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 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].

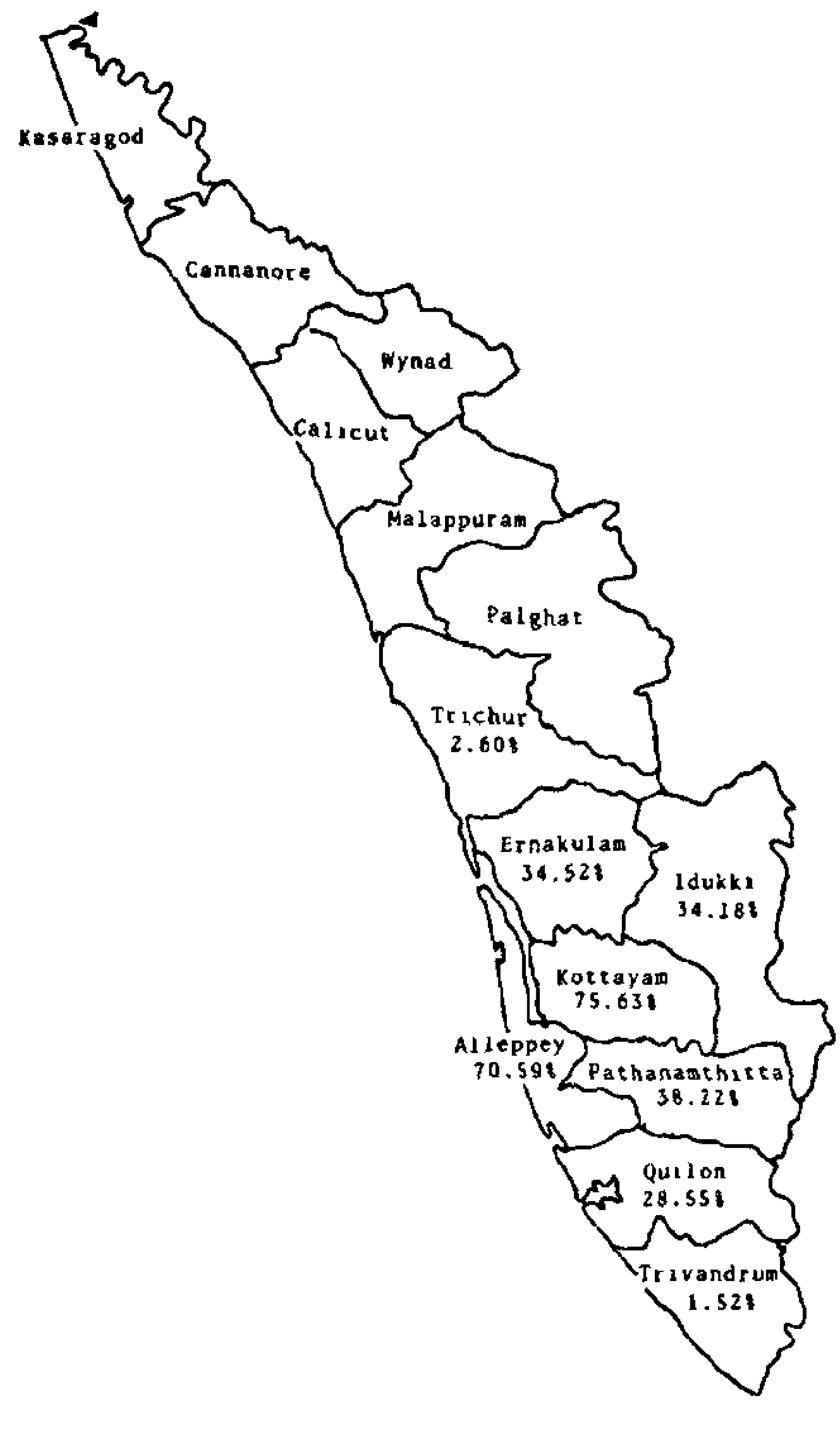

Figure 1. District-wise prevalence of coconut root (wilt) in Kerala. (Based on ref. 1.)

