ELEMENT CONTENTS OF SOIL AND LEAVES AND THEIR CORRELATION IN FIVE TREE SPECIES IN AN AREA OF THE RESERVA BIOLOGICA ALBERTO BRENES, COSTA RICA

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INTRODUCCION

There are several reasons causing an increased research activity in the sector of tropical ecological research and conservation: the sorrow that one of the richest and most complex terrestrial ecosystems on earth is further logged and vanishing without ever been really understood; the fear of the global effect of this development on our earth; and the sorrow about the loss of immense genetic resources. The Deutsche Forschungsgemeinschaft ("German Research Community") created among other things a programme called "Mechanisms of the maintenance of tropical diversity" in which many scientists are working on different subjects. In this context and in coordination with the team of Prof. Dr. S.-W. Breckle the first author drew up a diploma thesis about (among other things) nutrient intake from the soil and nutrient accumulation in leaves, as one aspect of the nutrient circle of a lower mountain rain forest. Many aspects were investigated: soil and leaf contents of the elements calcium, potassium, magnesium, manganese and zinc, as well as the pH of the soil. The comparison of dry and rainy season regarding the above mentioned element contents; investigations about correlations of the element contents between soil and leaves; time depending differences in the mineral status of palm leaves, which become many years old and grow over a long period of time; concentration differences in young and old leaves of different trees and the connected accumulation and shifting mechanisms of the distinct elements; small scale inhomogeneities of element concentrations in the soil etc.. The title of the thesis is: "Mineral accumulation of five tree species in a lower mountain rain forest in Costa Rica" (Birkelbach 1995; in German).

In this paper the main results of this thesis are presented. On the one hand a comparative inventory of the ion equipment in the leaves of five frequent tree species in one area of the Reserva Biològica Alberto Brenes is shown. Furthermore the nutrient status of the soil is investigated, leading to an ecological evaluation of that area concerning their mineral content. The key point of this investigation is the question, if there are correlations between soil and leaf contents in some cases. For this, results of the obtained mineral contents and statistical tests are presented and discussed.

MATERIAL

The investigated area is situated at the east-southeast edge just outside the Reserva Biológica Alberto Brenes. It is half an hour walk east of the station. The dimension of this area is 1 hectare, up to 50 m in width and 330 m in length. It runs along a ridge in northeast-southwest direction. Compared to the surrounding area the relief of the plot is relatively homogeneous. The altitude at the NE edge is approx. 1000 m above sea level, rising slowly in small waves and reaching approx. 1040 m above sea level at the SW edge. Because the investigated area is located at the rather even and horizontal ridge we can assume climatic homogeneous conditions.

The whole investigated area is divided into 100 squares of 10 x 10 m. This was installed by Leyers and Römich (Leyers, 1993; Römich, 1993) and is used for this investigation with slight alterations. In the following text this is referred to as L/R plot.

In the new relief map of the Reserva Biològica Alberto Brenes (Breckle & Breckle in this volume, published for the first time) the longish plot can be seen at the east edge of the map.

Vegetation: The forest in the investigated area is primary forest in the climax stadium phase. Among the five investigated tree species there are three Arecaceae: *Iriartea deltoidea* Ruíz Lopez & Pavón, *Euterpe macrospadix* Oerst., *Crysophila albida* Bartlett, one Euphorbiaceae: *Acalypha apodanthes* Standley & L.O. Williams and one Clusiaceae: *Symphonia globulifera* L.f.

METHODS

Among all areas close to the station the L/R plot was chosen as the most suitable plot for this investigation. It is important to aim for homogeneity in the site features concerning the investigated plants in order to keep other disturbing influences as small as possible.

The five species were chosen because of their high numbers in the L/R plot. Hence they are typical species for the vegetation of this site.

13 individual trees of every species, approx. 4 to 8 m in height, and exposed to similar light and relief conditions, were marked with a numerical code on small yellow plastic signs (approx. 5 x 5 cm) and samples were taken. If more than 13 individuals per species were corresponding to this conditions, they were chosen by chance.

Samples were taken during the rains from June 3rd to June 6th, 1993. (Since additional samples of the three Arecaceae were taken in the dry season from March 20th to March 22nd, 1993, it was possible to compare some of the results with data from the dry season.)

In case of the Arecaceae several leaflets of one leaf and in case of *Symphonia globulifera* and *Acalypha apodanthes* approximately 25 leaves from different parts of the tree were joined to a mixed sample. In all species only ripe and fully developed leaves without brownish changes in colour were taken.

