LEAF NUTRIENT STATUS OF THE RUBBER PLANTATIONS OF SOUTH INDIA

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Received: 04 September 2018 Accepted: 08 October 2018

Joseph, M., Chandy, B. and Aneesh, P. (2018). Leaf nutrient status of the rubber plantations of South India. *Rubber Science*, **31**(3): 217-226.

Leaf is a metabolically active part of any plant and its chemical composition is a good guide to the plants' nutritional status. Leaf nutrient status of mature rubber plantations in the estate sector of South India was assessed in a uniform population for the nutrients N, P, K, Ca and Mg. Less than three per cent of the population alone expressed low values for N and P. Six per cent of the population expressed low values for K and 11.0 per cent of the population recorded low values for Mg. However, 30 per cent of the population recorded Ca values lower than the critical level indicating the necessity of supplementation of Ca along with N, P, K and Mg. Among the five nutrients studied, the coefficient of variation was high for K, Ca and Mg. Though a negative correlation was observed between P and Ca concentration with yield, the regression coefficient was too small as expected, as the yield is influenced by many factors and the tree nutritional status in totality with optimum balance among the nutrients, is influencing the yield. Significant interrelationship among the nutrients was recorded in correlation studies.

Key words: Dry rubber yield, Foliar diagnosis, *Hevea brasiliensis*, Leaf analysis, Rubber plantations

INTRODUCTION

Nutrient concentration in leaves of a plant is influenced by various factors like soil, climate, management practices, physiology, nutrition, genotype and root system. Leaf is metabolically active part of any plant and its composition is a good guide to the plants' nutritional status (Martin-Prevel *et al*., 1987). Foliar analysis is widely practiced in rubber for assessing fertilizer requirement in conjunction with soil analysis. Sampling techniques (Shorrocks, 1962) and interpretation of the data in relation to plant characteristics and growing conditions are well established (Shorrocks, 1965a; 1965b; Pushparajah and Guha, 1968; Guha and Narayanan, 1969; Pushparajah and Tan, 1972). Sufficiency range ratings for individual nutrients are being followed for diagnosis of sufficiency or deficiency of nutrients (Karthikakuttyamma *et al*., 2000). The diagnosis and recommendation integrated system (DRIS) norms for the nutrients nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (Joseph *et al*., 1993) and the critical levels for the nutrients N, P, K, Ca and Mg (Joseph and Ranganathan, 1996) are also available for assessing the nutritional status.

Rubber growing soils of South India are highly weathered red ferruginous soils rich in iron and aluminium oxides and hydrous oxides and kaolinite clay and belong to the three orders *viz*. Ultisols, Inceptisols and Entisols of which major share belong to

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Ultisols (NBSS & LUP, 1999). These are moderately deep to very deep soils and are acidic with pH ranging from extremely acidic (<4.5) to moderately acidic (5.1-5.5), medium to high in organic carbon, deficient in P, low to medium in K, low in cation exchange capacity and poor in base status (Joseph *et al*., 1990; Karthikakuttyamma *et al*., 1998; NBSS & LUP, 1999; Krishnakumar *et al*., 2003; Joseph, 2016). The average annual rainfall in this traditional belt of rubber cultivation ranges from 2000 to nearly 5000 mm and the dry period ranges from three to five months. The base saturation per cent and exchangeable bases showed wide variation with variations in average annual rainfall. Soils of the high rainfall areas showed very low base saturation with extremely low status of K, Ca and Mg (Joseph, 2011).

Of the total area under rubber cultivation in India, around nine per cent is in the large plantation sector or the estate sector (Rubber Board, 2017). Rubber plantations in the estate sector are managed scientifically following good agricultural practices including soil and leaf analysis based site-specific fertilizer applications. Owing to the general characteristics of the rubber growing soils and the complexities of the nutrient dynamics in this perennial crop system, it was felt that an assessment of the leaf nutritional status of the rubber plantations will provide a better understanding of the nutrient availability to the trees. Hence, the study was undertaken with the objective of assessing the leaf nutrient status of the rubber plantations of South India.

