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

M. S. Valiathan, J. T. Eapen, C. K. Mathews*
Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram 695 011, India
*Indira Gandhi Centre for Atomic Research, Kalpakkam 603 102, India

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 nuts[1]. 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 palms[4] and improved yields by soil enrichment with magnesium sulphate[5]. 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 Kerala[6]. Given the abundance of monazite in the soil of Kerala and its high cerium content[7], 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 crop[8] and that cerium mimics magnesium as a co-factor in enzymatic reactions[9]. 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 latter[7].

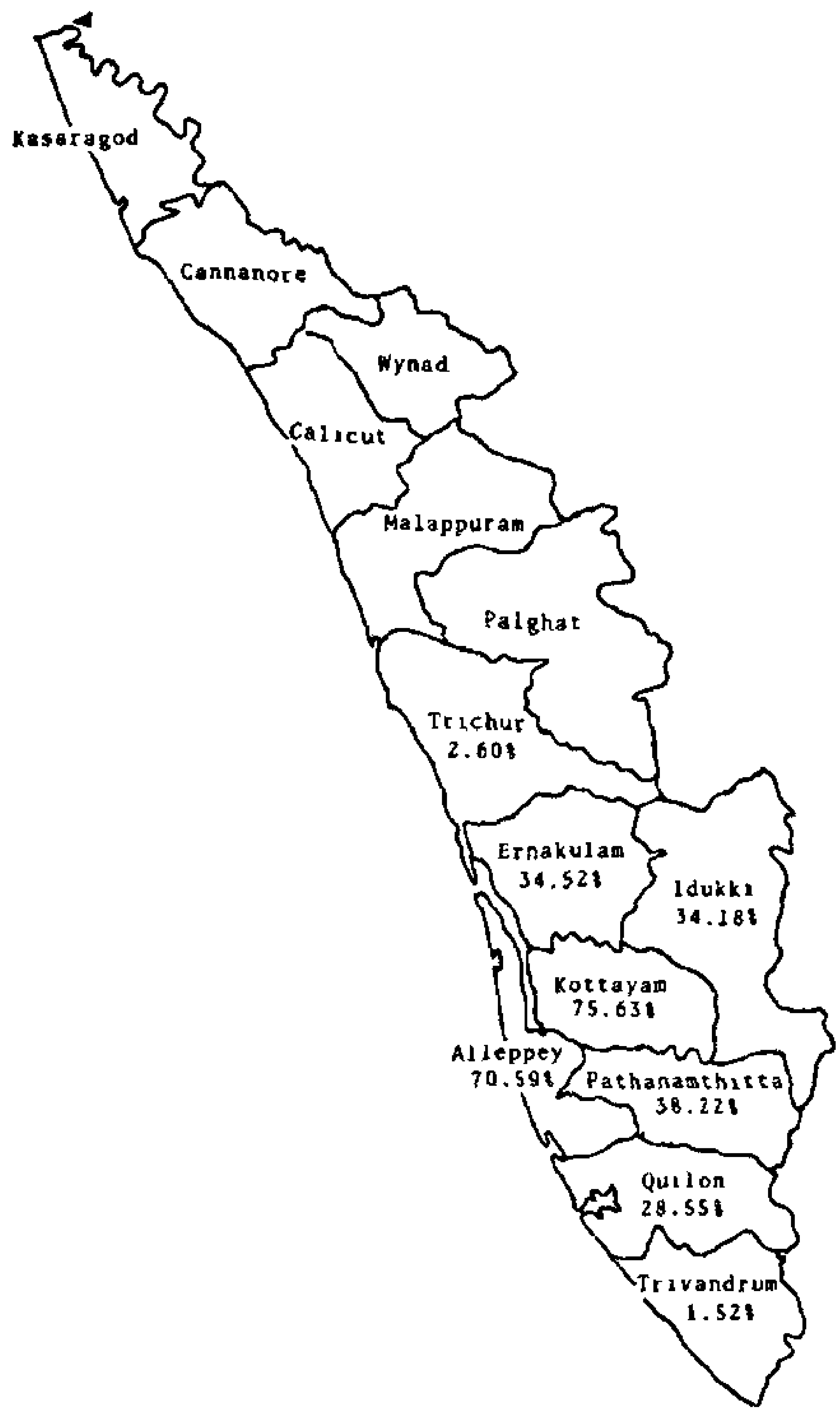

Figure 1. District-wise prevalence of coconut root (wilt) in Kerala. (Based on ref. 1.)