For the soil samples the content of four drill holes (each 0 to 20 cm deep) was united to one mixed sample. These samples were taken within a radius of 1 m away from the stem.

All leaf and soil samples were dried and vacuum-packed into polyethylene bags and then transported to Germany.

The laboratory work was carried out in the department of ecology at the University of Bielefeld (Germany). At first the pH of the soil samples was determined (in a KCl solution) according to the method of Briceño & Pacheco (1984). Measuring in an electrolyte suspension avoids the typical suspension effects of watery solutions (Kuntze *et al.*, 1988). For the measurement of the share of cations in the soil samples, which are approximately available for the plants, the samples were extracted with ammonium acetate (CH_3COONH_4). The leaf samples were fully mineralised through wet calcination with 65 % HNO_3 in the so called "teflon pressure break down process" (Heinrichs *et al.*, 1986).

All measurements were carried out with Atomic Absorption Spectrophotometers of the company PERKIN-ELMER (PE 380 and PE 5100) under application of the flame technique. In this way the elements calcium (Ca), potassium (K), magnesium (Mg), manganese (Mn) and zinc (Zn) of soil and leaf samples were measured.

Evaluation: All data for the elements were calculated in mmol/kg dw (dry weight) or mmol/g dw. The choice of these units neglects the atomar weight and allows a comparison among the elements by their molarity (number of atoms). In the presentation of the results species names are partly indicated by their genus name, or the first three letters of the genus name respectively.

The statistical evaluation of the present data (and of other results given in the thesis) was done with the software SPSS for Windows 6.0.1. Only nonparametric tests were used.

In all results the mean is indicated by the median. In the figure the median is marked by the bold black line in the middle of the boxplot. The box above and under the median indicates the upper and the lower interquartil. Interquartils convey an impression about the deviation of the distribution. In the sector of the boxes 25 % of the values are above and 25 % are lower than the median. Therefore 50 % of the values are visible at a glance. The upper and lower limit of the plot is signed by the maximum and minimum value of the distribution. Furthermore deviating values (circles) and extreme values (stars) of a distribution are mentioned. See Bühl & Zöfel (1994) and Sachs (1992).

The number of samples is indicated as N in the figures and located under the x-axis.

RESULTS

Soil samples: The concentration of the elements Ca, K, Mg, Mn and Zn in [mmol/kg] are shown in two figures with different scales because of the different dimensions in concentration (Fig. 1 a - b). Zn is shown in Fig. 1 a in [mmol/g].

Ca shows the highest concentration in the soil (among the investigated elements). The median of the Ca concentration is at 4.1 mmol/kg. It is also Ca showing the highest deviation. The minimum of the Ca distribution is even lower as the minima of K and Mg. It touches the dimension of the Mn concentration (Fig. 1 b). The median of the K concentration is at 1.5 mmol/kg. Here the deviation of the distribution is the lowest of the investigated elements. The median of the Mg concentration is at 2.3 mmol/kg. In the case of Mn the median is at 0.27 mmol/kg with a maximum value around the minimum values of Ca, K and Mg. Zinc shows the lowest concentration in the soil. Its median is at 4.1 mmol/g.

Additional to the concentration of the elements, the pH (KCl) (not shown in Fig. 1) was determined as pH 4.35.

The difference between the five tree species locations (n=13 each) concerning the pH and the concentration of the elements in the soil is not significant. But there are high variations in the element concentrations in small scale distances (in the dimension of up to several metres). This variation does not occur with the pH.

Leaf samples: The leaves of the five tree species are showing significant differences in the element concentration (Fig. 2 - Fig. 6). The difference in mineral concentration between the three Arecadeae is remarkable. All investigated elements are accumulated to a higher extent by *Iriartea deltoidea* than by *Euterpe macrospadix*.

Correlations: Table 1 shows the possible correlations of the element concentrations and the K/Ca ratio between soil and leaves of the five investigated species. The correlation coefficient rs and the error probability p, which (in this case) gives evidence about the significance of the correlation coefficient, is also listed in this table.