MATERIALS AND METHODS

A data bank of 1500 recordings on nutrient concentration of index leaf for N, P, K, Ca and Mg of individual fields from 12 large estates representing the traditional rubber growing tract of South India was established. The leaf samples collected as per the standard procedure outlined by Shorrocks (1962) were processed, powdered and total concentration of N, P, K, Ca and Mg were estimated as per Piper (1942). Nitrogen was estimated by micro-Kjeldhal digestion and distillation using N analyzer. Phosphorus and K concentrations were measured by an Autoanalyzer (Bran+Lubbe, UK), and Ca and Mg by Atomic Absorption Spectrophotometer (GBC Avanta, Australia). The population of 1500 individual fields was regrouped on the basis of age and system of tapping and a population of 327 fields having uniform age (10 to 18 years old) and following S/2 d2 system of tapping were selected and the yield data for the individual fields were processed and expressed as kg $tree^{-1}$ $year^{-1}$.

For the uniform population, the values for individual nutrients were grouped into low, medium and high category based on the sufficiency range ratings (Karthikakuttyamma *et al*., 2000). The range and mean value of the nutrients as well as the frequency distribution of the population in the low, medium and high status for the nutrients were calculated. Correlations between individual nutrients and yield and correlation among the nutrients were also calculated. Variance ratio between the low yielding and high yielding population for individual nutrients was calculated (Gomez and Gomez, 1976). Similarly, the initial population of 1500 individual fields was regrouped into different age classes *viz*. less than seven, 7-11, 12-16, 17-21, 22-26 and above 26 years of age. The range and mean value of the nutrients in the different age groups were calculated.

RESULTS AND DISCUSSION

The 12 large plantations from where the data gathered were managed scientifically following the agro management practices including site specific nutrient management on the basis of soil and leaf analysis as per the recommendation of Rubber Research Institute of India. The status of N, P, K, Ca and Mg for the uniform populations are presented in Table 1 and the frequency distribution of these nutrients into low, medium and high category are presented in Figures 1- 5. Nitrogen concentration ranged from 2.56 to 4.59 per cent with a mean of 3.56 per cent. Similarly, the P concentration ranged from 0.15 to 0.40 per cent with a mean of 0.26. The K concentration ranged from 0.80 to 1.98 per cent with a mean of 1.14 per cent and Mg concentration ranged from 0.12 to 0.50 per cent with mean of 0.32 per cent. Frequency distribution of the values indicated that 2.4 per cent and 2.75 per cent of the observation alone were in the lower level for N (<3.0 %) and P (<0.20 %), respectively. Similarly, for K, 6.4 per cent of the population recoded low values (<1.0 %) and for Mg, 11.3 per cent of the population recoded low values (<0.20 %) as per the sufficiency range ratings (Karthikakuttyamma *et al.*, 2000). It can be inferred that even though the Ultisols under rubber cultivation are low in nutrient status, the tree nutrient status can be maintained with adequate fertilizer application and proper nutrient management strategies. Nutritional self sufficiency of the mature rubber crop system was reported earlier based on the studies in Malaysia. The organic carbon rich surface layer with constant cycling of litter, extensive feeder root system, nutrient uptake from the deeper layers and internal recycling and mobilization of nutrients will be contributing to the

Table 1. **Range and mean values of the leaf nutrient concentration of the uniform population**

Nutrient	Concentration (%)		SD	CV (%)
	Range	Mean		
N	2.56-4.79	3.56	0.35	9.7
P	0.15-0.40	0.26	0.04	14.3
K	0.80-1.98	1.36	0.23	16.8
Ca	0.37-1.88	1.14	0.22	19.4
Mg	0.12-0.50	0.32	0.07	22.0

