/2S+RR *vs* 3PI+RR	NS	NS	NS	NS	NS
1/8S-ns *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/8S-ns *vs* 1/8S+RR	NS	–0.047*	–0.017*	NS	NS
1/8S-ns *vs* 3PI-ns	NA	NA	NA	NA	NA
1/8S-ns *vs* 3PI+ET	NS	0.047*	NS	NS	NS
1/8S-ns *vs* 3PI+RR	–0.117*	–0.093*	–0.130*	0.017*	NS
1/8S+ET *vs* 1/8S+RR	NS	–0.057*	NS	NS	5.64*
1/8S+ET *vs* 3PI-ns	NA	NA	NA	NA	NA
1/8S+ET *vs* 3PI+ET	NS	NS	0.176*	NS	NS
1/8S+ET *vs* 3PI+RR	–0.104*	–0.103*	–0.286*	0.018*	–7.53*
1/8S+RR *vs* 3PI-ns	NA	NA	NA	NA	NA
1/8S+RR *vs* 3PI+ET	NS	0.093*	NS	NS	–7.05*
1/8S+RR *vs* 3PI+RR	NS	–0.047*	–0.113*	NS	NS
3PI-ns *vs* 3PI+ET	NA	NA	NA	NA	NA
3PI-ns *vs* 3PI+RR	NA	NA	NA	NA	NA
3PI+ET *vs* 3PI+RR	–0.152*	0.140*	–0.150*	NS	8.95*

[a]Clone RRIM 901, *Panel BO-1*, Field 19, Rubber Research Institute Experiment Station, Sg. Buloh
NA = Not available; NS = Not Significant; *Significant at p<0.05

TABLE 5. CONTRAST (P<0.05) FOR N, P, K, MG AND CA IN BARK[a]

Contrast	N	P	K	Mg	Ca
1/2S–ns *vs* 1/2S+ET	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/2S+RR	–0.219*	–0.036*	–0.296*	–2.133*	0.47*
1/2S–ns *vs* 1/8S-ns	NS	NS	0.110*	NS	NS
1/2S–ns *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/2S–ns *vs* 1/8S+RR	–0.133*	–0.036*	–0.197*	–1.700*	0.47*
1/2S–ns *vs* 3PI-ns	–0.095*	0.030*	0.305*	–3.833*	NS
1/2S–ns *vs* 3PI+ET	–0.081*	0.029*	0.239*	–2.700*	NS
1/2S–ns *vs* 3PI+RR	–0.404*	NS	–0.223*	–9.400*	0.70*
1/2S+ET *vs* 1/2S+RR	–0.212*	–0.031*	–0.357*	NS	0.37*
1/2S+ET *vs* 1/8S-ns	NS	NS	NS	NS	NS
1/2S+ET *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/2S+ET *vs* 1/8S+RR	–0.127*	–0.031*	–0.257*	NS	0.36*
1/2S+ET *vs* 3PI-ns	–0.089*	0.035*	0.245*	–3.067*	NS
1/2S+ET *vs* 3PI+ET	NS	0.035*	0.179*	–1.933*	NS
1/2S+ET *vs* 3PI+RR	–0.397*	NS	–0.283*	–8.633*	0.60*
1/2S+RR *vs* 1/8S-ns	0.207*	0.048*	0.406*	2.400*	–0.42*
1/2S+RR *vs* 1/8S+ET	0.242*	0.041*	0.360*	2.200*	–0.35*
1/2S+RR *vs* 1/8S+RR	0.086*	NS	NS	NS	NS
1/2S+RR *vs* 3PI-ns	0.124*	0.066*	0.602*	–1.700*	–0.56*
1/2S+RR *vs* 3PI+ET	0.138*	0.066*	0.536*	NS	–0.47*
1/2S+RR *vs* 3PI+RR	–0.185*	0.029*	NS	–7.267*	–0.23*
1/8S-ns *vs* 1/8S+ET	NS	NS	NS	NS	NS
1/8S-ns *vs* 1/8S+RR	–0.122*	–0.048*	–0.307*	–1.967*	0.41*
1/8S-ns *vs* 3PI-ns	–0.084*	NS	0.196*	–4.100*	NS
1/8S-ns *vs* 3PI+ET	NS	NS	0.130*	–2.967*	NS
1/8S-ns *vs* 3PI+RR	–0.392*	NS	–0.332*	–9.667*	0.65*
1/8S+ET *vs* 1/8S+RR	–0.156*	–0.041*	–0.260*	–1.767*	0.34*
1/8S+ET *vs* 3PI-ns	–0.118*	NS	0.242*	–3.900*	NS
1/8S+ET *vs* 3PI+ET	–0.104*	NS	0.176*	–2.767*	NS
1/8S+ET *vs* 3PI+RR	–0.427*	NS	–0.283*	–9.467*	0.58*
1/8S+RR *vs* 3PI-ns	NS	0.066*	0.502*	–2.133*	–0.55*
1/8S+RR *vs* 3PI+ET	NS	0.066*	0.436*	NS	–0.46*
1/8S+RR *vs* 3PI+RR	–0.270*	0.029*	–0.026*	–7.700*	0.24*
3PI-ns *vs* 3PI+ET	NS	NS	NS	NS	NS
3PI-ns *vs* 3PI+RR	–0.308*	–0.307*	–0.528*	–5.567*	0.79*
3PI+ET *vs* 3PI+RR	–0.323*	–0.036*	–0.426*	–6.700*	0.70*

