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DIAGNOSIS AND RECOMMENDATION INTEGRATED SYSTEM : 2. DERIVATION OF CRITICAL LEVEL OF LEAF NUTRIENT CONCENTRATIONS IN RUBBER

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Leaf nutrient critical values were established from a data bank of leaf nutrient concentration, soil nutrient status and yield of rubber (*Hevea brasiliensis*) in South India by applying the principles of DRIS taking into consideration the simultaneous optima for all the nutrients. The critical level for each nutrient was derived using multiple linear regression model relating the foliar nutrient concentration with DRIS indices of all the nutrients. These values were compared with the DRIS derived critical levels. The DRIS derived optima as percentages of dry matter for N, P, K, Ca and Mg were 3.590, 0.258, 1.314, 0.997 and 0.302 respectively. These values were found to be comparable to those derived by multiple as well as simple linear regression and the values reported in the literature. Many of the constraints associated with the development of critical values through the conventional procedure could be overcome by this approach.

Key words : *Hevea brasiliensis*, Foliar analysis, Critical values, DRIS.

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INTRODUCTION

Chemical analysis of plant samples and diagnosis based on critical values have been used for many years in assessing the nutritional status of plants. Ulrich (1952) originally defined critical concentrations for diagnostic purposes as the concentration of a nutrient in a plant needed to produce near-maximal growth. Later, Ulrich and Hills (1967) and Mead (1984) defined critical level as the nutrient concentration required in a plant tissue for optimum growth, yield and/or quality assuming that no other factor is limiting.

The critical values are fixed for each nutrient based on the results of controlled experiments assuming that all other factors limiting growth and production are optimum which is not achieved in most of the situations resulting in variation in critical values for the same crop under different situations (Sumner, 1990). The concentration of a nutrient in a particular plant tissue varies with the concentrations of other nutrients because of the interactions among nutrients in the plant system (Schwartz and Kafkafi, 1978; Sumner and Farina, 1986; Sumner, 1990). According to Sumner and Boswell (1981) simultaneously optimum conditions for nutrients is very important for fixing the critical values.

The Diagnosis and Recommendation Integrated System (DRIS) developed by Beaufils (1973) provides a mechanism for defining the optimum nutrient levels and a method for measuring simultaneously optimum conditions among nutrients. According to Needham *et al.* (1990) the DRIS method can be used to estimate optimum foliar nutrient levels circumventing many problems associated with the conventional critical level determinations. In this study the leaf nutrient critical values for *Hevea brasiliensis* were derived using the DRIS approach. The methodology illustrated by Needham *et al.* (1990) has been modified for deriving the critical values.

MATERIALS AND METHODS

A data bank comprising of yield, leaf nutrient concentration for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) and soil nutrient status were generated from 1200 rubber fields of 15 estates representing the traditional rubber growing tract of South India. The leaf samples were collected according to the standard procedure (Shorrocks, 1962) during August to October when the leaves were 6 to 8 months old. The nutrient content of the leaf samples was estimated through standard procedure (Piper, 1966). The 1200 observations were regrouped and only 359 having uniform age and system of tapping were selected for the present study. The trees were on under BO2 panel following half spiral alternate daily tapping (1/2S d/2) system. The trees were further divided into low yielding (296 nos) and high yielding (63 nos) subgroups. The standard DRIS norms for the nutrients N, P, K, Ca and Mg were developed following the methodology outlined by Walworth and Sumner (1987) as indicated in detail elsewhere (Joseph *et al.*, 1993). The standard DRIS norms are presented in Table 1. The variance ratios were not significant for the expressions Ca/N, Ca/P and Ca/K. But they were included in the computation of DRIS indices to ensure that interactions with other nutrients were considered.