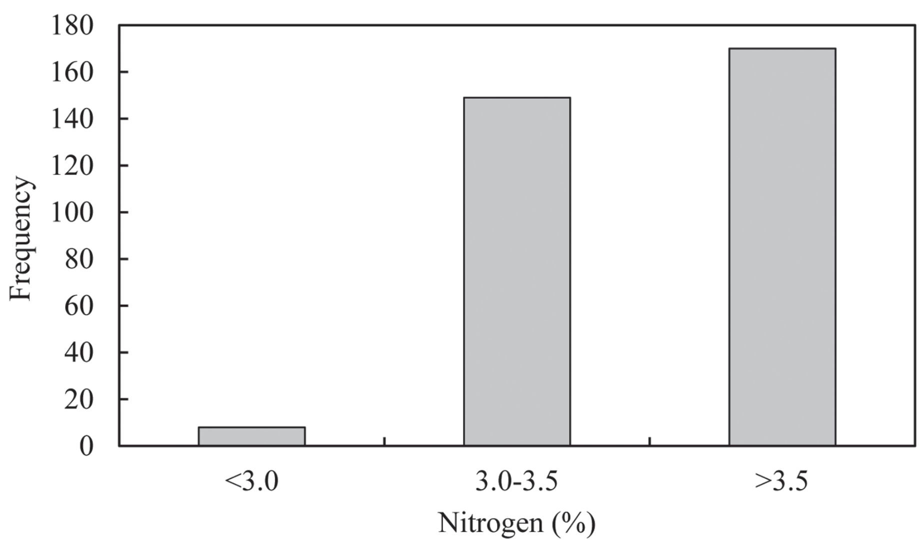

Fig. 1. Frequency distribution of the nitrogen concentration of leaf

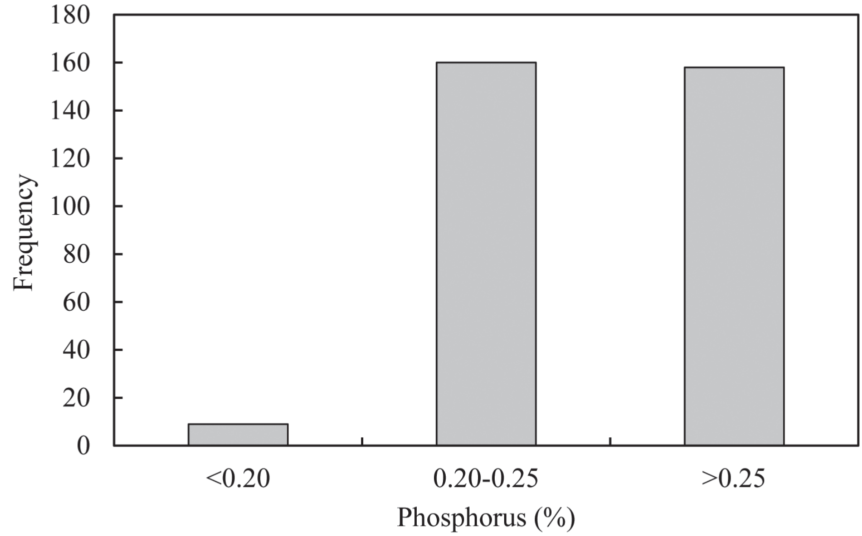

Fig. 2. Frequency distribution of the phosphorus concentration of leaf

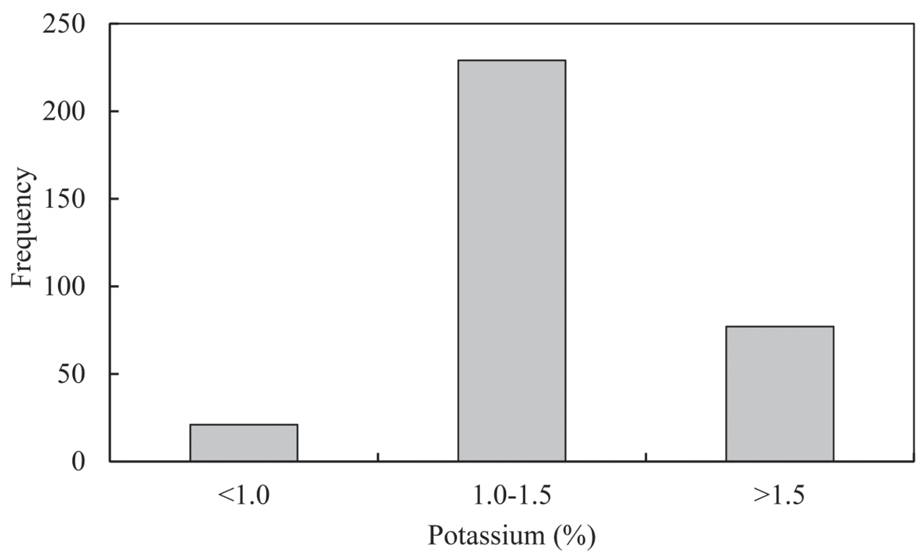

Fig. 3. Frequency distribution of the potassium concentration of leaf

nutritional self-sufficiency. In general, the Bray II P values for the rubber growing soils registered low value. Even then, 48 per cent of the population recorded P values in the high range. The organic P status of the soil was reported to be very high ranging from 65 to 85 per cent in the rubber growing soils of Kerala and Tamil Nadu (Prasannakumari *et al.*, 2008) which might be replenishing the soil available pool and the availability of P

