

Nutritional status of rubber growing soils in the Moneragala district

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Abstract

Rubber cultivation is being expanded extensively into non traditional rubber growing areas such as Moneragala district in the intermediate zone of Sri Lanka. This study determines the nutritional status of these soils for the growth of rubber [Hevea brasiliensis (A. Juss.) Muell. Arg.] and the degree of nutrient variability. Soil samples were collected from the surface layers (0 – 0.3 m) and the availability of N, P, K, and Mg status and the urease activity were determined. Leaf N, P, K, and Mg status in samples collected from Kalutara, Kegalle and Moneragala regions, were also determined to compare the nutritional status of the plants among regions. Soils in the Moneragala region exhibited a very high variability with regard to exchangeable K (23 – 273 ppm) and exchangeable Mg (15 – 346 ppm) contents. The urease activity of the soils was very low (7 μg of $\text{NH}_4^+\text{-N}$ released $\text{g}^{-1} \text{hr}^{-1}$) compared to traditional rubber growing areas. This highlights the need to evaluate the agronomic effectiveness of urea as the N fertilizer in rubber growing soils in this region. Leaf N levels in the Moneragala region was significantly low but leaf Mg levels in all regions were in the high range. The fertilizer requirement of rubber plants could be highly site-specific in this region and therefore the currently used low K fertilizer mixture with a Mg source may not be equally effective in all parts of the region.

Key words: intermediate zone, Moneragala, nutrients, rubber growing soils, urease activity

Introduction

Rubber cultivation is being promoted in non traditional areas in the intermediate zone of Sri Lanka (e.g. Moneragala district) to increase the rubber production in Sri Lanka, to increase the forest cover in the region and also to improve the social status of the poor in these areas. Although it is

known that rubber plant can be grown in the intermediate zone of the Moneragala district, various aspects on efficient resource management to obtain the maximum economic benefits is yet to be studied in detail. One important input often been used in rubber plantations to increase the growth and yields of rubber is application of inorganic fertilizers.

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Incorrect fertilizer use not only leads to poor crop growth and lower yields, but also could be a threat to the environment. Therefore, there is an urgent need to evaluate the fertilizer requirement of rubber grown in the Moneragala district in order to identify ways and means to increase the fertilizer use efficiency and to minimize the environmental pollution in the region.

Rubber growing soils in the traditional areas have been evaluated for their nutritional status and it is imperative that the application of N, P, K and Mg in correct proportions is essential to obtain optimum yields in these areas. Therefore, different fertilizer mixtures have been formulated for the three broad soil groups in the traditional rubber growing areas (Silva, 1971). Such studies have so far not been conducted for the rubber grown in the Moneragala region. Therefore, fertilizer mixtures formulated for rubber growing soils in the Low country Wet zone (traditional areas) are being applied by the rubber growers in the Moneragala district. Mostly, a urea based NPK fertilizer mixture (R/U/12:14:14) is used in this region with a Mg fertilizer at rates applied to the traditional rubber growing soils.

Rocks from which soils in the Moneragala district has been derived, and their mineralogy are different from that in the traditional rubber growing areas Cooray (1967). Apart from this soil forming factors such as climate and vegetation are also different in the

Moneragala region. This could lead to the formation of different soils in this region. Studying Wet zone and Intermediate zone soils of Sri Lanka, Mapa *et al.* (1999 and 2005) have classified soils in the Moneragala region into completely different soil series that are having different chemical and physical properties. Therefore, it could be hypothesized that the availability and the requirement of nutrient for *Hevea* is different under the eco-physiological situations in Moneragala.

Therefore, the objectives of this study were 1). to determine the nutrient status of the rubber growing soils in the intermediate zone of the Moneragala district and to compare it with traditional rubber growing soils 2). to determine the degree of variation in the nutritional status of these soils in order to evaluate the current practice of using a single fertilizer mixture for the entire Moneragala region.

Materials and Methods

The study was conducted in 1995 in the intermediate zone of the Moneragala district. Efforts were taken to collect soils samples from the existing rubber growing fields as much as possible while covering the entire intermediate zone of the Moneragala district (Fig. 1). Soil samples were collected from two depths (0-0.15 m and 0.15-0.30 m) and at the centre of four rubber plants, where applicable. Samples were air-dried and brought to the laboratory for analyses.

