

Reciprocal relationship between magnesium and cerium as a common basis for coconut root (wilt) and a human cardiomyopathy

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The leaves of coconut palms affected by root (wilt) in Kerala showed lower level of magnesium and higher concentration of cerium in significant contrast to control samples from palms in Manavalakurichi and Bombay. The reciprocal relationship between magnesium and cerium in the diseased palms is similar to their relationship in the cardiac tissues of patients with endomyocardial fibrosis. A common geochemical basis for these two conditions warrants further study.

Root (wilt) disease of coconut palms (*Cocos nucifera* Linn.) in Kerala, South India has baffled investigators for a century. A survey (Figure 1) showed 59.1 million bearing and 32.4 million non-bearing palms to be diseased with an annual loss of over 900 million nuts¹. While several studies sought to identify infective pathogens^{2,3}, others noted the deficiency of magnesium in the leaves and surrounding soil of the diseased palms⁴ and improved yields by soil enrichment with magnesium sulphate⁵. The deficiency of magnesium was also noted in association with the elevation of cerium in the cardiac tissues of patients with endomyocardial fibrosis, a common cardiomyopathy in Kerala⁶. Given the abundance of monazite in the soil of Kerala and its high cerium content⁷, cerium was believed to be enhanced in the cardiac tissues by magnesium deficiency which characterized the poor nutrition of these patients. Subsequent studies showed that magnesium deficiency in the medium enhances the concentration of cerium in a tuber crop⁸ and that cerium mimics magnesium as a co-factor in enzymatic reactions⁹. These observations suggested the operation of a similar mechanism in coconut root (wilt) in Kerala where the soil in several locations is deficient in magnesium and rich in deposits of monazite.

Thirty palms with root (wilt) were chosen for the present study from Quilon and Alleppey districts where the disease is prevalent (Figure 1). An equal number of healthy-looking palms from the same locations, 3 from Bombay and 10 from Manavalakurichi formed the controls (Figure 2). The samples from Bombay and Manavalakurichi were included because of the absence of coconut root (wilt) and the characteristic soil composition in these areas. While the soil in Bombay and Manavalakurichi does not lack magnesium, monazite is negligible in the former but abundant in the latter⁷.

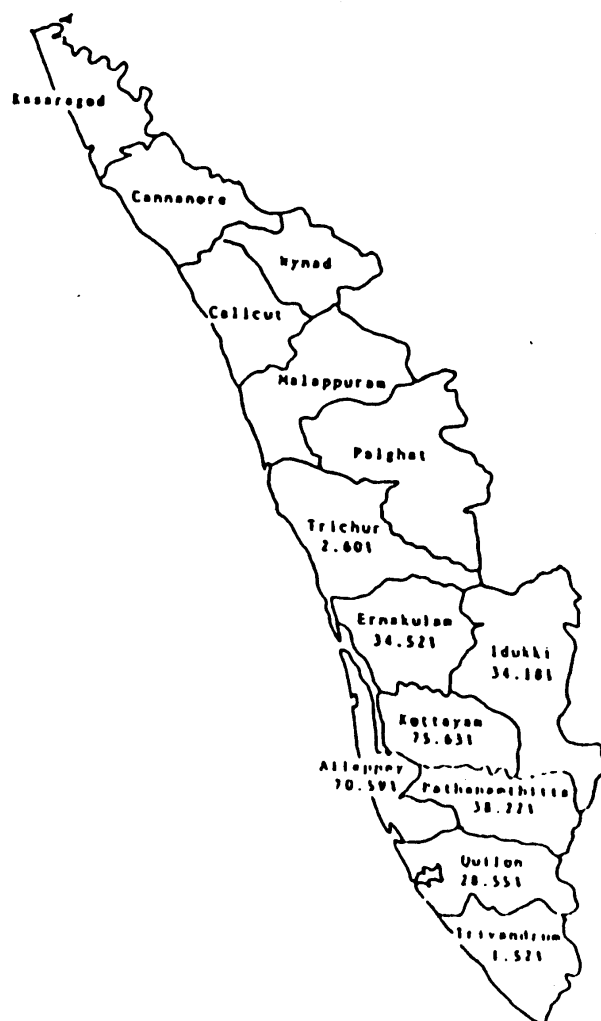


Figure 1. District-wise prevalence of coconut root (wilt) in Kerala. (Based on ref. 1.)

