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Interaction between the mineral content and the occurrence number of aquatic fungi in leaves submerged in a stream in the Atlantic rainforest, São Paulo, Brazil

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ABSTRACT - (Interaction between the mineral content and the occurrence number of aquatic fungi in leaves submerged in a stream in the Atlantic rainforest, São Paulo, Brazil). Leaves of *Ficus microcarpa* L. f., *Quercus robur* L., and *Alchornea triplinervia* (Spreng.) Muell. Arg., submerged in a stream of the Atlantic rainforest in the "Reserva Biológica do Alto da Serra de Paranapiacaba", State of São Paulo, Brazil, were collected monthly, from April to November 1990, in order to determine the number of fungal occurrences (zoosporic fungi and aquatic Hyphomycetes), and the content of total N (%), total P (%), K^{+} (%), Ca^{+2} (%), Mg^{+2} (%), S^{+3} (%), Fe^{+3} (ppm), Cu^{+3} (ppm), Mn^{+2} (ppm), Zn^{+2} (ppm), Bo (ppm), Na^{+2} (ppm) and Al^{+3} (ppm). According to the tests of Kruskal-Wallis, Mann-Whitney and Wilcoxon, the means of the mineral content of the three types of leaves were significantly different, except for Mg^{+2} (%), Mn^{+2} (ppm), Zn^{+2} (ppm) and Na^{+2} (ppm). On comparing the mineral content with the number of fungal occurrence, an independence test showed a positive correlation between the presence of zoosporic fungi on the leaves of *A. triplinervia* and the total nitrogen, phosphorus and S^{+3} content, whereas the aquatic Hyphomycetes depended on the amount of Ca^{+2} available. Regarding leaves of *F. microcarpa*, the occurrence of zoosporic fungi was linked to the S^{+3} level, and the presence of aquatic Hyphomycetes, to the content of K^{+}, Ca^{+2}, S^{+3} and Bo. On *Q. robur* leaves, zoosporic fungi showed a positive correlation with the Ca^{+2} content, but a negative one with Fe^{+3} and Al^{+3} levels, while the occurrence of aquatic Hyphomycetes was influenced by the content of Ca^{+2}, Mg^{+2}, Fe^{+3}, Al^{+3}, Mn^{+2}, Zn^{+2} and Na^{+2}. The correlation between the occurrence number of aquatic Hyphomycetes and a high mineral content indicates that their nutritional requirements may be more complex than those of zoosporic fungi. Further studies are still required to understand the implications of this tendency on the diversity of aquatic native mycota.

RESUMO - (Interações entre os teores de elementos minerais e o número de ocorrências de fungos aquáticos em folhas submersas em um riacho na Mata Atlântica, São Paulo, Brasil). Folhas de *Ficus microcarpa* L.f., *Quercus robur* L. e *Alchornea triplinervia* (Spreng.) Muell. Arg., submersas em um riacho na Mata Atlântica da Reserva Biológica do Alto da Serra de Paranapiacaba, no estado de São Paulo, Brasil, foram coletadas mensalmente, de abril a novembro de 1990, para a determinação do número de ocorrências de fungos (fungos zoospóricos e Hyphomycetes aquáticos), teores de N total (%), P total (%), K^{+} (%), Ca^{+2} (%), Mg^{+2} (%), S^{+3} (%), Fe^{+3} (ppm), Cu^{+3} (ppm), Mn^{+2} (ppm), Zn^{+2} (ppm), Bo (ppm), Na^{+2} (ppm) e Al^{+3} (ppm). De acordo com os testes de Kruskal-Wallis, Mann-Whitney e Wilcoxon, as médias dos parâmetros determinados nos três tipos de folhas diferiram significativamente, com exceção de Mg^{+2} (%), Mn^{+2} (ppm), Zn^{+2} (ppm) e Na^{+2} (ppm). Confrontando os teores de elementos minerais com o número total de ocorrências dos fungos, o teste de independência revelou correlação positiva do número de ocorrências dos fungos zoospóricos nas folhas de *A. triplinervia* com os teores de N, P e S^{+3}, enquanto a presença dos Hyphomycetes aquáticos dependeu da disponibilidade de Ca^{+2} nos substratos. Nas folhas de *F. microcarpa*, a ocorrência de fungos zoospóricos relacionou-se com o teor de S^{+3} e a presença dos Hyphomycetes aquáticos aos teores de K, Ca^{+2}, S^{+3} e Bo. Nas folhas de *Q. robur*, os fungos zoospóricos mostraram correlação positiva com o teor de Ca^{+2}, mas negativa com os de Fe^{+3} e Al^{+3}, enquanto a ocorrência de Hyphomycetes aquáticos foi influenciada pelos teores de Ca^{+2}, Mg^{+2}, Fe^{+3}, Al^{+3}, Mn^{+2}, Zn^{+2} e Na^{+2}. A correlação do número de ocorrências dos Hyphomycetes aquáticos com elevado número de teores de elementos minerais pode indicar que as exigências nutricionais desse grupo são mais complexas do que as dos fungos zoospóricos. Estudos subseqüentes ainda são necessários para entender as implicações dessa tendência sobre a diversidade da micota aquática nativa.