[a]Clone RRIM 901, *Panel BO-1*, Field 19, Rubber Research Institute Experiment Station, Sg. Buloh
NS = Not Significant; *Significant at p<0.05

specifically REACTORRIM technique which was significantly ($p<0.05$) higher, compared to the K content in the non-REACTORRIM stimulated treatments.

In general the average K content in the bark of trees tapped with REACTORRIM method of stimulation was 46% higher than the K content in the bark of the non-REACTORRIM stimulated treatments. The effect of tapped surface area of the tapping systems was confined to the non-REACTORRIM stimulated treatments. The K content in the bark of $^1/_2$S d/3 and $^1/_8$S d/3 systems, was significantly ($p<0.05$) higher than K content in the bark of the puncture tapping system.

The Mg content in the bark was significantly higher than in the latex which was influenced by the T × S interaction. The effect of the methods of stimulation on Mg content in the bark was not significant in the trees tapped with $^1/_2$S d/3 and $^1/_8$S d/3 systems. The effect of the methods of stimulation was only observed when the tapped surface area was reduced in the puncture tapping system where the Mg content was higher than in the non-REACTORRIM stimulated puncture tapping system.

The Ca content in the bark was significantly ($p<0.001$) affected by the main effect, namely methods of stimulation. Results showed that the Ca content of the non-stimulated treatments was comparable and significantly higher ($p<0.05$) than the Ca content of the REACTORRIM stimulated treatments. The highest Ca content in the bark was obtained from a combination of the smallest tapped surface area with no stimulation, but the Ca content was drastically reduced when the same surface area was stimulated with the REACTORRIM method of stimulation. Although similar trends were observed, trees tapped with a larger tapped surface area combined with similar methods of stimulation did not experience a drastic drop in the Ca content as observed in the puncture tapping system.

Correlation between Yield and Mineral Element Status in the Leaf, Bark and Latex

In an attempt to establish correlations, it was hypothesised that the tree productivity (g/t/t) and mineral elements in the leaf, bark and latex were linearly correlated ($\rho = 0$). There was sufficient evidence to reject the hypothesis that g/t/t and elements in the leaf were linearly correlated at $p<0.05$ because g/t/t was not significantly correlated to the elements determined in the study (*Table 6*).

Correlations between g/t/t and N, P and K in the latex were observed to be significant ($p<0.05$), except for Mg and Ca. These elements showed positive correlation, indicating that the higher the g/t/t, the higher the amount of N, P and K being drained from the latex which implied rapid mobility of these elements within the laticiferous system. Large removal of K and Mg was quantified from the bark which was significantly correlated to g/t/t but for K, a similar correlation was observed in the latex (*Table 6*).

Annual Loss per Hectare of Elements from Tissues

The loss of nutrients (*Figures 6–9*) was estimated based on land productivity (kg/ha/year) for a one year period (June 1996 to May 1997). The annual loss of N, K and Mg per hectare over the period showed that the loss of elements was significantly higher in the bark than in the latex of clone RRIM 901, *Panel BO-1* used in this study, except for P, where the loss was higher in the latex than in the bark. The loss of Ca, was negligible; less

TABLE 6. PEARSON CORRELATION COEFFICIENT OF MEAN DRY RUBBER YIELD (G/T/T) WITH LEAF, BARK AND LATEX MINERAL NUTRITION[a]

