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ECONOMICS AND EFFICIENCY OF FERTILIZER UTILIZATION IN MATURE RUBBER

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INTRODUCTION

The introduction of high yielding clones of rubber has no doubt provided a mechanism for obtaining high production levels, given a set of specific conditions. It is also a known fact that the implementation of a proper package of agro-management practices in accordance to soil and climate is a pre-requisite to the realization of the crop's potential yield capacity. In this package proper fertilizer use is a vital component. This article attempts to highlight the following important issues related to fertilization of mature rubber as shown in Fig 1.

1. Importance of fertilizer application during mature period (Why fertilizer should be applied to mature rubber)
2. The present fertilizer recommendation for mature rubber (What is the current fertilizer recommendation and its basis)
3. Other factors to be considered in fertilizer application for mature rubber (What are the factors to be considered in determination the fertilizer quantity)

1. Importance of fertilizer application during mature period

It appears that with sufficient manuring during the immature period a steady build up of nutrient reserves within the whole tree system will result. This nutrient bank, within the tree system, coupled with a continuous but steady supply of large amounts of nutrients from degenerating legume cover residues are expected to adequately sustain nutrient needs of mature trees.. This is made possible because a mature rubber stand, by functioning like a "closed" forest type ecosystem, with efficient nutrient cycling and relatively small outflow of nutrients via the latex, is expected to conserve and utilize this reserve of nutrients more stringently than most other conventional agricultural systems. In addition, nutrient needs of trees under tapping are also expected to plateau off or decrease, in view of a reduction in tree biomass, resulting from intensified self-pruning and thinning off of canopy. Thus, it can be construed that mature trees which have received good agronomic management and adequate fertilization during the early growth phase, by being self-reliant and able to thrive on past residual effects, are expected to sustain a high level of productivity, without requiring much fertilizers after commencement of tapping.