Key words - Leaf litter, zoosporic fungi, aquatic Hyphomycetes, Atlantic rainforest, nutritional requirements

Introduction

Information concerning the decomposing potential and nutritional requirements of the aquatic Hyphomycetes has reinforced recognition of their importance for the recycling of mineral content in the aquatic ecosystems (Gessner & Chauvert 1994). On the other hand, very little is known about the decomposing activity, the influence of the chemical properties of the environment, and nutrient requirements of zoosporic fungi in submerged substrates, in spite of the typical aquatic nature of this extensive fungal group. Knowledge about the nutritional requirements of zoosporic fungi, provided by experiments in laboratories (Craseman 1954, Cantino & Turian 1959, Goldstein 1961) might not reflect the actual situation of zoosporic mycota in

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the field, especially in high diversified tropical ecosystems, such as the Atlantic rainforest. Studies of the fungi in decomposing leaves of *Ficus microcarpa* L. f (Schoenlein-Crusius & Milanez 1989), *Quercus robur* L. (Schoenlein-Crusius et al. 1990) and the fungal succession in submerged leaves of *Alchornea triplinervia* (Spreng.) Muell. Arg. (Schoenlein-Crusius & Milanez 1998), revealed an increase of the diversity of the decomposing mycota in response to an intensive replacement or addition of fungal species, including more zoosporic fungi than aquatic Hyphomycetes in the submerged substrates.

The aim of this paper is to evaluate the interaction of the mineral content and the number of occurrence of zoosporic fungi and aquatic Hyphomycetes during the decomposition process of leaves of *Alchornea triplinervia*, *Quercus robur* and *Ficus microcarpa* submerged in a stream in the Brazilian Atlantic rainforest.

Material and methods

The study was undertaken in the Atlantic rainforest in the "Reserva Biológica do Alto da Serra de Paranapiacaba" in the municipality of Santo André, São Paulo state. In a small stream (4 m wide and 50 to 80 cm deep), 400 litter bags (20 x 20 x 1 mm nylon net mesh) containing separately, about 20 g of dried leaves in air temperature (around 20ºC) of *Alchornea triplinervia*, *Quercus robur* and *Ficus microcarpa* were submerged at 20 cm deep at five equidistant (20 meters) sites, to be monthly collected, from April to November of 1990, for the chemical analysis of mineral content and fungal isolation.

Portions of the leaves were oven dried at 60ºC, ground and sent to the Department of Analytical Chemistry of the "Centro de Energia Nuclear para a Agricultura" in the municipality of Piracicaba, SP, for the chemical determination of total N (%), total P (%), K^+ (%), Ca^{+2} (%), Mg^{+2} (%), S^{+3} (%), Fe^{+3} (ppm), Cu^{+3} (ppm), Mn^{+2} (ppm), Zn^{+2} (ppm), Bo (ppm), Na^{+2} (ppm) and Al^{+3} (ppm) content.

The baiting method used to isolate the zoosporic fungi, the technique to observe the development of aquatic Hyphomycetes on the substrates and the individual occurrence of each fungal species on the three kind of leaves were described in detail in a previous paper (Schoenlein-Crusius et al. 1992). From the former study, only the total number of monthly occurrences of zoosporic fungi and aquatic Hyphomycetes was used for the statistical procedures employed here as described in Lehmann & D'Abrera (1975).

The mean of the mineral content among the leaves was compared using the Kruskal-Wallis test, and the comparison between the content of the leaf types "two by two" was done using the Mann-Whitney and Wilcoxon tests. The association between the occurrence of fungi (biotic parameters) and the mineral content of the three leaf species (abiotic parameters) was established through an independence test and expressed by the Spearman correlation coefficient. The statistical analysis were done according to Siegel (1975).