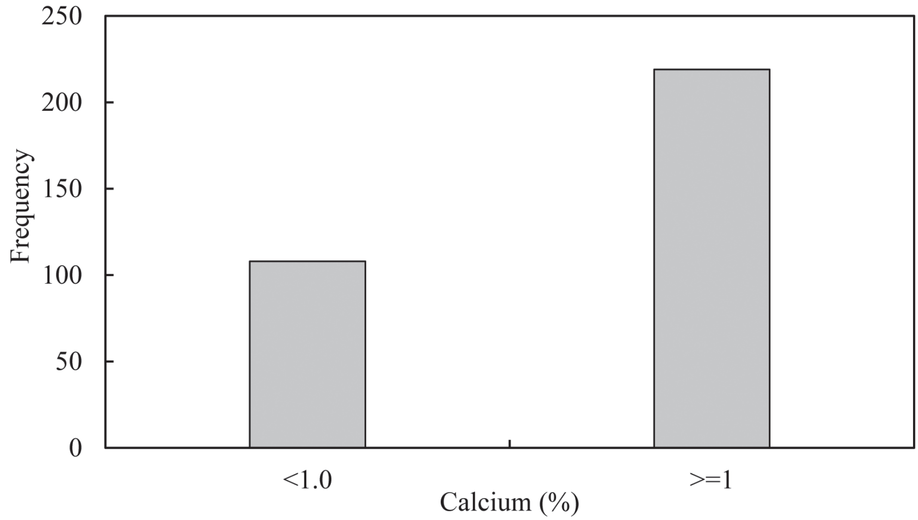

Fig. 4. Frequency distribution of the Ca concentration of leaf

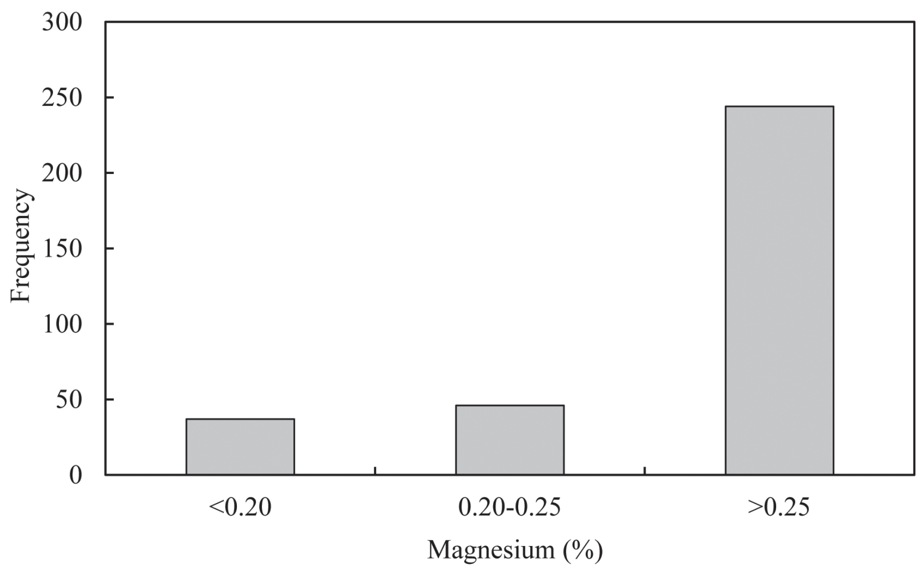

Fig. 5. Frequency distribution of Mg concentration of leaf

to the plants. Calcium concentration in the leaf ranged from 0.37 to 1.88 per cent with the mean value of 1.14 per cent. Nearly 1/3rd of the population is in the low range as per the critical value of 1.0 per cent reported by Joseph and Ranganathan (1996) indicating that the growing condition or the system is experiencing deficiency of Ca. Rubber growing soils are very strongly to extremely acidic and low in base status, especially Ca status (NBSS&LUP, 1999; Joseph, 2016). Direct supplementation of Ca is not practiced in rubber plantations neither in the immature or mature phase. The general fertilizer recommendation for mature rubber is only 30:30:30 kg ha^{-1} of N, P and K. The major source of N, P and K fertilizers are urea, rajphos and muriate of potash. Magnesium is supplied in the initial four years of the immature phase on the basis of soil analysis ratings. Through rock phosphate addition a small quantity of Ca is supplied to the soil every year. Even then, 30 per cent of the population recorded low values indicating the necessity of supplementation of Ca for sustaining the productivity of rubber growing soils as major share of which is Ultisoils with extremely acidic pH, dominated by kaolinite clay and oxides and hydrous oxides of Fe and Al. Calcium requirement for optimum growth is determined by the concentration of other cations in the soil solution and the requirement increases with increasing external concentration of heavy metals, Al or protons (Wallace *et al.*, 1966). At low pH, Ca^{2+} concentration in the soil solution has to be several times higher to counter the adverse effect of high H^{+} concentration on root elongation (Asher and Edwards, 1983).

The coefficient of variation (Table 1) was the lowest for N (9.7 %), followed by P (14.3 %) and high for K (16.8 %), Ca (19.4 %) and Mg (22.0 %) indicating the existence of very high spatial variability in these three nutrients contributed possibly by the topographic features and the heavy rainfall conditions experienced in the rubber growing regions of South India. Wide variation in the concentration of K, Ca and Mg depending on the growing conditions, plant species and plant organ is reported in different crops (Loneragan *et al.*, 1968; 1976).

Table 2. **Age wise grouping of the population and the corresponding leaf nutrient status**