Mineral nutrition	Leaf	bark	latex
Nitrogen (N)	0.3756 NS	0.2569 NS	0.5764**
Phosphorus (P)	–0.3472 NS	0.6350 NS	0.8744**
Potassium (K)	–0.4541 NS	0.6966*	0.9110**
Magnesium (Mg)	–0.3236 NS	0.8433**	0.3873 NS
Calcium (Ca)	–0.2996 NS	–0.4960 NS	–0.4315 NS

[a]Clone RRIM 901, *Panel BO-1*, Field 19, Rubber Research Institute Experiment Station, Sg. Buloh
NS = Not significant; *Significant at $p<0.05$; **Significant at $p<0.01$; ***Significant at $p<0.001$

than 0.05 kg/ha/year. Although the loss of N, P, K, Mg and Ca per tree basis was higher in the REACTORRIM stimulated treatments, the pattern was only observed in the treatments tapped with 1/8S d/3 and the puncture tapping system. The primary reason was due to land productivity of the REACTORRIM stimulated 1/8S d/3 and the puncture tapping system which was higher than in the non-REACTORRIM stimulated treatments, while for the 1/2S d/3 system, the pattern was the reverse.

The non-stimulated 1/2S d/3 loss of 6.8 kg/ha/year of N in latex which was 75% to 81% of the loss in the non-stimulated 1/2S d/3 system, while in the bark, the loss was higher ranging from 13.2 kg to 13.3 kg/ha/year. The total annual loss of N from tissue *viz*. latex and bark, of the non-REACTORRIM stimulated treatments ranged from 21.6 to 22.4 kg/ha/year *versus* 20.1 kg/ha/year from the REACTORRIM stimulated 1/2S d/3 system (*Figure 6*). For the 1/8S d/3 system, the total loss of N from tissues of the REACTORRIM stimulated trees was 13.8 kg/ha/year which was 55% to 126% higher than the non-REACTORRIM stimulated trees. The annual loss of N from the REACTORRIM stimulated puncture tapping system was 25.2 kg/ha/year, 687% higher than the ethephon stimulated puncture tapping system. A similar pattern was shown by K and Mg (*Figures 7*, *8* and *9*).

The level of K loss was comparable to N which was markedly higher than P and Mg. A pattern was established where for the 1/2S d/3 system, the influence of the methods of latex extraction, referring to the tapped surface area was more apparent than the influence of the methods of stimulation. For the 1/8S d/3 and the puncture tapping system, the loss of N, P, K and Mg was influenced more by the methods of stimulation.

DISCUSSION

Leaf Nutrient Status of Clone RRIM 901, *Panel BO-1* in Relation to Methods of Latex Extraction and Stimulation

N, P, K, Mg and Ca in the leaf were not affected by the T × S interaction and there was no correlation between these elements and yield (g/t/t). It was observed that the element content was significantly higher in the leaf than in the bark and latex. Irrespective of the methods of latex extraction, the K content was the highest in the bark followed by that of in the leaf and latex. A negative correlation was observed[10] between the yield and K in the leaf

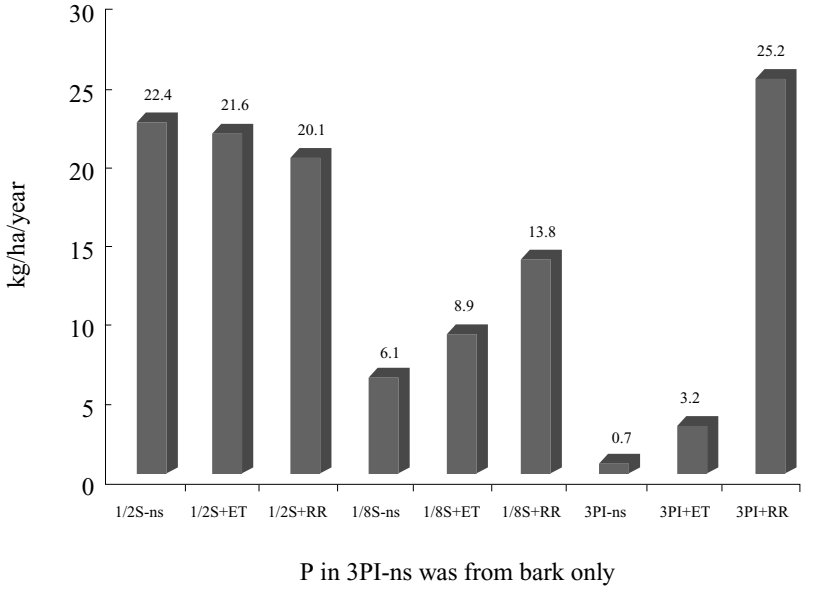

Figure 6. Loss of N (kg/ha/year) from tissues (bark and latex).