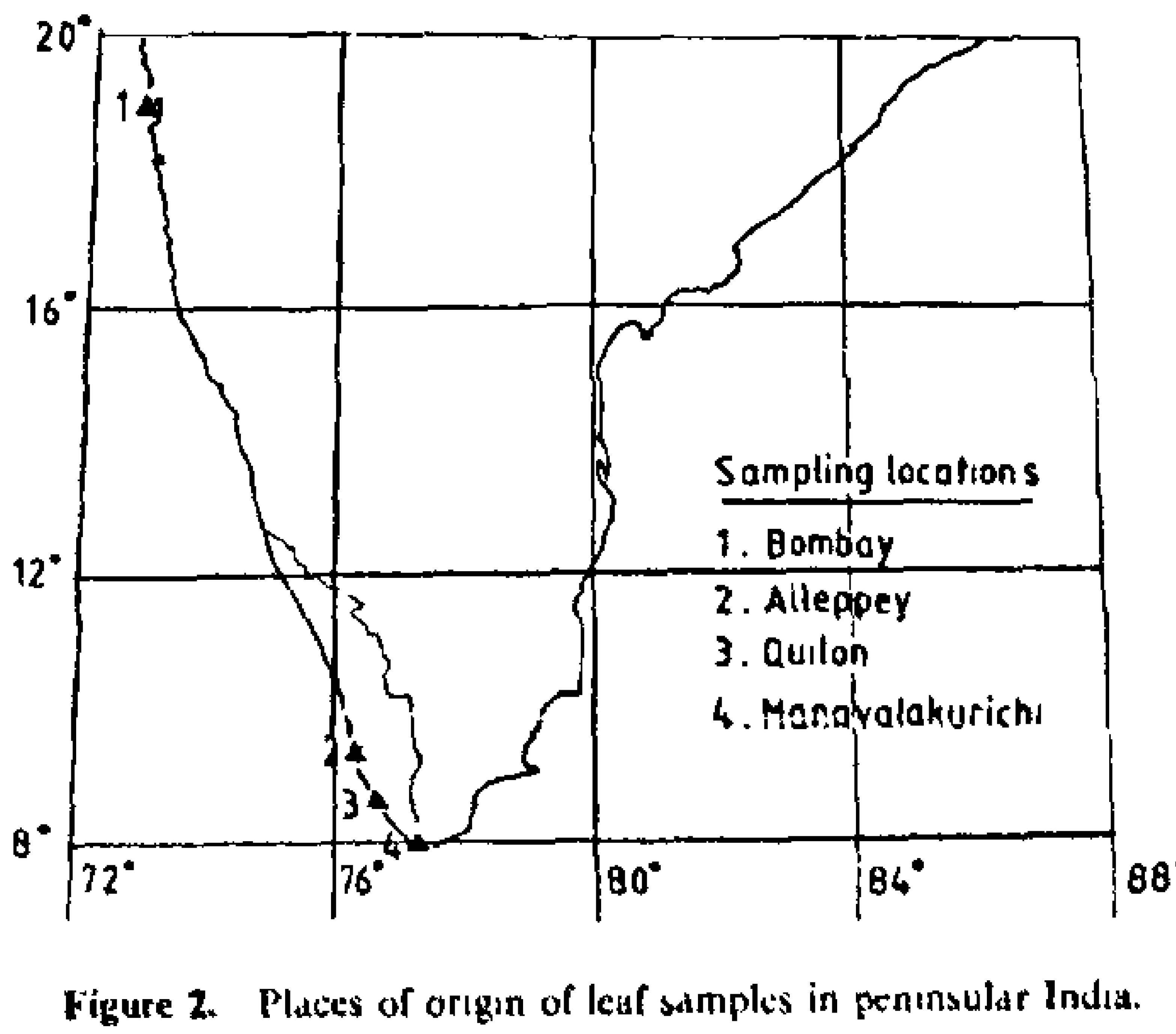

Figure 2. Places of origin of leaf samples in peninsular India.

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

Element*	Palms: Diseased ($n = 30$)	Healthy looking controls: 1 Quilon and Alleppey ($n = 30$)	2 Bombay ($n = 3$)	3 Manavalakurichi ($n = 10$)	Statistical significance
Mg**	252 ± 95.7	261 ± 94	336.7 ± 162	377.4 ± 80.1	DG lower than 3 ($P < 0.001$).
Ce†	856 ± 320	622 ± 215	16.9 ± 5.8	195.7 ± 81.4	DG higher than 1, 2 and 3 ($P < 0.001$). 1 higher than 2 and 3 ($P < 0.001$).
La†	476 ± 170	359 ± 116	< 2	70.4 ± 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.
**$\mu g g^{-1}$ wet wt.
†$ng g^{-1}$ wet wt.
DG, Diseased group

In accordance with standard practice, median leaflets of the 14th leaf or mth 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 elsewhere[10].

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 areas[11]. 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 lanthanides[12]. 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 plants[13]. 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 permeability[14]. Given the similarity in the reciprocal relationship between magnesium and cerium, coprevalence 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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