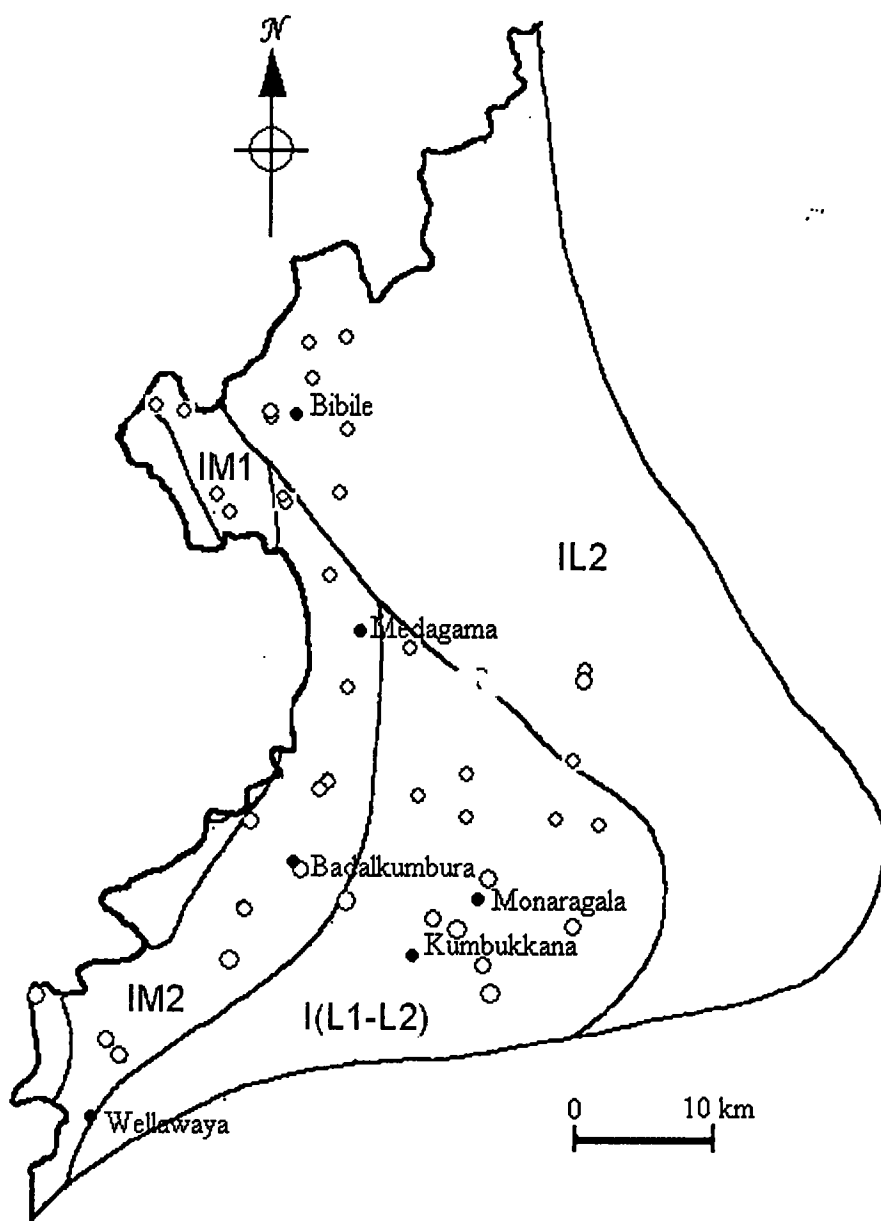


Fig. 1. Map of Moneragala district Intermediate zone showing the approximate distribution of soil sampling points (o) and major agroecological regions

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Soil analyses:

Soil samples were characterized for the basic soil properties and nutrient contents. The pH (1:2 CaCl₂), organic C (Walkley, 1947), texture (Day, 1965) were determined as the basic soil properties. Nutritional status of the soils was characterized by determining total N by Se/H₂SO₄ digestion, available P by NH₄F/HCl extraction, and exchangeable K and Mg by ammonium acetate extraction. Nitrogen and P contents in the extractions were determined colorimetrically using a Technicon II auto analyzer whereas K and Mg in the extractions were determined using a GBC atomic absorption spectrophotometer. These methods have been described in detail by Yapa (1983) and Jayasundara (1984). In addition, the urease activity was also determined by a non buffer method (Zantua & Bremner, 1975) as modified by Dharmakeerthi *et al.* (1997).