Tabla 1. Result of the Spearman rank order correlation test for n = 13 samples from the soil and leaves of one species

			Ca	K	Mg	Mn	Zn
Correlation of the molar element conc. between soil and leaves of the five tree species	IRI	r =	0,729	0,058	-0,022	0,357	-0,2076
		p =	0,005**	0,851 ns	0,943 ns	0,231 ns	0,498 ns
	EUT	r =	0,517	0,624	0,234	0,143	-0,137
		p =	0,070 ns	0,023*	0,441 ns	0,641 ns	0,655 ns
	CRY	r =	0,435	0,069	0,195	-0,077	-0,342
		p =	0,138 ns	0,823 ns	0,523 ns	0,803 ns	0,253 ns
	SYM	r =	0,126	0,264	0,160	0,668	-0,306
		p =	0,681 ns	0,384 ns	0,603 ns	0,012*	0,310 ns
	ACA	r =	0,179	-0,424	0,209	0,044	0,366
		p =	0,558 ns	0,149 ns	0,492 ns	0,886 ns	0,212 ns

		IRI	EUT	CRY	SYM	ACA
Correlation of the molar K/Ca ratio between soil and leaves	r =	0,781	0,484	0,522	-0,247	0,081
	p =	0,002**	0,094 ns	0,067 ns	0,415 ns	0,792 ns

IRI = *I. deltoidea*, EUT = *E. macrospadix*, CRY = *C. albida*, SYM = *S. globulifera*, ACA = *A. apodanthes*, r = correlation coefficient: very small correlation: r < 0.2, small correlation: 0.2 <£ r <£ 0.5, medium correlation: 0.5 <£ r <£ 0.7, high correlation: 0.7 <£ r <£ 0.9, very high correlation: r > 0.9, p = error probability: no significance: p > 0.05 ns (ns = not significant), significance: p <£ 0.05*, high significance: p <£ 0.01**, highest significance: p <£ 0.001***

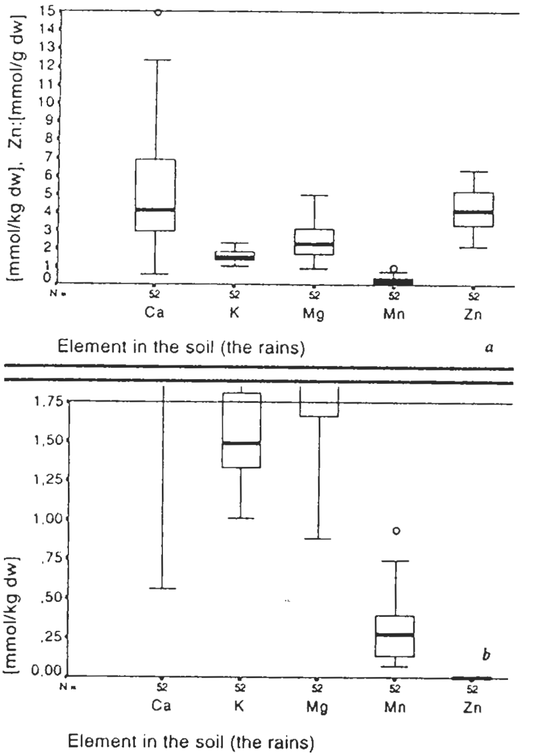

Fig. 1. Concentration of the elements in the soil during the rains (n = 52). In b a smaller sector of concentration with a more stretched scale (up to 1.75 mmol/kg) is shown. The concentration of Zn in a is given in [mmol/g].

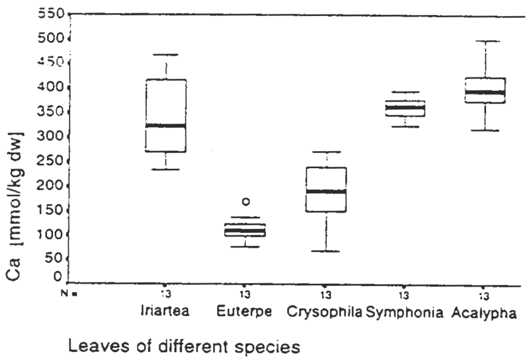

Fig 2. Ca concentration in leaves of different tree species. Exact value of the median in [mmol/kg]: IRI: 323; EUT: 111; CRY: 191; SYM: 364; ACA: 397.

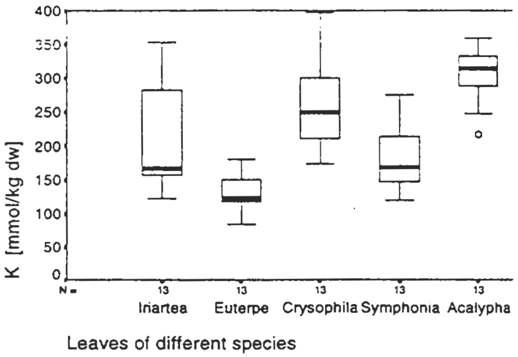

Fig 3 K concentration in leaves of different tree species. Exact value of the median in [mmol/kg]: IRI: 167; EUT: 123; CRY: 251; SYM: 168; ACA: 314.