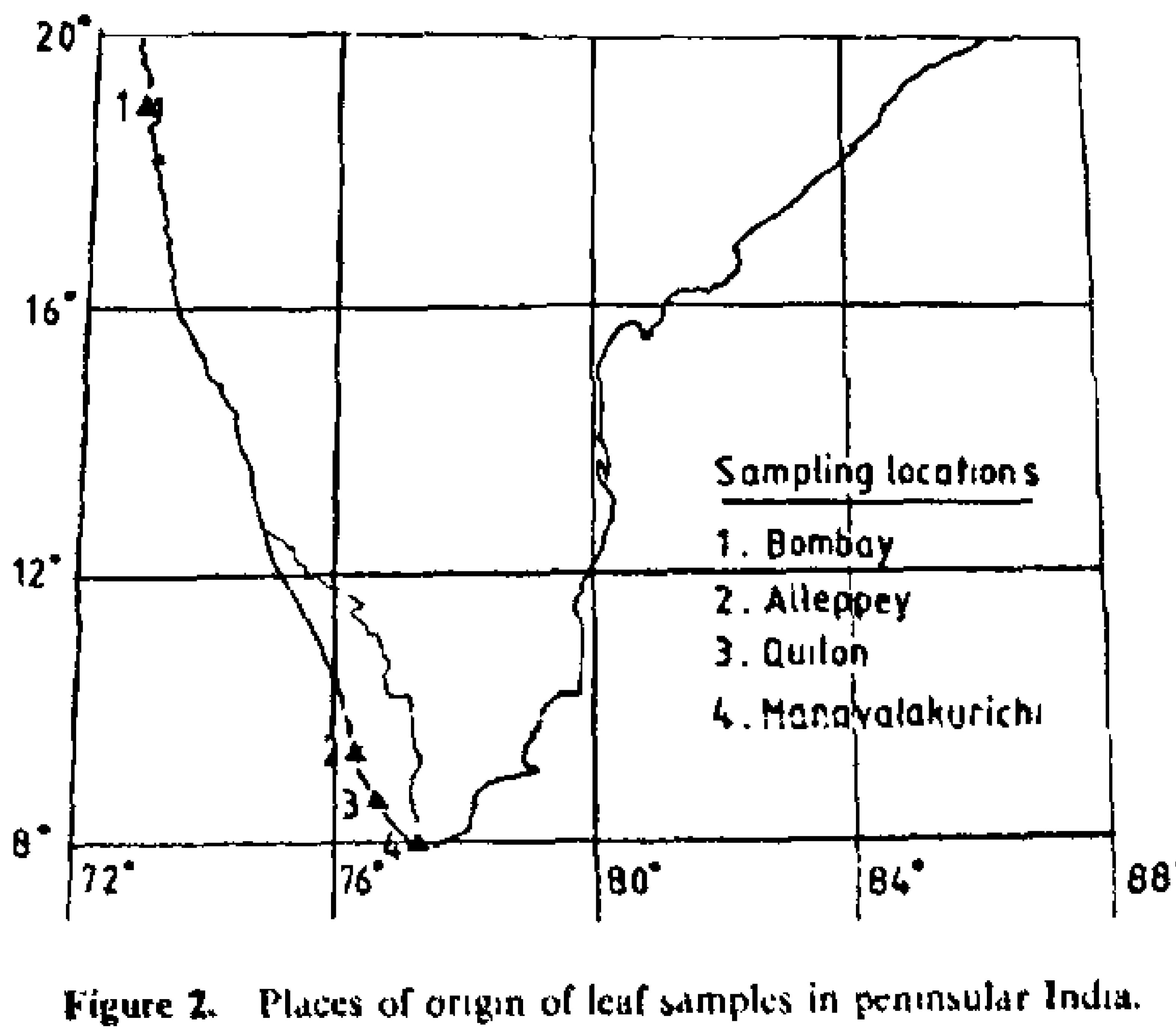

Figure 2. Places of origin of leaf samples in peninsular India.

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

	Palms				
		Healthy looking controls			
		1	2	3	
Element*	Diseased ($n=30$)	Quilon and Alleppey ($n=30$)	Bombay ($n=3$)	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, 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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ACKNOWLEDGEMENTS. We thank Dr C. C. Kartha, Dr K. Shivakumar and Dr Renuka Nair for critical reading of the manuscript and Dr V. Ramankutty for statistical assistance. We are grateful to Dr M. K. Nair and Dr P. K. Koshy of Central Plantation Crops Institute and Dr N. P. Jayasankar for useful discussions. The work was supported by the Department of Science and Technology, Government of India.