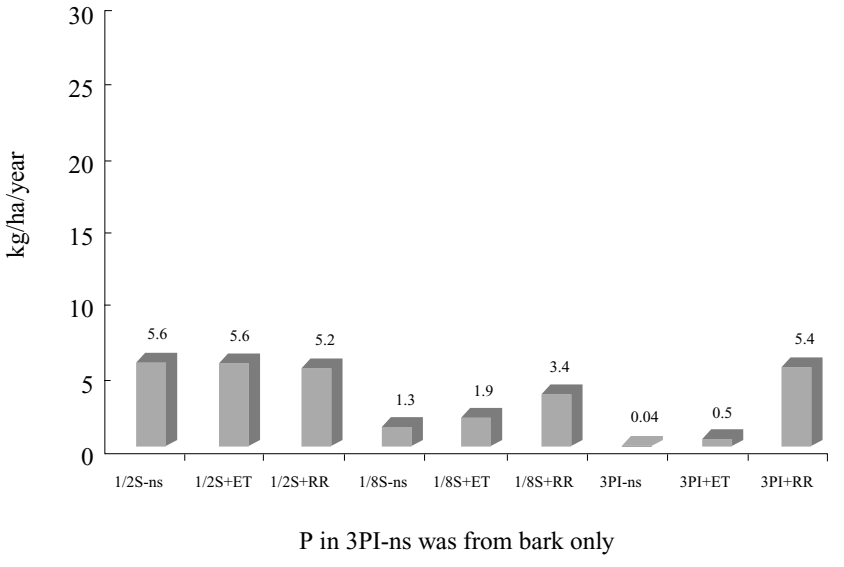

Figure 7. Loss of P (kg/ha/year) from tissues (bark and latex).

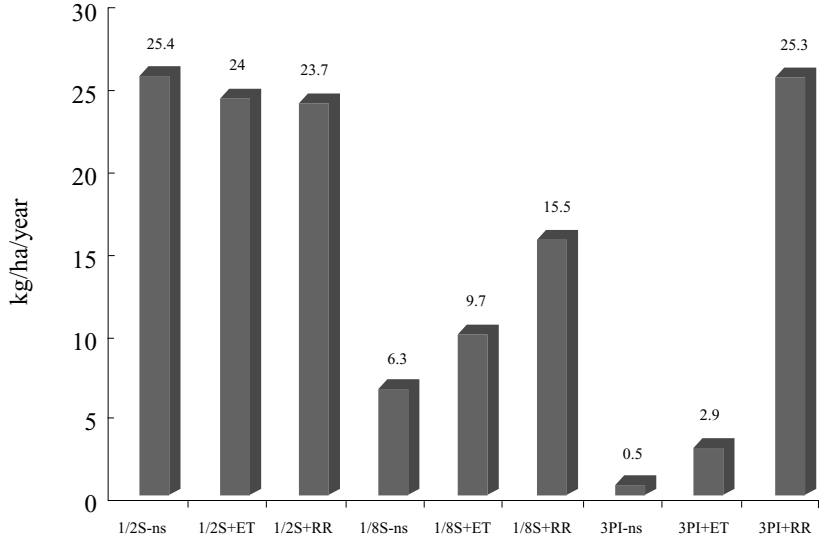

Figure 8. Loss of K (kg/ha/year) from tissues (bark and latex).