Results and Discussion

The mineral content composition, expressed by the monthly mean (table 1), were significantly different among the three leaf types, according to the Kruskal-Wallis test, except for Mg^{+2}, Mn^{+3}, Zn^{+2} and Na^{+2} (table 2).

According to a comparison among the different leaf types, using the Mann-Whitney and Wilcoxon tests (table 3), the leaves of *A. triplinervia* contained significantly higher levels of K^+, Fe^{+3}, Cu^{+3} and Al^{+3}, and lower total N, Ca^{+2} and S^{+3} levels. *Q. robur* contained higher content of total N, P, S^{+3} and lower K^+, Fe^{+3} and Al^{+3}. The content of Ca^{+2} and Bo were higher, and K^+ lower in the leaves of *F. microcarpa*.

In terms of aquatic fungi, the leaves of *F. microcarpa* contained a higher total number of occurrences of zoosporic fungi, followed by *A. triplinervia* and *Q. robur*. However, the latter leaf type presented the highest total occurrence number for aquatic Hyphomycetes (table 4). The similarity among the mycotas was always above 70% (Schoenlein-Crusius et al. 1992).

Confronting the mineral content (table 1) with the monthly distribution of fungal occurrences (table 4) using the independence test (table 5), it was revealed that in the case of the *A. triplinervia* leaves, the occurrence of zoosporic fungi was positively related to the total N, P and S content, whereas the occurrence of aquatic Hyphomycetes was related to the calcium content.

In a similar way, there is evidence that the occurrence of the zoosporic fungi in the *F. microcarpa* samples was positively related to sulfur content (table 5), justifying the observation of a higher number of zoosporic fungi (table 4) at the same time when the level of sulfur increased during leaf decomposition (table 1).

On the leaves of *Q. robur*, the occurrence of zoosporic fungi was positively correlated to the levels of Ca^{+2} and negatively to the iron content (table 5). The total number of zoosporic fungi (table 4) presented a fluctuation pattern similar to that of the calcium content, reaching maximum figures from April to July, but decreasing sharply from September until the end of the decomposition of the leaves (table 1). On the other hand, the occurrence of aquatic Hyphomycetes may be dependent on the levels of calcium, magnesium, zinc, sodium and aluminum of the substrate.

Table 1. Mean concentrations of mineral elements in leaves of *A. triplinervia*, *F. microcarpa* and *Q. robur* submerged in a stream of the Atlantic rainforest in Paranapiacaba, SP, from April to November of 1990.