Leaf analyses:

In order to compare the nutritional status of plants grown in different regions, leaf samples were collected from the clone PB 86 grown in Kalutara, Kegalle and Moneragala regions. Eight fields in each region, established in 1986 or 1987, were sampled. In order to represent the soil surveyed area in the Moneragala district, leaf samples were collected from small holder fields whereas leaf samples from the Kalutara and Kegalle regions were collected from commercial plantations. Leaf sampling was done

according to the procedures described by Yogaratnam (1984). After a Kjeldhal digestion procedure, the nutrient contents in the extractions were determined using a Technicon II auto analyzer (N, P and K) or GBC atomic absorption spectrophotometer (Mg).

Statistical procedure:

Simple statistics of the soil analyses were conducted through SAS statistical package (SAS Institute Inc., 1996). Soil nutrient levels in the intermediate zone of the Moneragala district were compared with those in the traditional rubber growing areas using available literature. ANOVA was conducted for the data from leaf analysis to identify the differences among different soil groups using SAS statistical package (SAS Institute Inc., 1996).

Results and Discussion

Basic soil properties

As expected, pH, OC and available nutrient contents were all lower in the 0.15 – 0.30 m depth compared to those in the 0 – 0.15 m depth. However, for the purpose of comparison of these values with those available in the literature, all values were expressed for the 0 – 0.30 m depth by taking the averages of two depths (Table 1). The pH and sand content had a low variation (CV <15%) whereas clay, silt and OC contents showed a medium variation (CV 15-50%) according to the guidelines provided by the Warrick (1998). All these properties

Table 1. Simple statistics of some basic soil properties in the surface (0 - 0.30m) horizon of the soils in Moneragala

Property	n	Mean	Min	Max	CV %	Skewness	Kurtosis	P value of Shapiro-Wilk's W test
pH 1:2 CaCl ₂	42	5.8	5.1	6.6	5	-0.190	0.569	0.444
Sand (%)	42	78.3	69.5	86.4	6	0.023	-0.662	0.512
Silt (%)	42	7.3	0.0	15.6	49	0.474	0.579	0.057
Clay (%)	42	14.5	10.6	21.8	16	0.810	1.536	0.098
OC (%)	42	0.9	0.4	1.5	29	0.310	-0.180	0.912

were normally distributed ($p < 0.05$) as indicated by the Shapiro-Wilk's W test. Clay content data showed a slight peakedness as indicated by the kurtosis value.

Soils in the Intermediate zone one are not intensively weathered and not subjected to extreme leaching environments as the Wet zone soils. As a result, these soils are not strongly acidic in reaction as is the case in the wet zone soils. The pH in the studied soils has ranged from 5.1 to 6.6. Soils in the traditional rubber growing areas are strongly acidic to moderately acidic (4.5 to 6.0) which is ideal for the growth of rubber. Therefore, soils with slightly acidic pH (6.0 to 6.6) could impose a problem on micro nutrient availability if the micronutrient levels are low in these soils. Organic C levels ranged from 0.4 to 1.5% in these soils indicating a low soil fertility conditions. We observed the soils with eroded surface horizons had the lowest OC levels and these soils were found in the ridge and valley landform in the mid country intermediate zone (Fig. 1). The surface

layer of these soils were partially or almost completely eroded leaving only a thin layer of surface soils containing high percentage of decomposing rock fragments. Texture varied from loamy sand to sandy clay loam where clay content ranged from 11 to 22%.

Nutrient availability

Total N and available P showed a medium variation where as all other nutrients had a high variability (CV > 50%). Available P and exchangeable K values were not normally distributed ($p < 0.05$) and skewed to the right. Exchangeable K values additionally showed a peakedness (Table 2). The distribution of these data within the Moneragala district was studied and then the mean values were compared with those available in the literature for the traditional rubber growing areas (Table 3). Traditional rubber growing soils have been categorized to three broad groups for the fertilizer recommendation purposes based on the differences in the K and Mg status in the soil (Silva, 1971). According to him,

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Table 2. Simple statistics of the nutritional status of some important macro nutrients and urease activity in the surface (0 -0.30m) horizon of the soils in Moneragala.