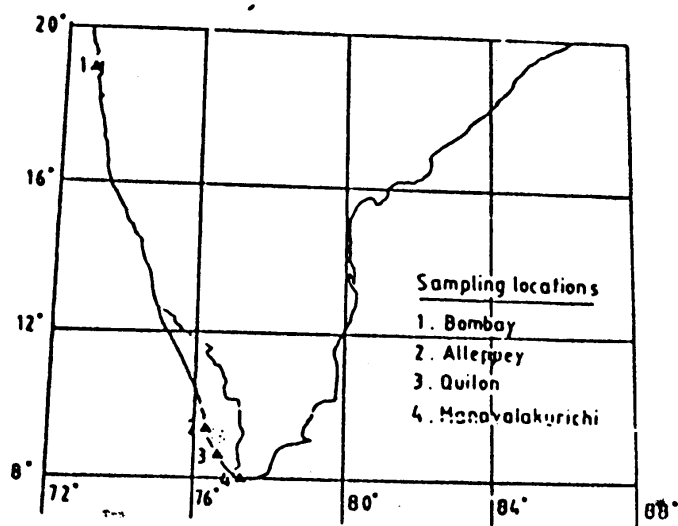


Figure 2. Places of origin of leaf samples in peninsular India.

Table 1. Elemental concentration in the palms (mean \pm SD)

Element*	Palms				Statistical significance
	Healthy looking controls				
	Diseased (n = 30)	1 Quilon and Alleppey (n = 30)	2 Bombay (n = 3)	3 Manavalakurichi (n = 10)	
Mg**	252 \pm 95.7	261 \pm 94	336.7 \pm 162	377.4 \pm 80.1	DG lower than 3 (P < 0.001).
Ce†	856 \pm 320	622 \pm 215	16.9 \pm 5.8	195.7 \pm 81.4	DG higher than 1, 2 and 3 (P < 0.001). 1 higher than 2 and 3 (P < 0.001).
La†	476 \pm 170	359 \pm 116	< 2	70.4 \pm 29	DG higher than 2 and 3 (P < 0.001)

*Pr and Nd were not significant when compared with controls. Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb and Lu were below detection limit.

Tm was used as internal standard in the analysis.

** $\mu\text{g g}^{-1}$ wet wt.

† ng g^{-1} wet wt.

DG, Diseased group

In accordance with standard practice, median leaflets of the 14th leaf or *m*th leaf ($m = n/2 + 1$, where *n* is the total number of fully open leaves) were collected, cleaned and pooled from each palm in the study and control groups. Composite samples of 0.5 g from each palm was digested in concentrated nitric acid and the levels of magnesium determined by atomic absorption spectrometry. A Sciex ICP-MS instrument was used to estimate 13 members of the lanthanide series. Statistical significance between two groups was analysed by Student's *t* test and the variation between groups tested by Anova (one-way variance analysis) using SPSS + Ver 4 on PC/AT on a 286 computer. Instrumental conditions chosen for the analysis are reported elsewhere¹⁰.

The study showed that magnesium levels in the diseased palms in Quilon and Alleppey districts were lower than those from Bombay and Manavalakurichi (Table 1). However, the leaves of the healthy looking palms from Quilon and Alleppey also had comparable levels, suggesting that both reflected the low soil content of magnesium in the disease-affected areas¹¹. In contrast to magnesium, the level of cerium in the diseased palms was significantly higher than those in all the three control groups ($P > 0.001$). While the cerium level in the diseased palms exceeded that in the apparently healthy palms of Quilon and Alleppey, the levels in both these groups were strikingly higher than the cerium concentration in the samples from Manavalakurichi (Table 1). Among the other lanthanides, only lanthanum showed a trend similar to that of cerium, but its concentrations were much lower (Table 1). The elemental data suggest that the relative insufficiency of magnesium in the palm enhances the concentration of cerium, and to a lesser extent lanthanum, to high levels in the palms of Quilon and

Alleppey whereas a similar event fails to occur in the palms of Manavalakurichi which have no deficiency of magnesium. Interestingly, similar trends in the levels of magnesium and cerium in the diseased and healthy looking palms seem to justify the belief among coconut farmers that palms in the affected areas are either diseased or potentially diseased. The leaf samples from Bombay which have little monazite in the soil showed negligible concentration of cerium.