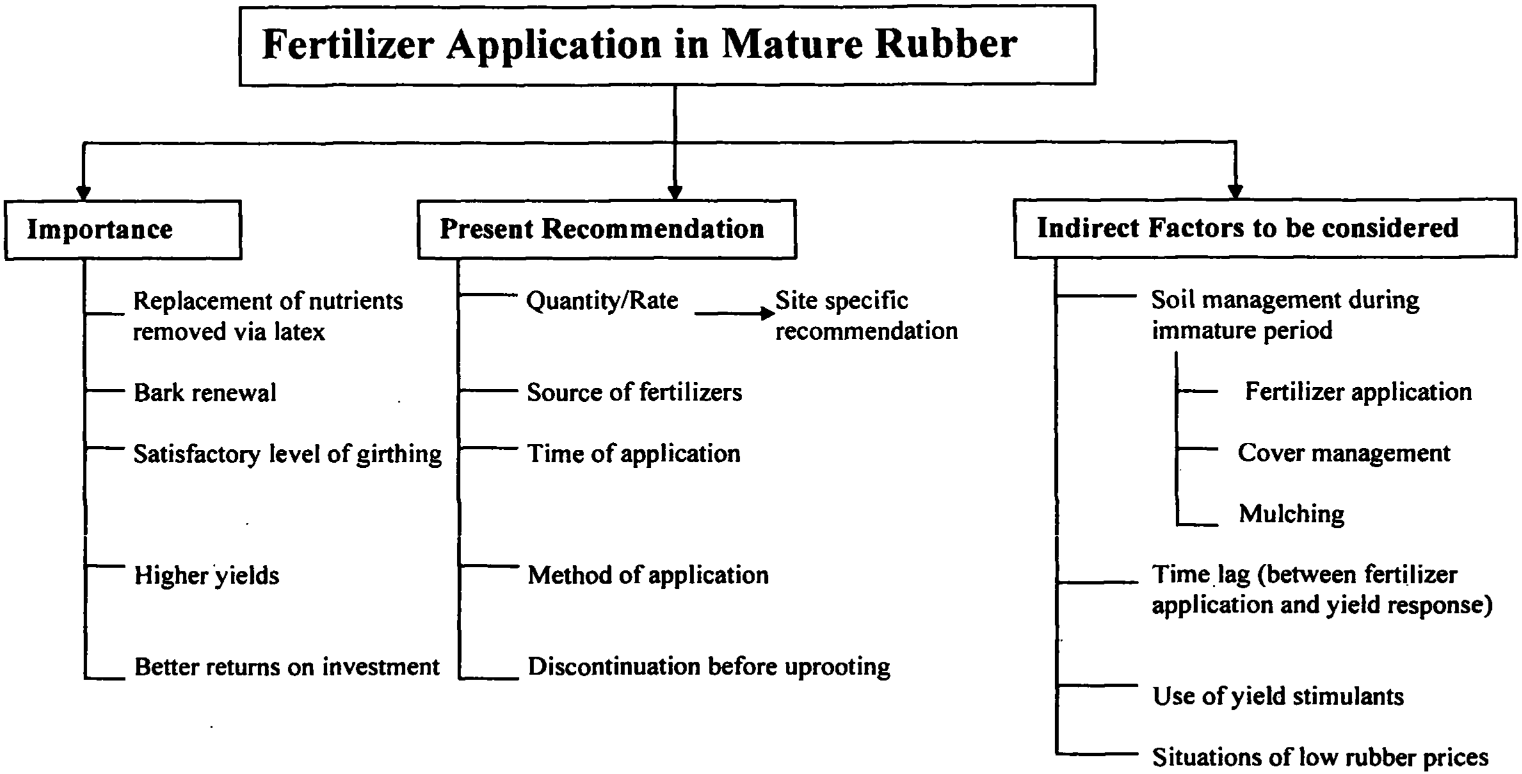

Fig.1. A schematic representation of the importance, present recommendation and indirect factors to be considered in fertilizer application in mature rubber

The application of fertilizers during maturity, therefore, could be minimized by considering the residual effect of the soil management practices carried out during the immature period and the likely leveling off in nutrient immobilization that takes place within the tree along with maturity. The ultimate objective of fertilizer application for mature rubber is to enhance latex yields and thereby to achieve higher return on investment. Fertilizer application also plays a key role in maintaining a satisfactory rate of girthing during mature period and renewal of the bark apart from replacing of nutrient removal via latex (tapping).

1.1 *Higher yields*

It is evident that major nutrients, N, P, K and Mg have positive effect on rubber yield (Table 1). Application of N to mature rubber under Sri Lankan conditions has been proved to be beneficial even in areas with a history of good agronomic management practices. The role of K is not only limited to increase in yield levels (Table 2), but also plays a significant role in the determination of flow characteristics and stability of latex. The recommended levels of P and Mg application during the immature phase of rubber result in a considerable build-up of P and Mg in the soil. This build-up is more than sufficient to supply the tree's needs as indicated by the levels of P and Mg in the leaves during maturity. Thus in most estates, where the conventional levels of P and Mg were applied as recommended in the normal manuring schedules for young rubber, maintain satisfactory levels of both P and Mg in the leaves and there was no need for application of P and Mg fertilizers after the trees came into tapping. It appears, therefore, that while N and K may have to be perennially retained in every year's manuring programme, P and Mg applications can be considered for omission for a period of time (Table 3). This finding is substantiated not only from the long-term fertilizer trials but also from performance of commercial fields.

Table 1. *Effect of application of fertilizers on yield*

Fertilizer Treatment	Mean Yield* kg/ha/yr	Relative yield increase (%)
No fertilizer	990	100
NPKMg fertilizer	1,184	122
Difference	194	22

* Average of 8 years

The commercial yields of rubber plantations have shown a marked increase over the years from about 250 kg/ha to the present level of about 2000 kg/ha with the introduction of new high yielding clones in particular. The performance of high yielding clones depends on the presence of certain additional inputs or a "package" of agro-management practices. In such circumstances the emphasis given on proper soil management and fertilizer application is far too greater to be ignored in achieving the targeted yields (Table 4).

Table 2. *Effect of N and K fertilizers on rubber yield*

Level of N	Relative yield	Treatment	Relative yield
No N	100	No K	100
Rec. N	128	Rec. K	124

Table 3. *Average quantity of recommended fertilizers for mature rubber: conventional* vs *soil and foliar survey based method*

Method	Amount (Kg/ha/yr)			
	Urea	ERP	MOP	Kieserite
Conventional	70	35	70	18
S & F based	70	-	70	-

Table 4. *Impact of soil management and fertilizer application on yield of different clones*

Clone	Yield (kg/ha/year[1])		
	Minimal inputs	Optimal inputs	Difference
PB 86	780	985	205
RRIC 100	948	1,215	267
RRIC 102	982	1,340	358
RRIC 121	877	1,155	278

[1] Yields in "panel A" with S2, d/2 tapping system

1.2 Higher returns on investment

Rubber yields could be increased by 15-20% due to fertilization. The Table 5 signifies the average net benefit of fertilizer application under different rubber prices.