Property	n	Mean	Min	Max	CV %	Skewness	Kurtosis	P value of Shapiro-Wilk's W test
Total N (%)	42	0.168	0.1	0.3	21	0.290	0.017	0.476
Available P (ppm)	42	23.1	15.9	38.6	18	1.505	3.572	0.001
Exchangeable K (ppm)	42	107.5	23.3	273.1	50	1.003	0.896	0.010
Exchangeable Mg (ppm)	42	128.7	15.2	346.2	57	0.840	0.746	0.065
Urease activity ($\mu\text{g NH}_4^+\text{-N released g}^{-1}\text{ h}^{-1}$)	42	7.3	0.0	18.1	58	0.464	-0.202	0.558

Parambe series soils contain high K levels compared to all other rubber growing soils and therefore require low K fertilizer mixtures. Matale series soils have very high Mg levels and therefore Mg fertilizers are not being applied to these soils.

Total N values ranged from 0.10 to 0.25 % with a mean of 0.17 % and this is higher than the values in the traditional rubber growing areas in the wet zone of Sri Lanka but comparable to the values in the Matale series soils in the intermediate zone of Sri Lanka (Silva, 1971). Samarappuli & Yogaratnam (1995) observed comparable total N values (0.18 %) in a rubber plantation with well established leguminous cover crop. Although higher total N values could benefit the rubber plants grown in Moneragala soils, it

depends on the synchrony between the rate of N released from the decomposition of soil organic matter and the rate of plant N uptake under the dryer climatic conditions.

Phosphorus is one of the most limiting nutrients in tropical soils due to low P contents and high P sorption capacities in these soils. Available P content in the Moneragala soils ranged from 16 to 39 ppm and was comparable to the values recorded for the Agalawatta series soils (Yogaratnam *et al.*, 1984, Kumaragamage *et al.*, 1999). Dissanayake *et al.* (1992) observed that rubber plants have positively responded to P application both in a wet zone soil (Boralu series) and an intermediate zone soil (Matale series). However, both of these soils have low available P content compared to that in the Moneragala

Table 3. Comparison of the mean nutritional status of rubber growing soils in the Moneragala district with the those in the traditional rubber growing soils

Soil series	Total N [†] (%)	Available P [†] (ppm)		Exchangeable K [†] (ppm)		Exchangeable Mg [†] (ppm)		Urease activity [†] ($\mu\text{g NH}_4^+\text{-N released g}^{-1}$ of soil hr ⁻¹)
Boralu	0.060 ^A	7.7 ^B	15 ^D	18 ^B	40 ^D	79 ^A	17 ^D	83 ^C
Parambe	0.076 ^A	2.0 ^B		94 ^B		250 ^A		48 ^C
Mawanella			2.5 ^D		240 ^D		79 ^D	
Matale	0.138 ^A		2.5 ^D		99 ^D	439 ^A	322 ^D	120 ^C
Agalawatta	0.104 ^A	23.5 ^B	27.5 ^D	24 ^B	40 ^D	24 ^A	8 ^D	82 ^C
Homagama	0.098 ^A	9.5 ^B	2.5 ^D	31 ^B	25 ^D	76 ^A	34 ^D	81 ^C
Rathnapura	0.060 ^A							88 ^C
Weddagala			2.5 ^E		70 ^D		22 ^D	
Moneragala [§]	0.168 ^E	23.1 ^E		108 ^E		129 ^E		7 ^E

[†] - sources: ^A Silva , 1971; ^B Yogaratnam *et al.*, 1984; ^C Dharmakeerthi *et al.*, 1997; ^D Kumaragamage *et al.*, 1999; ^E This study

[§] - Moneragala soils should contain many soil series (Mapa *et al.*, 2005)

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soils. Yogaratnam *et al.* (1984) observed that immature rubber plants grown in Agalawatta series soils, where the available P content is comparable to Moneragala soils, also have responded with improved growth to P fertilizer application. Although, it is likely that rubber grown in the Moneragala region would benefit from P fertilizer application, differences in P fixation capacities need to be considered in determining the optimum rates.