The DRIS indices (N, P, K, Ca and Mg) were calculated for the individual samples in the high yielding population using the following index equations (Beaufils, 1973) :

Table 1. **DRIS norms for *Hevea brasiliensis***

Nutrient ratios	Mean	SD	CV(%)
N/P*	13.876	1.990	14.3
K/N*	0.382	0.080	20.9
K/P*	5.259	1.169	22.2
Ca/N	0.299	0.088	29.7
Ca/P	4.102	1.303	31.8
Ca/K	0.823	0.339	41.2
Ca/Mg*	3.328	0.915	27.5
N/Mg*	11.383	2.382	20.9
P/Mg*	0.835	0.207	24.8
K/Mg*	4.397	1.443	32.8

* Variance ratio significant at 1% level

$$\text{N index} = \frac{f(N/P) - f(K/N) - f(Ca/N) + f(N/Mg)}{4} \quad ......(1)$$

$$\text{P index} = \frac{-f(N/P) - f(K/P) - f(Ca/P) + f(P/Mg)}{4} \quad ......(2)$$

$$\text{K index} = \frac{f(K/N) + f(K/P) - f(Ca/K) + f(K/Mg)}{4} \quad ......(3)$$

$$\text{Ca index} = \frac{f(Ca/N) + f(Ca/P) + f(Ca/K) + f(Ca/Mg)}{4} \quad ......(4)$$

$$\text{Mg index} = \frac{-f(N/Mg) - f(P/Mg) - f(K/Mg) - f(Ca/Mg)}{4} \quad ......(5)$$

where, f(A/B) for the hypothetical nutrient A and B are calculated by the following equations :

$$f(A/B) = \left[\frac{(A/B)-1}{(a/b)}\right]\frac{1000}{cv} \quad \text{if } (A/B) > a/b \quad ......(6)$$

$$f(A/B) = \left[\frac{1-(a/b)}{(A/B)}\right]\frac{1000}{cv} \quad \text{if } (A/B) < a/b \quad ......(7)$$

where A/B = sample nutrient ratio and a/b = corresponding norm value. From the DRIS indices of the high yielding population the optimum nutrient concentrations were calculated.

RESULTS AND DISCUSSION

Foliar nutrient optima were derived using two different procedures. In the first method, the optimal levels were fixed by taking the average of each respective element of all high yielding fields which exhibited simultaneously optimum nutrition. To obtain optimal level for each element, Beaufils' 4/3 standard deviation rule was followed (Beaufils, 1973). In the 63 sample fields of high yielding group, only 48 per cent exhibited simultaneously optimum nutrition for all the elements. The optimal levels fixed for the nutrients by this method are 3.59, 0.258, 1.314, 0.997 and 0.302 per cent for N, P, K, Ca and Mg, respectively.

In the second method, multiple linear regression was used to describe the relationship between foliar nutrient concentration of a nutrient and DRIS indices of all the nutrients. Simple linear regression has been used by other workers (Truman and Lambert, 1981; Needham *et al.*, 1990). But as pointed out by Needham *et al.* (1990), the critical levels fixed using simple regression were not theoretically correct as this method failed to take into account the concept of simultaneous optima. Hence multiple regression was used for deriving the foliar nutrient optima. In this method, the model assumed is :

$$L = b_0 + b_1NI + b_2PI + b_3KI + b_4CaI + b_5MgI \quad ....(8)$$

where, L is the leaf nutrient concentration of the particular element and NI, PI, KI, CaI and MgI are DRIS indices.

The values of NI, PI, KI, CaI and MgI are not independent. They are connected by the relation,

$$NI + PI + KI + CaI + MgI = 0 \quad ....(9)$$

So the number of independent variables on the R.H.S. of equation (8) can be effectively reduced to four using equation (9). Accordingly, multiple regression equation of the form,

$$L = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 \quad ....(10)$$

has been used in this study to describe the relationship between DRIS nutrient indices and foliar concentration where, X1 to X4 are the DRIS indices of the four selected nutrient elements. Only those four nutrients which had the highest correlation with L were selected for use in the multiple regression analysis. For this purpose the correlations between leaf nutrient concentration and DRIS indices were calculated (Table 2).