The increase in yield due to fertilizer application could be a direct effect or mediated through the effect on other factors such as girthing, growth of bark, bark renewal, canopy maintenance *etc*. Thus, no single factor can stand on its own; an integrated picture of all these factors are essential to sustain an economic yield.

Table 5. *Average net benefit of fertilizer application under different rubber prices*

Rubber Price (Rs/kg)	Yield increase by fertilizer application (kg/ha/yr)	Income (Rs/ha/yr)	Fertilizer cost (Rs/ha/yr)	Net Benefit (Rs/ha/yr)
35	150	5,250	1,680	3,570
40	150	6,000	1,680	4,320
45	150	6,750	1,680	5,070

1.3 *Maintenance of girth during mature period*

Latex yield is primarily dependent on the tree girth. To attain economic yields, the general health and girthing of the tree must be maintained at a satisfactory level even during the mature period. Experimental evidence suggests that N fertilizer enhances the annual girth increment of mature rubber and thereby increase the yield levels by about 35%. Studies have also shown that there is a considerable time lag between deterioration of growth (girth increment) due to lack of fertilizers and its negative impact on yield levels.

It is possible that larger trees (as a consequence of fertilizer application, specially N and K), may have thicker bark and greater length of the tapping cut or yield more per inch of the tapping cut than the smaller trees. Moreover, the number of latex vessels, their size and starch reserves in the bark are all related to tree girth. The effect of fertilizers on girthing of mature trees is given in Tables 6 and 7 and it is clearly shown that the N and K fertilizer application is essential for maintenance of girth during mature period.

Table 6. *Fertilizers on girthing of mature rubber trees (at the end of panel B)*

Treatment	Girth* (at the end of panel B)	
	(cm)	(%)
Without fertilizer	51.0	100
With fertilizer	63.3	124

* At 5ft. above the bud union

Table 7. *NPK fertilizers on girthing of mature rubber trees (at the end of panel B)*

Treatment	Girth* (at the end of panel B)	
	(cm)	(%)
Without N fertilizer	57.0	100
With N fertilizer	63.3	111
Without P fertilizer	61.0	100
With P fertilizer	63.3	104
Without K fertilizer	51.0	100
With K fertilizer	63.3	117

* At 5ft. above the bud union

1.4 *Bark renewal*

In well maintained rubber plantings, withholding fertilizers for a year to two may not show immediate reduction or losses in yield. Yet, it is important to realize that for satisfactory bark renewal, adequate nutrition, especially N and K, are important (Table 8). For instance, when fertilizers are withheld for a year or two, the bark renewal during that period would be poorer. The adverse effect of such improper agronomic practice would be felt only when that particular portion of the poorly renewed bark is tapped some years later. Moreover, the more common condition of poor bark regeneration that is the consequences of prolonged soil deterioration is hard to correct.

Table 8. *Effect of fertilizers on bark renewal*

Treatment	Thickness of renewed bark at 3 years after tapping (mm)
Without N	5.1
With N	5.5
Without K	5.1
With K	5.4
Without Mg	5.2
With Mg	5.3

1.5 *Canopy maintenance*

The maintenance of the foliage (tree canopy) at a satisfactory level is essential in all mature rubber plantings. In fact it is the key source of dry matter production, a part of which is harvested as latex yield. The foliage of the canopy is primarily dependent on the nutrient status of the tree. Hence, there should be no delay in fertilization once the first sign of canopy deterioration appears. In view of this, it is advisable to apply an extra dose of N and K fertilizers to the fields badly affected with *Oidium* secondary leaf fall. The condition of thin canopy resulting by prolonged soil deterioration can be hard to correct.

1.6 *Replacement of nutrient removal via latex*

A certain quantity of nutrients get removed from the mature rubber lands almost every other day through the harvest (latex). However, the quantity of nutrients removed could vary from one crop to another. A comparison of nutrient outflow in major plantation crops is presented in Table 9. It is evident that the outflow of nutrients via harvest is lower in rubber plantations compared to tea, coconut and oil palm. The Table 9, further suggests that the level of fertilizer required to supplement 1000 kg of harvest removed from a plantation is much lower for mature rubber compared to tea, coconut and oil palm.