Exchangeable K values in Moneragala ranged from 23 to 273 ppm with a mean of 107 ppm. The mean value was comparable to that of a Parambe series soils observed by Yogaratnam *et al.* (1984). Parambe series soils have been categorized as a high K soil in the traditional rubber growing areas (Silva, 1971). Majority of these soils exhibit a higher K status than group III soils (low K) in the traditional rubber growing areas; *e.g.* Boralu, Homagama and Agalawatta series soils (Kumaragamage *et al.*, 1999). However, we observed a very high variation in the exchangeable K values in this region which could be attributable to the presence of different soil series in this region (Mapa *et al.*, 2005). Therefore it may be necessary to demarcate areas with very high K status from the others for efficient nutrient management strategies. Soil samples collected from the IM2 zone (especially in Hingurukaduwa, Ranugalla, Randeniya and Karandagama area) and some soils in the IL2 zone, especially around southern and eastern borders of the Moneragala hills (*i.e.* Hulandawa south,

Kiwuleara and Kolonwinna area) and areas around Bibile (*e.g.* Bokagonna, Kindagolla, Kotagama and Ykunnawa area) recorded high K values. In traditional areas, plants grown in low and high K soils have responded differently to K fertilizer application where growth increase is higher in low K soils (Yogaratnam *et al.*, 1984). Therefore, for high K soils in the Moneragala region, a relatively low K mixture appears to be more effective both economically and agronomically.

Exchangeable Mg content in these soils varied from 15 to 346 ppm with a mean of 129 ppm. The mean exchangeable Mg value is significantly higher than Boralu, Homagama and Agalawatta series soils but comparable to Mawanella series soils in the traditional rubber growing areas (Kumaragamage *et al.*, 1999). The Mawanella series soils are similar to Parambe series soils classified by Silva *et al.* (1969). We observed that soils collected from the IM2 zone (especially in Ranugalla, Gamewela, Ambalanpotha and Karandagama area) and some soils in the IL2 zone, especially around northern and eastern borders of the Moneragala hills (*i.e.* Ihawa, Thampalawela, Ambalanda and Inawellegama area) had the highest Mg levels. Application of Mg fertilizers to high Mg soils could lead to lower yields (Yogaratnam *et al.*, 1984), due to antagonistic effects with K, and therefore the effectiveness of Mg fertilizers in this region need to be evaluated.

Urease activity

Urea based fertilizer mixtures are being used by the rubber growers in this region. The efficiency of urea as a N fertilizer depends on the ability of a soil to convert it to plant available forms NH_4^+ or NO_3^- . Conversion of urea to NH_4^+ is governed by the level of urease activity in the soil (Dharmakeerthi¹ & Thenabadu, 1996). Urease activity in these soils showed a high variability (CV 58%) and ranged from 0 to 18.1 g NH_4^+ -N released g^{-1} hr^{-1} (Table 2). These values are lower than the lowest values observed in the traditional rubber growing areas in Sri Lanka (Table 3) but comparable with values reported for rubber growing soils in Malaysia (Tan, 1982). Yogaratnam & Perera (1981) speculated that the higher urease activity in traditional rubber growing areas could in part be due to continuous use of urea as a N fertilizer which in turn have resulted a proliferation of microorganisms responsible for the release of urease enzyme.

Lower urease activity indicates that the amount of urea need to saturate the urease enzyme is also expected to be low. Therefore, Tan (1982) cautioned that one should avoid application of a high rate of urea at one time to soils with low urease activity as there is a possibility of leaching of unhydrolyzed urea down to lower depths or washed away, especially if heavy torrential rain falls soon after fertilizer application. The pH of some soils in this region is slightly higher than that in the traditional rubber growing areas. During

the urea hydrolysis process the pH in the soil could increase even further. Although this increase is temporary, the risk of N loss through ammonia volatilization is greater especially in the high pH soils (Dharmakeerthi & Thenabadu, 1996). These possibilities can result in lower efficiency in urea application. Therefore, deep placement of urea in these soils is essential to increase the fertilizer use efficiency of urea, as practiced in the traditional rubber growing areas. These findings indicate the need to evaluate the agronomic effectiveness as well as the environmental concerns of different N fertilizers when used in rubber growing soils in the Moneragala District.

Plant nutrient status

Fields in the Moneragala district had been managed by small holders who apply little inorganic fertilizers after first five years, with the termination of subsidy scheme. Farmers in leaf sample collected fields indicated a minimum N, P and K application during the mature phase. Further, a Mg source had never been applied during this period. Therefore these plants had received very little amount of fertilizer during the last five years. On the other hand leaf sample collected fields from the traditional rubber growing areas were from commercial plantations where RRISL recommended fertilizer application had been carried out during the preceding five years. Therefore one should expect lower leaf nutrient levels in Moneragala region.