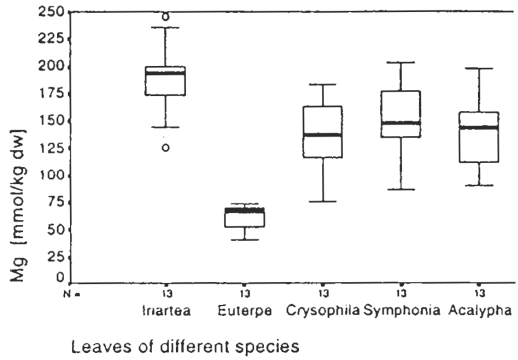

Fig. 4 Mg concentration in leaves of different tree species. Exact value of the median in [mmol/kg] : IRI: 194; EUT: 67; CRY: 138; SYM: 149; ACA: 144.

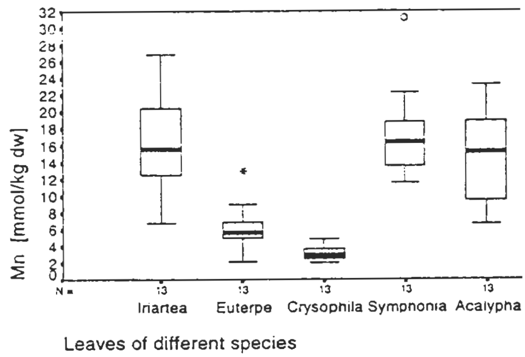

Fig 5 Mn concentration in leaves of different tree species. Exact value of the median in [mmol/kg]: IRI: 15.6; EUT: 5.68; CRY: 2.96; SYM: 16.5; ACA: 15.2.

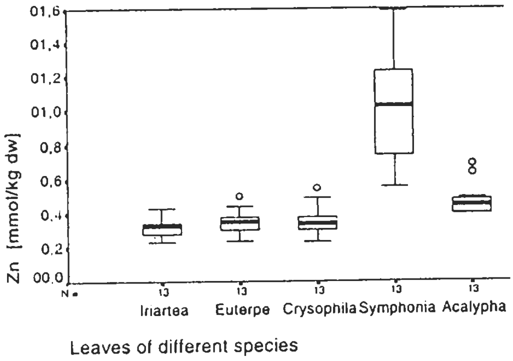

Fig. 6 Zn concentration in leaves of different tree species. Exact value of the median in [mmol/kg]: IRI: 0.33; EUT: 0.35; CRY: 0.34; SYM: 1.03; ACA: 0.45

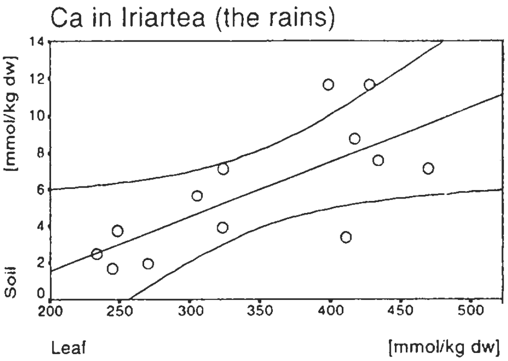

Fig. 7 Distribution of the Ca concentration in soil and leaves in *I. deltoidea* (the rains). Number of soil and leaf samples is n = 13 each. A regression line deduced from the data and a 99 % confidence interval for mean values is shown.

Regarding the element concentration there is a significant medium correlation in two cases: *Euterpe macrospadix* (K) and *Symphonia globulifera* (Mn). In another case - *Iriartea deltoidea* (Ca) - there is a high correlation which is highly significant. Furthermore there is a tendency towards a significant medium correlation concerning the Ca concentration of *Euterpe macrospadix* ($p = 0.070$; see Table 1). The Ca concentrations in soil and leaves of *Iriartea deltoidea* are given exemplary in Fig. 7. In order to allow a better optical estimation of the area of distribution, a confidence interval and a regression line (which is deduced from the data) is drawn. But even without these devices a correlation is easily visible.

Concerning the K/Ca ratio a highly significant high correlation between the soil and leaf values is shown for *Iriartea deltoidea*; for *Crysophila albida* there is a clear tendency towards a significant medium correlation (Table 1).