Nevertheless, the removal of nutrients is much higher when yield stimulants are applied (Table 10). This is due to the greater volume of latex being removed from the trees. Under such conditions N and K fertilizers are necessary to maintain a satisfactory nutritional status within the tree and thereby to sustain the impact of stimulation.

Table 9. *Removal of nutrients via yield by different crops*

Crop	Yield (kg/ha/yr)	Nutrient removal *via* crop (kg)							
		per ha/yr				per 1000 kg of yield			
		N	P	K	Mg	N	P	K	Mg
Rubber	1,400	9	2	8	2	6.4	1.4	5.7	1.4
Tea	1,300	60	5	30	5	46.2	3.9	23.1	3.9
Coconut	2,000	48	10	92	13	24.0	5.0	46.0	6.5
Oil palm	2,500	162	30	217	30	64.8	12.0	86.8	12.0

Table 10. *Effect of stimulation on removal of nutrients* via *latex*

Situation	Nutrients removed (kg/ha)			
	N	P	K	Mg
Without stimulation	9	2	8	2
With stimulation	24	7	22	4

2. The present fertilizer recommendation

It is only a "maintenance" dressing that has been recommended for rubber during its mature stage (up to five years before uprooting). Accordingly, the recommended fertilizer levels of N, P, K and Mg are much lower for rubber compared to tea and coconut (Table 11). The present fertilizer recommendation for mature rubber is based basically on its nutrient status (site specific fertilizer recommendation based on soil and foliar analysis). The important parameters that should be taken in to consideration in the process of fertilizer application for mature rubber are; quantity (rate), source of fertilizers, time of application, method of application and the optimum time to discontinue fertilizer application prior to uprooting.

Table 11. *Recommended nutrient levels for some plantation crops during mature period*

Crop	Yield (Kg/ha/yr)	Amount of nutrients (Kg/ha/yr)			
		N	P	K	Mg
Rubber	1,400	32	4	35	3
Tea	1,300	160	12	67	5
Coconut	2,000	55	11	120	22

2.1 *Quantity/Rate - Site specific fertilizer recommendation*

Fertilizer inputs are further optimized in mature rubber plantings with the aid of soil and foliar analysis based discriminatory fertilizer recommendation procedure. The concept of discriminatory fertilizer recommendation envisages supply of adequate quantity of nutrients to rubber plants taking into consideration the nutrient reserves and the available nutrient content in the soil, plant nutrient status, site characteristics and other specific parameters. This practice has been widely accepted and extensively used as the basis for formulating site specific fertilizer recommendations for mature rubber. Under this site specific fertilizer recommendation programme implemented by the RRI each estate is surveyed once in every 3 years and only the required fertilizer quantities are recommended for each field accordingly. The Table 12, (compiled by using soil and foliar survey data of last 20 years) and Fig.2 indicate the advantage of using soil and foliar survey based fertilizer recommendations compared to the conventional (general) recommendation of a blanket application.

2.2 *Sources of fertilizer*

Fertilizer cost can be minimized and fertilizer use efficiency can be improved by proper selection of the source of straight fertilizer. Two types of nitrogenous fertilizers are used for rubber in Sri Lanka *i.e.* Urea and Sulphate of Ammonia (SA).

Urea has been subsidized by the Government of Sri Lanka according to the revised fertilizer subsidy scheme. As a result, the cost of a unit N in the form of urea has become much cheaper compared to a unit N in the form of SA (Table 13). Eppawela Rock Phosphate (ERP) being the cheaper source compared to Imported Rock Phosphate (IRP), ERP can be considered to be more cost effective when used during the mature period. During the mature period of rubber, application of Dolomite is not recommended in order to avoid pre-coagulation of latex due to high Ca content in the Dolomite ($CaCO_3.MgCO_3$) which contains 12% Mg and 22% Ca, despite its cheapness compared to the other source of Mg, kieserite (Table 14).