Received 19 September 1992; accepted 21 September 1992

Stable isotopic variations in foraminiferal test from Arabian Sea and its relation to the annual south-west monsoonal rainfall over the Indian subcontinent

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Examination of $\delta^{18}O$ estimations from the planktonic foraminifera, *Globigerinoides ruber* (white variety), collected at fortnightly intervals using deep sea sediment traps moored at depths of 1000 and 2787 m in the eastern Arabian Sea (15° 28′ N and 68° 45′ E) shows very little variation during May to October 1987—the period of intense southwest monsoon activity over the north Indian Ocean and the adjoining land mass. This implies that the sea surface temperature in this part of the Arabian Sea did not change significantly during the study period. As the monsoonal rainfall of 1987 over the subcontinent was anomalously weak in nature, the above observational finding of low swing in $\delta^{18}O$ values underlines the use of seasonal variability in the planktonic foraminifera as a proxy for the monsoon performance.

THE western Indian Ocean and the marginal sea—Arabian Sea—experience premonsoonal warming and monsoon-induced cooling each year accompanied by a drop in temperature of 3–4°C. This is more so in the equatorial region beginning from the coast of Somalia. Interestingly, events leading to irregularities in this process contribute to drought over the Indian subcontinent. Coastal upwelling, offshore advection, advection of relatively cold waters from the southern hemisphere, strong southwest monsoon winds, etc. are the most important contributors to the overall cooling of waters of the Arabian Sea[1–4].

Due to summer monsoon winds, large scale upwelling and intense vertical mixing take place in the Arabian Sea over different time and spatial scales[5]. During the years of normal monsoonal regime, the cycles of warming and cooling episodes occur in a near periodic way. Departures from this contribute to prevalence of unusual conditions of monsoons over the subcontinent. For example, during the last decade, the years 1980, 1983, 1987 and 1988 (considered as drought years) showed anomalous behaviour in the sea surface temperature (SST) resulting in continuance of the warmer conditions[4].

In the past there have been several attempts to derive statistical correlations between the summer monsoon rains over the Indian subcontinent and SST[6,7]. If any naturally available sensor that either records or carries the signatures of variations in SST exists, one then can make use of it to establish the empirical correlations. The oxygen isotopic ratio $^{18}O/^{16}O$ (expressed as $\delta^{18}O$ in per mil) in the planktonic foraminifera is one such indicator, that reflects the ambient temperature of water in which the foram thrives[8–10]. $\delta^{18}O$ of calcite shows an increase by about 0.25 per mil when the temperature decreases by 1°C (ref. 11). It is, therefore, possible to use the $\delta^{18}O$ content of the surface dwelling foraminifera to make inferences about the sea surface conditions that prevailed during their growth.

Foraminiferal $\delta^{18}O$ studies from the Arabian Sea sediment core samples indicated a reduction in the summer monsoon intensity during the last glacial maximum[12–14]. Prediction of changes over shorter time-scales of one decade or so may not pose any difficulty when changes over thousands of years could be resolved. For example, Chakraborty and Ramesh[15] have examined the possibility of the use of $\delta^{18}O$ and $\delta^{13}C$ contents in the corals from Lakshadweep to detect or to isolate years with climatologically significant events like droughts. They documented low amplitudes of $\delta^{18}O$ during 1987—a year of drought. Apart from this, one also commonly notices year-to-year changes and their prediction using $\delta^{18}O$ on yearly basis may well be more meaningful. At this stage, the author attempts to address the possibility to document the signature of events of this nature. Here the occurrence of drought in the year 1987, as reflected in the temperature pattern of SST derived from $\delta^{18}O$ in the living foraminifera from the Arabian Sea, has been demonstrated.

The planktonic forams were collected using PARAFLUX Mark VI sediment traps from the eastern Arabian Sea (15° 28′ N, 68° 45′ E). The traps were first deployed in May 1986, and recovered and redeployed