Age group (years)	Range	mean	SD	CV (%)
Nitrogen (%)				
<7	2.65-4.65	3.60	0.35	9.8
7-11	2.01-4.74	3.68	0.34	9.2
12-16	2.56-4.79	3.65	0.36	9.9
17-21	2.30-4.59	3.57	0.40	11.1
22-26	2.63-4.32	3.53	0.35	9.9
>26	2.63-4.32	3.53	0.32	9.1
Phosphorus (%)				
< 7	0.15-0.31	0.22	0.03	13.8
7-11	0.16-0.39	0.24	0.04	14.5
12-16	0.15-0.40	0.24	0.03	14.3
17-21	0.14-0.38	0.26	0.04	15.2
22-26	0.17-0.41	0.26	0.04	14.0
>26	0.18-0.45	0.27	0.04	14.9
Potassium (%)				
< 7	0.56-1.68	1.05	0.21	20.2
7-11	0.60-2.00	1.18	0.23	19.6
12-16	0.60-2.00	1.26	0.24	19.5
17-21	0.66-2.20	1.33	0.26	19.7
22-26	0.66-2.14	1.35	0.23	17.3
>26	0.86-1.90	1.34	0.24	17.6
Calcium (%)				
< 7	0.60-2.50	1.39	0.36	25.9
7-11	0.46-2.50	1.27	0.34	26.5
12-16	0.56-2.50	1.23	0.32	26.1
17-21	0.41-2.11	1.14	0.29	25.2
22-26	0.37-2.20	1.11	0.27	24.2
>26	0.57-2.38	1.10	0.24	22.1
Magnesium (%)				
< 7	0.15-0.56	0.31	0.08	26.6
7-11	0.11-0.66	0.37	0.07	20.4
12-16	0.10-0.62	0.35	0.08	22.0
17-21	0.12-0.77	0.33	0.08	25.1
22-26	0.15-0.57	0.31	0.09	28.4
>26	0.15-0.46	0.29	0.06	21.1

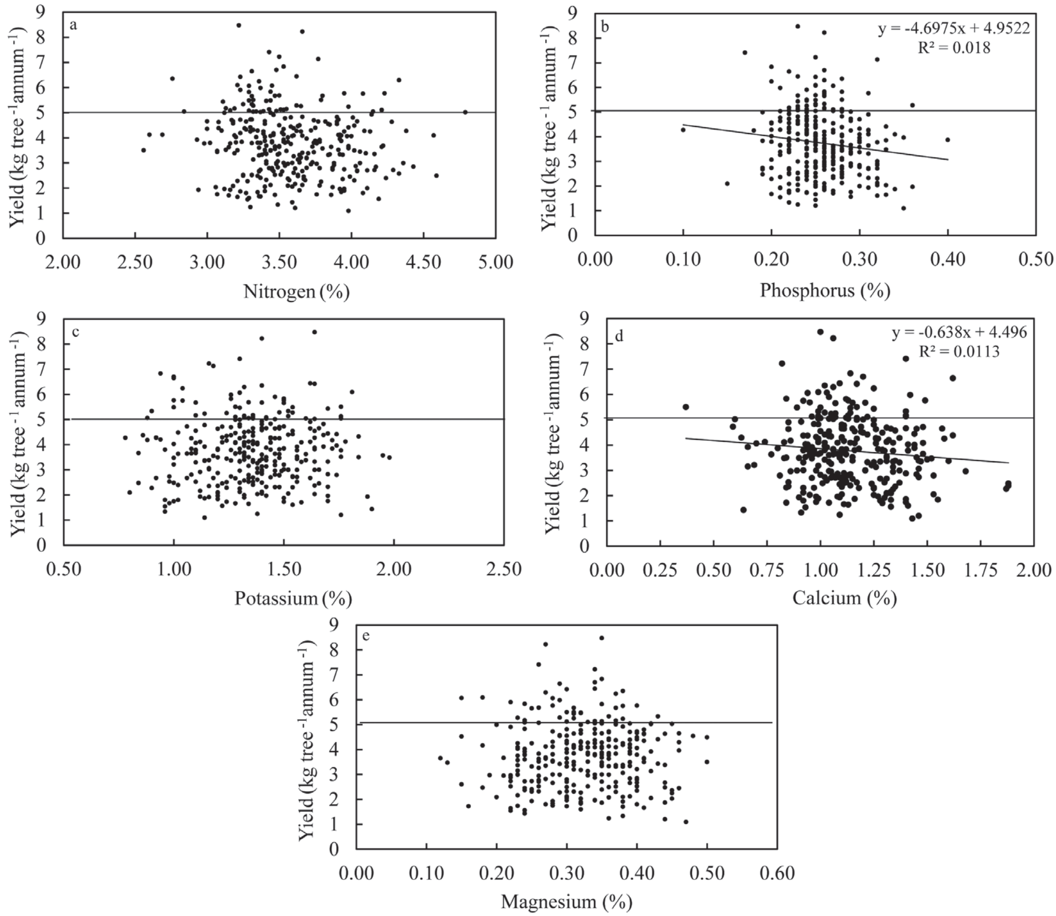

Fig. 6. Relationship between nutrient concentration and yield

In the age wise grouping of nutrients (Table 2), the range of data showed the same pattern as that of the uniform population. No difference was noticed in the concentration of nutrients between the age groups. However, the coefficient of variation was high for Ca and Mg. In the case of K, the coefficient of variation was the highest in the young population and decreased with age of the population.