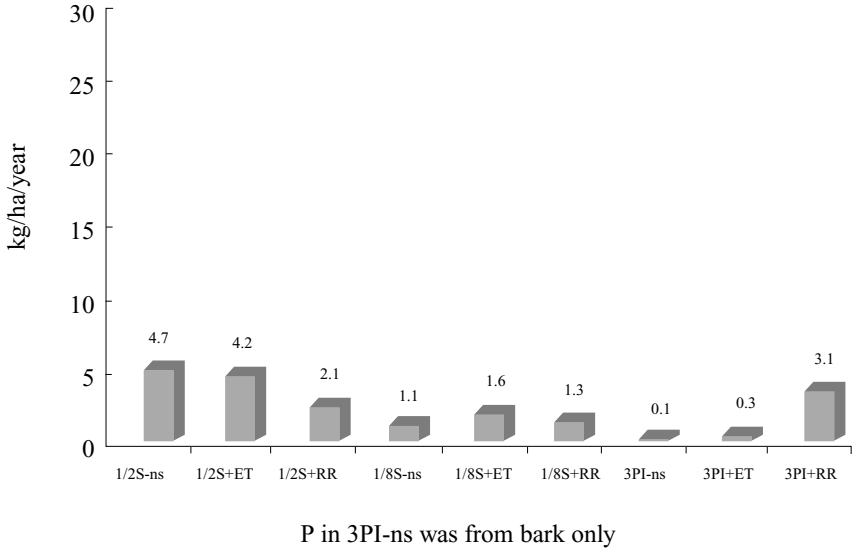

Figure 9. Loss of Mg (kg/ha/year) from tissues (bark and latex).

and this indicated that K might be the most important nutrient in relation to stimulation response.

Drainage of Nutrient from the Latex of Clone RRIM 901, *Panel BO-1* in Relation to Methods of Latex Extraction and Stimulation

A significant interaction effect of T × S on the N and Mg content in the latex was observed while P, K and Ca were not affected by the interaction effect. The drainage of K was significantly influenced by the main effect, namely methods of latex extraction, while the drainage of Ca from latex was influenced by methods of stimulation. The results indicated that there was no consistent pattern on the influence of the interaction effect or the influence of the main effects on the drainage of elements from latex of young *Hevea* trees of clone RRIM 901, *Panel BO-1* used in this study.

It has been established that the nutrient content in the latex of the non-REACTORRIM stimulated puncture tapping system was consistently lower than in the latex of REACTORRIM stimulated cut system. The trend changed when it was combined with the REACTORRIM method of stimulation where no significant difference was observed in the N, P, Mg and Ca contents between the REACTORRIM stimulated cut systems and the puncture tapping system.

Nutrient drainage is not always a reflection of the yield increase obtained from stimulation[11]. Irrespective of clones and the exploitation systems employed, there seems to be an increase in nutrient drainage from ethephon stimulated treatments compared to the control. The results were consistent with observations made in earlier work[12,13] where it was established that stimulation increased the drainage area, and extended the duration of latex flow resulting in a larger volume of latex being removed from the stimulated *Hevea* trees accompanied by heavier drainage of N, P, K and Mg. The decline in yield response obtained with yield stimulation was attributed by the nutritional stress within the trees, even over a short period of time[14].

Results obtained from the present study showed mixed results. The REACTORRIM stimulated $^{1}/_{2}$S d/3 system gave the lowest yield compared to the other treatments but the treatment drained most P and K in the latex while draining the least Mg. Higher yield obtained from the REACTORRIM stimulated $^{1}/_{8}$S d/3 and the puncture tapping systems was accompanied by high drainage of N, P and K which was consistent with observations made by earlier researchers[14,15], except for Mg which had the opposite trend in their studies. It was speculated[16] that the effect on Mg as a result of application of ethephon may be due to the inherent higher Mg levels in the trees prior to the application of stimulants. For $^{1}/_{8}$S d/3 and the puncture tapping system, the nutrient loss was markedly higher in the REACTORRIM stimulated treatments than in the non-REACTORRIM stimulated treatments. On a per hectare basis, the annual loss of P was higher in latex than in the bark.

Low N, P, K and Mg in the latex non-rubber phase were detected[17,18] when *Hevea* trees were subjected to intensive tapping. The affected trees were unable to neutralise the negative charges of the colloidal suspension[19] which resulted in latex coagulation[20] or pre-coagulation as observed in the present study, especially on the tapping cuts of the REACTORRIM stimulated $^{1}/_{2}$S d/3 and $^{1}/_{8}$S d/3 systems and along the puncture groove. Lack of Mg would affect the activation of numerous enzymes in the latex such as ATPase and will be unable to inhibit other enzymes such as invertase[19]. Thus, the use of the REACTORRIM method

of stimulation in the present study showed a deviation from the normal balance of mineral elements in latex.