Table 12. *Recommended quantity of Fertilizers during mature stage (Conventional vs S and F survey based method)*

Stage of Maturity	Amount (kg/ha)		
	Conventional	S & F based (Average)	
(1)	(2)	(3)	[(3)/(2) x 100]
A + B Panel	4,200	1,680	40%
C Panel	1,470	630	43%

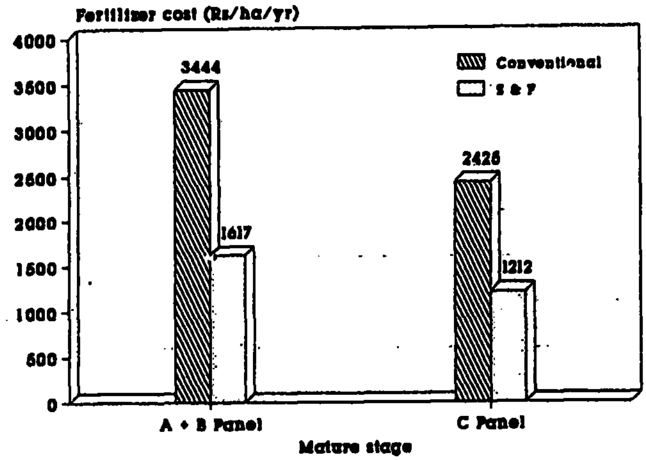

Fig. 2. Average cost of fertilizers during mature period (Conventional vs Soil and Foliar survey based method)

Table 13. *Cost of a unit N in urea and SA*

Source of fertilizer	Cost of a unit N (Rs/kg)
Urea	13.50
Sulphate of ammonia	48.60

Table 14. *Effect of different sources of Mg fertilizer on yield of rubber*

Treatment	Yield		Relative yield (%)
	(g/tree/tapping)	(kg/ha/yr)	
Kieserite	19.61	1,235	100
Dolomite	18.28	1,152	93

2.3 *Time of application*

In mature rubber plantings, the leaves are shed once a year, in January/February period. Thus, the active stage of leaf growth is immediately after the defoliation. It is clearly demonstrated that the uptake of nutrients by rubber trees is most active at the commencement of refoliation and up to four to five months thereafter. It is evident that protein synthesis and accumulation is observed only up to four to five months after refoliation. Thus, if wintering commences in January/February, nutrient uptake by the trees would be efficient till June/July; thereafter, the efficiency decreases rapidly until it is reduced to nil. Hence, fertilizers must be applied within three to four months from the commencement of refoliation to ensure its efficient utilization.

2.4 *Method of application*

The correct method of fertilizer placement is an essential pre-requisite for the economic use of fertilizer. It is observed that the active roots of mature rubber trees are concentrated at a depth of 15 cm and at a lateral distance of 75-100 cm from the tree. It is therefore possible to obtain better utilization of the added fertilizer by placing at such areas. A comparison between application of urea by forking-in and broadcasting indicated that forking-in gives higher yield which amounts to a 7% increase as compared to broadcasting (Table 15).

Table 15. *Effect of broadcasting urea fertilizers on yield of rubber*

Treatment	Yield		Relative yield (%)
	(g/tree/tapping)	(kg/ha/yr)	
Urea-forked in	18.9	1,189	100
Urea-broadcast	17.5	1,106	93

2.5 *Discontinuation of fertilizer application five years before uprooting*

Discontinuation of fertilizer application at a later stage of the cycle, probably in the D panel and later is recommended. Adequate fertilization coupled with other agronomic practices, during the early immature period, provides a continuous and steady supply of nutrients. This followed by more N and K fertilizers during the early mature phase enable a steady build up of nutrient reserves within the whole tree system. This possibly sustains the nutrient needs of mature trees during the later stages.

3. Other factors to be considered in fertilizer application for mature rubber

Some of the indirect factors to be considered in fertilizer application for mature rubber are; soil management practices adopted during immature period, use of yield stimulants, the time lag required for respond to fertilizer application and situations of low rubber prices.

3.1 *Soil management practices during immature period*

If proper initial soil management practices are adopted, especially with respect to application of optimum nutrients, ground cover management and mulching during the pre-tapping phase, it is concluded that fertilizer use during mature stage could be minimized to a great extent.

3.1.1 *Fertilizer application*

In general the leaf N, P, K and Mg contents are significantly higher in fields received optimum nutrition during the immature period. As a result, less quantities of nutrients (inorganic fertilizers) are recommended for such mature rubber fields on the basis of soil and foliar survey. The economic benefit that could be derived due to cut down in inorganic fertilizers on these well managed fields for the first 8 years of mature stage compared to fields with improper fertilization during immature period is given in Table 16.