DISCUSSION

Compared to data of other tropical rain forests of the lower mountain level (for more precise tables to this topic see Birkelbach, 1995), the following picture can be drawn: the moderate acidic soil exhibits low concentrations of Ca, K and Mg, medium concentrations of Mn, and very low concentrations of Zn. The K/Ca ratio of the soil is about to average, furthermore the supply of elements in the soil is quite balanced. In comparison to other soils and in terms of agricultural standards this soil can be described as only moderate fertile. The even profile of the area and the comparison of five tree species locations regarding their ion equipment in the soil, are indicating a large extent of homogeneity. But high variations in the element concentrations in small scale distances are occuring. Because of the climate and the high turnover in the soil, time depending small scale variations of element concentrations in the soil are anticipated.

Element concentrations in the leaves of the investigated species are showing big differences. The high Mn accumulation in *Iriartea deltoidea, Symphonia globulifera and Acalypha apodanthes* is remarkable, as well as the comparatively high Zn accumulation in *Symphonia globulifera*. Moreover the results indicate a comparatively high accumulation of the five examined elements in *Iriartea deltoidea, Symphonia globulifera and Acalypha apodanthes*; in contrast there is only a low accumulation of these elements in *Euterpe macrospadix*. Compared to leaf contents of trees in other rain forests, the obtained data for Ca, K, Mg and Zn are about average, whereas those for Mn are above average. Also the K/Ca ratio is comparatively high, but palms in lowland rain forests show clearly higher K/Ca ratios.

In some of the investigated tree species, a significant correlation between soil and leaves for distinct elements can be observed. These correlations emphasize the dependence of the element concentrations in the leaves from the availability of the same element in the soil. Hence edaphic factors are determining the mineral status in leaves. The same can be said about the K/Ca ratio in some species.

Additionally there are cases without correlations between soil and leaf contents among the investigated species. Some of these species show a very characteristic ion pattern with a rather little variation of the distribution in the leaves. This gives a hint of the plant's ability to maintain a characteristic ion pattern in the leaves against unfortunate external conditions. In this case all different element concentrations and conditions in the leaves must be based on an according selectivity of the ion intake. The obtained element contents in this survey could be explained with taxonomic determined features of the metabolism controlling active transport processes (as. e.g. phloem-mobility). Because of the few investigated species this can at the most be supposed for the rank of the species.

Apart from *Symphonia globulifera*, where no samples were taken during the dry season, all other significant and tendentious significant correlations of the rains, could in no case be confirmed with data of the dry season. Neither there were significant correlations of other results of the dry season. There are different possible explanations, why there are only few correlations and why these only occur during the rains:

In general it is very difficult to detect correlations in soils under comparatively homogeneous conditions. Therefore it would make sense to choose different homogeneous sites to exploit bigger differences in the soil content (differences in other parameters should still be small).

Since the 9 months lasting rainy season represents the normal status regarding the site conditions, the dry season could be a special situation because of specific conditions; hence there could be no correlations or they could be more difficult to detect.

Furthermore a correlation of the element contents between soil and leaves could occur - according to the species - not at the same time, but it could be seperated by a few or more days.

Despite the confirmation of the results by a non-parametric test (Spearman rank order correlation), random can not be fully excluded because of the relativ small number of samples (n = 13 per species and tree location).

Normally the highest element concentrations can be found in a soil depth of 0 to 20 cm (most of the root mass is located here as well). Depending on the soil some elements are sometimes present in higher concentrations in deeper layers (up to 1 m; see WEBER, 1994). Hence it can be expected, that trees cover a part of their nutrient demand from deeper soil layers.

The presented results with optimized methods might be altered and lead to evidence of correlations on a bigger scale in future. With the present correlation coefficients and significance values a tendency to more correlations in Ca, K and Mn might be registered. Weber (1994) gives evidence of correlations in some cases of the Ca, K and Mn content and additionally of the Zn content of tree ferns in the Reserva Biológica Alberto Brenes. Buljovcic (1994) detected two cases, one Ca and one K correlation in trees.

While a significant correlation gives clear evidence for the existence of dependences in the investigated number of samples, a test can not prove this easily in situations, where for example rather unchanging internal conditions are maintained against comparatively changing external conditions. Exact investigations in the laboratory under defined conditions would prove more easily, if active mobilisation of nutrients is caused by interactions of the plant. Pagel *et al.* (1982) assumes in this case stronger activities originated by the plant, than commonly proved by extraction methods.

Outlook: In planning future research in this field it should be clarified, if priorities should lie on a widely scattered but only tendentious insight, or if one should aim for clear evidence in special chosen species. In the first case frequent confirmations of returning trends could lead to a clear image; in the second case the most important task would be to optimize methods in order to give evidence of possible existing correlations.

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