Drainage of Nutrients from the Bark of Clone RRIM 901, *Panel BO-1*, in Relation to Methods of Latex Extraction and Stimulation

Tapping resulted in the simultaneous loss of elements through the flow of latex and the tapped bark. As observed in the latex, there was a strong influence of T × S interaction, methods of stimulation and latex extraction on the removal of N, K and Mg from the bark. The annual loss of N, K and Mg per hectare was higher in the bark than in the latex. The highest loss of N was recorded by the REACTORRIM stimulated puncture tapping system with 17.3 kg/ha/year, 30% to 96% more than in the $^{1}/_{8}$S d/3 and $^{1}/_{2}$S d/3 system with a similar method of stimulation. Loss of K from the REACTORRIM stimulated puncture tapping and the 1/8S d/3 system was marginal with 17.6 kg/ha/year and 17.2 kg/ha/year but higher than the $^{1}/_{8}$S d/3 system (11.5 kg/ha/year). The N and K contents in the bark of the REACTORRIM stimulated treatments were consistent with earlier observations[21]. However, the mild ethephon stimulated treatments did not show any impact on the N and K content in the bark of clone RRIM 901, *Panel BO-1* used in this study.

Deficiencies of N, P, K and Mg reduce the stem diameter, bark thickness, phloem region thickness, cell size, latex vessel number and latex vessel size[22]. Latex vessel index which is positively related to productivity is significantly lower for plants deficient in N, P, K and Mg. A negative correlation between K and the yield had been observed earlier[10] which was the reverse of the correlation obtained from the present study. High Ca content in the bark was associated with unhealthy rubber which responded poorly to stimulation. The results obtained from the present study which indicated that the bark Ca was not correlated with the yield, is not in accordance with the results, obtained from earlier studies[10].

CONCLUSION

There was no marked advantage in the use of the REACTORRIM method of stimulation on young *Hevea* trees of clone RRIM 901, *Panel BO-1*. Drainage through latex and removal of element from the bark were more dynamic than in the leaf. There was no consistent pattern observed on the influence of interaction effect of T × S on the drainage of elements from latex and removal of nutrients from the bark. The influence of T × S interaction on N and Mg was observed both in the latex and bark, while for P and K, the influence was confined solely in the latex or the bark.

The total loss of elements from tapping was mainly from the harvesting of latex and removal of bark, specifically for the gaseous stimulated short cut and puncture tapping system, indicating the severity of use of the REACTORRIM technique on young rubber trees of clone RRIM 901, *Panel BO-1*. Drainage of elements were higher in the latex of trees stimulated with the REACTORRIM method of stimulation caused by more dilution, longer latex flow and larger drainage area. However, it only happened when the REACTORRIM method of stimulation was effective, with no problems associated with the release of gas from the canister.

The annual loss of P per hectare was mostly from latex. For the non-stimulated and ethephon stimulated $^{1}/_{2}$S d/3 system, 71% to 73% of P in latex was drained during tapping and 68% from the latex of REACTORRIM stimulated $^{1}/_{2}$S d/3 system. A similar pattern was displayed by the $^{1}/_{8}$S d/3 system where the

least was drained from the REACTORRIM stimulated 1/8S d/3 system with 65% of the total loss *versus* 68% to 69% for the nil stimulated and ethephon stimulated 1/8S d/3 system. The pattern changed for the puncture tapped treatments because the highest loss of P was recorded by the REACTORRIM stimulated system with 74% of the total loss *versus* 60% from the ethephon stimulated puncture tapping system. A large removal of K from the latex and bark affected the long-term yield performance because of it's role as the enzyme co-factor in photosynthetic activity, involvement in osmotic activity in cells and regulation of nutrient uptake and transport such as in the translocation of sugar. Thus, K was required to be supplied adequately, as the other essential elements, to ensure that high production of latex could be sustained.

For N, K and Mg, the annual loss was more from the bark than latex. The annual loss of N was 59%, 61% and 66% for the nil, ethephon and REACTORRIM stimulated 1/2S d/3 system, respectively. Irrespective of the methods of stimulation used, the loss of N from the 1/8S d/3 was comparable ranging from 62% to 64% of the total loss, and 67% to 69% for the puncture tapping system.

This study revealed that nutritional stress was possibly one of the main factors causing declining yield response from gaseous stimulation on young *Hevea* trees of clone RRIM 901, *Panel BO-1* used in this study. Growth, governed by cambial activity was severely affected by the continuous presence of ethylene gas in the laticiferous tissue.

Although the loss of elements was comparatively lower than that which remained in the leaves, it is imperative to consider the impact of the use of gaseous method of stimulation like the REACTORRIM technique on young *Hevea* trees, as the loss of these elements was substantial and thus require quick replenishment for effective biosynthetic activity. For sustainable crop production, it is imperative to have a balanced situation between the amount of crop harvested and the ability of the tree to replenish, not only the crop harvested but also the amount of elements lost in the latex and bark after the completion of tapping.

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