Table 16. *Effect of fertilizer application during immature period on savings on inorganic fertilizers up to 8th year of maturity*

Practice during immature period	Total fertilizer cost up to 8th year of maturity* (Rs/ha)
Inadequate dose of fertilizer	40,760
Recommended dose of fertilizer	14,100
Saving	26,660

* Based on a survey, 1995

3.1.2 *Cover management*

It has shown that cover management is a cost-effective agronomic practice in obtaining a much higher yield during the exploitation of virgin panels and the increase in yield is estimated in the region of 30%. The Table 17 clearly indicates the contribution made towards cut down in fertilizers and the saving on fertilizer during the first 8 years of maturity.

Table 17. *Effect of cover management during immature period on savings on inorganic fertilizers up to 8th year of maturity*

Practice during immature period	Total fertilizer cost up to 8th year of maturity* (Rs/ha)
Without legume covers	23,850
With legume covers	12,250
Saving	11,600

* Based on a survey, 1995

3.1.3 *Mulching*

Residual effect of mulching around the base of the rubber plants during immature period on leaf N, P, K and Mg also indicates an increase compared to conventional growing of legumes only (Table 18). It further indicates the savings on fertilizer that could be obtained due to cut down in fertilizers during the first 8 years of mature stage.

Table 18. *Effect of mulching during immature period on savings on inorganic fertilizers up to 8th year of maturity*

Year	Recommended fertilizers (g/plant)		Cost of fertilizers (Rs/ha)		Savings on fertilizers (Rs/ha)
	Legumes	Mulch	Legume	Mulch	
1.	1100g 12:14:14 mix.+ 250g Dolomite	200g urea+ 200g MOP + 150g ERP	3,945	1,912	2,033
2.	200g Urea+ 200g MOP	125g urea+ 125g MOP	1,741	1,088	653
3.	200g urea+ 200g MOP	200g urea+ 125g MOP	1,741	1,420	321
4.	125g urea+ 200g MOP	125g urea+ 125g MOP	1,409	1,088	321
5.	200g urea+ 200g MOP	125g urea+ 125g MOP	1,741	1,088	653
6.	125g urea+ 200g MOP	125g urea+ 125g MOP	1,409	1,088	321
7.	200g urea+ 200g MOP	125g urea+ 125g MOP	1,741	1,088	653
8.	125g urea+ 200g MOP	125g urea+ 125g MOP	1,409	1,088	321
				Total	5,276

MOP - Muriate of potash ERP - Eppawela rock phosphate

3.2 *Use of yield stimulants*

It is evident that with application of yield stimulants, significantly large yield increases can be obtained mainly due to the greater volume of latex being removed from rubber trees. Under such conditions N and K are drained in large amounts, while P and Mg are lost in relatively smaller amounts (Table 10). Hence, it is recommended that an extra 25% of N and K fertilizers for stimulated rubber trees, where enhanced latex yield is obtained.

3.3 *Time lag required for respond to fertilizer application*

Experimental data has confirmed that, even though the leaf nutrient status of mature rubber responded quickly, the effects on yield took a longer time to respond. If manuring is stopped, a gradual drop in yield will commence although the effect may not be apparent immediately. It has shown that the yield response becomes evident only at 3-6 years after commencement of fertilization. It is noted that, bark, green twigs and roots as points in the rubber tree to which nutrients move during senescence, to be used at the time of the succeeding refoliation.

It is also identified the capacity of such tissues of storage as sufficient to sustain 2-3 years of refoliation, without any benefits from added fertilizers and so accounts for the long lapse that normally occurs between the application of fertilizers and the response in terms of latex yield.

3.4 ***Low rubber prices***

During periods of recession and/or low rubber prices, rubber growers generally cutback on input costs and savings is commonly ensured by abandoning fertilizer usage. While this appears to be a short-term solution, technical findings from long term research trials indicate that it often can be a short sighted policy leading over the long term to diminishing returns. Available information indicates the need to at least replace the easily drained nutrients of N and K and to maintain a satisfactory balance between nutrients. A re-examination of all relevant agronomic data, such as; results from fertilizer experiments, past soil and leaf analysis data, previous management history etc. is a better approach in computing the minimum fertilizer requirements during a crisis situation rather than the total omission of fertilizer application for a year or a cutdown of fertilizer application by an arbitrary percentage. Accordingly, a complete stoppage or reduction in fertilizer quantities by an arbitrary percentage could result in decline in yields after a period of 3-10 years. It should also be kept in mind under such conditions it may not be possible to increase the yield levels within a short period of time even with a higher dosage of fertilizers (when the rubber prices become attractive) because of the time lag required for respond to added fertilizer.