Leaf nutrient concentration was related with yield and the scatter diagram for individual nutrients (Fig. 6) indicated that the high yield, in general, was achieved at the middle point of the sufficiency range values for N, P and K. The values were comparable with the critical values derived through DRIS approach (Joseph and Ranganathan, 1996) and the critical concentration of K (1.26 %) derived from the response equation (Joseph *et al.*, 1998). Regarding Mg, the high yield group recorded values in the high range as per the sufficiency range rating of 0.20 to 0.25 per cent.

Table 3. **Correlation among the nutrients**

Nutrient	P	K	Ca	Mg
N	0.186 **	-0.116 *	-0.088	0.075
P		0.430 **	-0.116 *	0.098
K			-0.152 **	-0.025
Ca				0.112

** Significant at P=0.01 and * Significant at P = 0.05

Correlation between individual nutrients and yield indicated significant negative relation between P concentration and yield (-0.133*). Similarly, significant negative relation was recorded between Ca concentration and yield (-0.132*). However, the regression coefficient (R^2) was only 0.018 and 0.011, respectively for P and Ca with yield as expected, as the tree nutritional status is important in achieving optimum productivity but, at the same time, the role of individual nutrients on yield is not quantified or established. Significant difference between the variance ratio between low yielding and high yielding population was recorded only for P. Plant analysis indicate the potential for response to added nutrients and actual crop performance, both growth and yield is being dictated by the totality of the growing conditions (Martin-Prevel *et al.*, 1987). Extremely low concentration of Ca in the latex cytosol was reported by d'Auzac *et al.* (1989). Latex flow properties and yield is being influenced by the ratio of ions in the latex especially Mg/P ratio. In our study, Ca and P concentration in the leaf had negative influence on yield indicating that high concentration might have adversely affected the ionic balance and had negative effect on yield.

The importance of balance among the nutrients in the plant system for achieving high yield and the DRIS approach in diagnosing the nutritional balance was first reported in rubber by Beaufils (1957). In the present study (Table 3) N recorded significant positive correlation with P and negative correlation with K. Similarly, P recorded significant positive correlation with K, and negative correlation with Ca. Potassium and Ca recorded significant negative correlation (Table 3). The concentration of a nutrient in a particular plant tissue varies with the concentration of other nutrients because of the interactions among nutrients in the plant system (Schwartz and Kafkafi, 1978; Sumner and Farina, 1986; Sumner, 1990). Nutrient interactions highlight the importance of balance among the nutrients. However, the sufficiency level approach is being widely followed for assessing the individual nutrient status for optimizing fertilizer use.

CONCLUSION

Assessment of the leaf nutrient status indicated nutritional sufficiency for N, P, K, and Mg. However, thirty per cent of the population recorded Ca values in the lower range indicating low availability of Ca. The study points to the importance of replenishment of Ca through external sources in deficient areas as Ca is not included in our routine fertilizer recommendation. Coefficient of variation for the nutrients K, Ca and Mg was very high indicating high spatial variability of these nutrients in the soil. Though a negative correlation was observed between P and Ca concentration with yield, the regression coefficient was too small as expected, as the yield is influenced by many factors and the tree nutritional status in totality with the optimum balance among the nutrients is influencing the yield. Significant interrelationship among the nutrients was recorded in correlation studies indicating the importance of maintenance of nutritional balance in the plant system for achieving optimum productivity.

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