Earlier studies on micronutrients and heavy metals had not suggested metal toxicity as a causal factor in coconut root (wilt), nor had they considered the possible role of lanthanides¹². The accumulation of cerium as reported here may be important in the pathogenesis of root (wilt) because the concentration of lanthanides like cerium which exist in more than one oxidation state causes flaccidity in plants¹³. In fact, root (wilt) manifests in coconut palms with flaccidity, yellowing and marginal necrosis which are conspicuous in the leaves of the central and outer whorls.

Cerium is the most bioactive member of the lanthanide series. The reciprocal enhancement of its level is consistent with the synergistic role of magnesium deficiency which increases the cytotoxicity of metals by various mechanisms, including the increase in membrane permeability¹⁴. Given the similarity in the reciprocal relationship between magnesium and cerium, co-prevalence in Kerala and the analogous course in degenerative tissue changes, a common geochemical basis for coconut root (wilt) and endomyocardial fibrosis warrants further study.

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Magnesium level

Apropos the article on the reciprocal relationship between magnesium and cerium as a common basis for coconut root (wilt) disease and a human cardiomyopathy (by Valiathan *et al.*¹), it is seen that Mg level has been presented as $\mu\text{g g}^{-1}$ wet weight in this article. It is customary to present mineral concentration in plant tissues on dry weight basis, as it is the most accurate and dependable method. By taking the dry weight/wet weight ratio of the middle leaf of palm as 0.39 in diseased and 0.44 in healthy plasm (Chacko Mathew, *J. of Plantation Crops*, 1981, 9, 51-55) and converting the values as percentage on dry matter, the figures of Valiathan *et al.* become 0.065% in diseased palms, 0.059% in healthy-looking palms in Quilon and Alleppey, 0.077% in Bombay and 0.086% in Manavalakurichy, which are exceedingly low, and with such low levels, the palms would show acute Mg deficiency symptoms like severe yellowing of foliage. The critical level of Mg (frond 14) is 0.2% on dry matter basis. The magnesium contents of healthy plantations in most of the coconut-growing countries of the world range from 0.2 to 0.4% of dry matter (Manciot *et al.*, *Oleagineux*, 1979, 34, (12), 576-580). Based on such a data the different situations were qualified as deficient or sufficient with respect to magnesium and the authors ventured to justify that the 'palms in the affected areas are either diseased or potentially diseased'. I feel that the data are too meagre for publication in your esteemed journal.

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M. S. Valiathan and
J. T. Eapen reply:

1. While elemental concentration is more often reported on dry weight basis, expression in wet weight continues to remain in vogue (ref. 1). In fact, the measurements are being made on dry weight in our ongoing studies on the possible role of metal ions in the pathogenesis of the disease.
2. The values in dry weight of magnesium which Nair had worked out from our data in wet weight, despite the marked reduction in absolute quantities which is intriguing, confirm our observation that the magnesium level in the leaves of diseased palms is lower than that in the leaves from the healthy palms of Manavalakurichi. Nor do the dry weight values of magnesium negate in any manner the reciprocal relationship between magnesium and cerium which was the central theme in our paper.
3. In determining whether a particular relationship exists between two groups, the size of the sample should be such as to enable one to draw statistically valid conclusions and rule out chance associations. Beyond this, the large size of a sample *per se* does little to strengthen a new observation. In the paper which Nair relied upon for the conversion of wet weight to dry weight, for example, the sample size was only 20 palms.

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