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Nutrient status of leaf samples collected from three regions showed some significant differences (Table 4). As discussed earlier the nutrient availability in these soils is either comparable or higher than those in the traditional areas. Leaf N levels were significantly lower in Moneragala than that in the traditional areas. According to the guidelines given by Yogaratnam & Silva (1977), leaf N values in Moneragala were in the very low range whereas those in traditional areas were in the low to medium range. Even though the total N values in Moneragala soils were higher than in Kalutara or Kegalle soils (Table 3), minimum input situation could have resulted lower leaf N values in Moneragala. Even when fertilizer is applied, a urea based mixture had been used by these farmers. Low urease activity and the higher propensity for volatilization loss of ammonia in these soils could also be responsible for the lower leaf N values in the Moneragala region.

Leaf P levels were in the medium to high range in Moneragala, medium to very high in Kegalle region, and low to medium in Kalutara region. However, these differences were not statistically significant. Silva (1971)

also observed no difference in leaf P contents among Parambe, Boralu and Agalawatta series although there were some differences in the soil P availability.

Even though the leaf K values in Moneragala region is slightly lower than that in Kegalle region, that difference was not statistically significant. Soil K levels is high in Kegalle region and therefore a low K fertilizer mixture has been recommended for this region (Silva, 1971). The exchangeable K values in some regions in Moneragala are comparable to that in Parambe series soils. Therefore, one could hypothesize that a low K mixture is more efficient in these areas. However, as the higher leaf K levels helps to counter moisture stress situations (Samarappuli *et al*, 1993) in dryer areas like Moneragala, plant K requirement could be high in the Moneragala region. On the other hand the leaf K status in Moneragala was in the very low range. Therefore, high K mixtures could continue to be used in this region until the use of a different K level is substantiated through experimental evidence using different clones suitable for this region.

Table 4. Comparison of the leaf nutrient status of PB 86 clone in three rubber growing regions

Region	N [†]	P [†]	K [†]	Mg [†]
	%			
Moneragala	2.40 ^B	0.233 ^A	1.08 ^A	0.25 ^A
Kegalle	3.16 ^A	0.251 ^A	1.22 ^A	0.27 ^A
Kalutara	3.06 ^A	0.215 ^A	0.87 ^B	0.28 ^A

[†] values with the same superscript within a column are not significantly different at p < 0.05.

Leaf Mg levels are not significantly different among regions and these values were in the medium to very high range (Yogarathnam & Silva, 1977). It is interesting to note that the plants grown in the Moneragala region is capable of maintaining a high leaf Mg levels even without applying any Mg fertilizer during the preceding five years. The mean exchangeable Mg levels in Moneragala soils is higher than that in other two regions and slightly lower than Matale series soils (Table 3) where a Mg fertilizer has not been recommended for plants grown in the Matale region. Yogarathnam *et al.* (1984) observed that increasing soil Mg levels by applying higher rates of Mg could lead to yield decrease in soils where the leaf Mg content is maintained over 0.25% without the application of a Mg fertilizer. Moreover, Weerasooriya & Yogarathnam (1987) have observed that application of higher levels of Mg could lead to lower the leaf K levels which could in turn result poor moisture stress tolerance by the plant. This analysis suggests that application of Mg fertilizer for rubber plants grown in the Moneragala region could be reduced from the currently applied levels.

Conclusions

Moneragala is a relatively dryer area than other traditional rubber growing areas. Therefore, the rates of plant growth as well as the nutrient requirement are expected to be different under the agro-ecological situations in the Moneragala region. Soil pH in this region is slightly higher than in

traditional rubber growing soils and availability of some essential macro nutrients is also different. Total N content in these soils is higher than in traditional rubber growing soils but the urease activity is very low. Therefore, the agronomic effectiveness of different N fertilizers in the Moneragala region needs to be determined. The mean exchangeable K and Mg values in Moneragala soils are high but there is a considerable variation among sites as well. Leaf Mg levels in the mature plants exhibited a high value even with minimum or no Mg application during preceding five years. Therefore, either K requirement or Mg requirement or both appears to be highly site specific in this region. This study highlights the necessity of careful investigation of N, P, K and Mg fertilizer requirement under different sites in the Moneragala region using clones recommended for dryer areas in order to increase the fertilizer use efficiency while minimizing the environmental pollution.

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