The results of the regression analyses are presented in Table 3. The optimal levels of foliar nutrient concentration were obtained by setting all the four DRIS index values to zero in the regression equations. The derived optimal values were 3.551 for N, 0.260 for P, 1.370 for K, 1.083 for Ca and 0.317 for Mg (Table 4). For comparison, the results obtained from simple regression analyses are also given. The optimal values obtained under both the methods are nearly

Table 2. **Correlation coefficients between leaf nutrient concentrations and DRIS indices of nutrients**

Leaf nutrient concentration	DRIS index				
	N	P	K	Ca	Mg
N	0.485	0.066	-0.156	-0.385	0.144
P	-0.614	0.885	-0.065	-0.099	-0.084
K	-0.275	0.159	0.894	-0.451	-0.440
Ca	-0.574	-0.135	-0.563	0.911	0.221
Mg	-0.450	-0.142	-0.593	0.095	0.936

Table 3. **Relationship between nutrient concentrations and nutrient indices derived by multiple regression equations**

Equation	R^2
** ** ** ** N = 3.5510 + .0.0099NI – 0.0117KI – 0.0134CaI – 0.0029MgI	0.4437
** ** ** ** P = 0.2600 – 0.0019NI + 0.0044PI + 0.0004MgI	0.9085
(The calculated coefficient for CaI was less than 10-4 and hence omitted)	
** ** ** * K = 1.3704 – 0.0132NI – 0.0210KI – 0.0027CaI – 0.0007MgI	0.9214
** ** ** ** Ca = 1.0829 – 0.0109NI – 0.0012KI + 0.0212CaI + 0.0032MgI	0.9444
** ** ** Mg = 0.3170 – 0.0027NI + 0.0006PI – 0.0003KI + 0.0062MgI	0.9532

* Significant at 5% level ** Significant at 1% level

the same. In the case of N and K, the values reported by Beaufils (1957) are low compared to the values established in this study (Table 4). The values of P, Ca and Mg are almost the same. The values established by Beaufils were under Vietnamese conditions for older, low yielding clones. The soils of Vietnam are reported to be oxisols derived from basalt rich in Mg. The very high Mg status of the soil might have affected the uptake of K due to the interaction between each other.

At present, the sufficiency range values are used for diagnosis of mineral sufficiency or deficiency. The medium values for the leaf nutrient concentration ranges from 3.0 to 3.50 per cent (N), 0.20 to 0.25 per cent (P and Mg) and 1.0 to 1.50 per cent (K) (Pushpadas and Ahammed, 1980). The critical values established through the present study are in the higher range for N, P and Mg. The critical Ca concentration for 100 days old leaf under Malaysian conditions is reported to be 0.60 per cent, a value much lower than our estimate. The concentration of Ca increases with age of the leaf. It also shows variation between clones (Pushparajah and Tan, 1972).

Table 4. **Comparison of optimal levels of leaf nutrient concentrations derived by different methods**

Method	Foliar nutrient concentration (%)				
	N	P	K	Ca	Mg
DRIS derived optimum	3.590	0.258	1.314	0.997	0.302
Nutrient level when DRIS Index = 0 using MLR	3.551	0.260	1.370	1.083	0.317 **
Nutrient level when DRIS Index = 0 using SLR	3.572	0.261	1.370	1.095	0.318
Beaufils (1957)	3.360	0.257	0.930	1.067	0.331

MLR - Multiple linear regression ; SLR - Simple linear regression

CONCLUSION

Optimum leaf nutrient concentration can be established from a representative data bank using the DRIS approach. The methodology helps in overcoming many of the problems associated with the conventional single factor experiments in the establishment of critical values for perennial crops, *viz.*, the long growth cycle, locking up of the nutrient in different plant parts and difficulty in the correct assessment of the nutrient uptake, fixing up of the response variable etc. Being based on field survey DRIS values will be more realistic compared to values obtained through conventional procedures. In *Hevea brasiliensis* the critical concentration in the leaf for the nutrients N, P, K, Ca and Mg were established through DRIS approach.

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