Species Mineral elements	April	May	June	July	August	September	October	November
A. triplinervia								
N% (total)	1.49	1.19	1.23	1.72	1.53	1.80	0.62	1.20
P% (total)	0.09	0.06	0.08	0.08	0.10	0.13	0.08	0.09
K^{+} %	0.19	0.12	0.15	0.20	0.19	0.14	0.20	0.13
Ca^{+2} %	0.47	0.17	0.17	0.17	0.14	0.14	0.09	0.17
Mg^{+2} %	0.12	0.07	0.07	0.09	0.08	0.06	0.12	0.05
S^{+3} %	0.03	0.03	0.04	0.03	0.06	0.03	0.03	0.03
Fe^{+3} ppm	8741.00	7451.00	9871.00	9979.50	11390.00	9821.00	14030.00	8267.00
Cu^{+3} ppm	19.70	18.65	19.50	23.80	25.40	23.40	24.10	16.70
Mn^{+2} ppm	136.50	68.50	76.50	94.00	79.00	71.00	71.00	58.00
Zn^{+2} ppm	43.00	31.00	33.00	35.50	41.00	27.00	25.00	20.00
Bo ppm	5.00	5.00	5.00	8.00	5.00	5.00	5.00	5.00
Na^{+2} ppm	170.00	83.50	149.50	143.00	98.00	103.00	107.00	77.00
Al^{+3} ppm	11490.00	9680.00	13010.00	13375.00	14910.00	9827.00	23680.00	9738.00
F. microcarpa								
N% (total)	1.68	1.47	1.53	1.57	1.84	1.26	1.40	1.61
P% (total)	0.07	0.07	0.07	0.08	0.09	0.06	0.09	0.09
K^{+} %	0.14	0.11	0.09	0.10	0.08	0.09	0.11	0.08
Ca^{+2} %	1.32	0.47	0.39	0.49	0.35	0.23	0.29	0.19
Mg^{+2} %	0.14	0.08	0.07	0.11	0.06	0.05	0.09	0.05
S^{+3} %	0.03	0.03	0.02	0.06	0.14	0.08	0.07	0.05
Fe^{+3} ppm	3882.50	6718.00	7316.50	7252.50	7989.50	5914.00	11560.00	7782.00
Cu^{+3} ppm	14.90	16.30	15.60	18.60	17.20	13.50	20.60	15.75
Mn^{+2} ppm	107.50	74.00	62.50	80.00	64.00	51.00	71.00	43.00
Zn^{+2} ppm	49.50	40.50	43.00	71.00	35.50	24.50	30.00	30.50
Bo ppm	54.00	19.00	18.00	16.00	14.50	11.00	25.50	13.00
Na^{+2} ppm	151.50	110.50	148.50	178.50	90.50	92.50	109.00	117.50
Al^{+3} ppm	6135.00	8586.00	10570.00	9114.50	9726.50	8514.50	14595.00	8067.00
Q. robur								
N% (total)	2.90	2.42	2.39	2.86	2.75	2.21	1.94	2.53
P% (total)	0.10	0.09	0.08	0.10	0.10	0.11	0.10	0.10
K^{+} %	0.09	0.10	0.11	0.09	0.11	0.09	0.08	0.07
Ca^{+2} %	0.51	0.73	0.40	0.43	0.17	0.11	0.17	0.18
Mg^{+2} %	0.13	0.10	0.08	0.13	0.05	0.04	0.06	0.04
S^{+3} %	0.06	0.07	0.05	0.14	0.07	0.15	0.09	0.11
Fe^{+3} ppm	2280.00	5630.00	6003.00	5391.00	8374.00	7853.00	8136.00	6491.00
Cu^{+3} ppm	14.95	20.60	19.10	20.6	20.9	21.50	16.25	16.20
Mn^{+2} ppm	347.00	289.50	154.50	322.00	164.00	127.50	61.50	57.50
Zn^{+2} ppm	50.50	78.00	52.50	62.00	31.50	19.50	22.50	30.50
Bo ppm	11.00	8.50	6.50	10.00	11.00	6.50	9.50	8.00
Na^{+2} ppm	152.50	164.00	274.00	128.00	104.50	93.50	106.50	117.50
Al^{+3} ppm	2728.50	7313.50	7947.50	6939.00	10209.50	9228.00	8868.00	7314.50

Table 2. Comparisons among the means of the mineral elements of leaves of *A. triplinervia*, *F. microcarpa* and *Q. robur* submerged in a stream of the Atlantic rainforest in Paranapiacaba, SP, from April to November of 1990, by the Kruskal-Wallis test. P = critical value; * = significant at 5%; NS = not significant.

Mineral elements	Chi-Square	P	Significance
N% (total)	16.4184	0.0003	*
P% (total)	8.4680	0.0145	*
K^+ %	14.5059	0.0007	*
Ca^{+2} %	7.2070	0.0272	*
Mg^{+2} %	0.1256	0.9391	NS
S^{+3} %	10.8352	0.0044	*
Fe^{+3} ppm	10.1150	0.0064	*
Cu^{+3} ppm	8.4347	0.0147	*
Mn^{+2} ppm	5.5897	0.0611	NS
Zn^{+2} ppm	1.2279	0.5412	NS
Bo ppm	19.9207	0	*
Na^{+2} ppm	1.4269	0.4900	NS
Al^{+3} ppm	1.1150	0.0039	*

Although *Q. robur* and *F. microcarpa* are exotic plant species for the Atlantic rainforest in Paranapiacaba, the nitrogen content found in the present study is similar to the rates situated between 2% and 4%, encountered in the leaf litter of native vegetation (De Vuono et al. 1989). In all types of leaves, nitrogen levels showed a tendency to decrease at the beginning of decomposition, followed by an increase at the end of the process (table 1). The nitrogen content of leaves has been considered an important parameter for the decomposition rate, being connected with an increase of palatability for invertebrates (Wylie 1987).

The influence of the total nitrogen content of the leaves on zoosporic fungi may be connected with the fact that Mastigomycota has been considered one of the most primitive group, being able to utilize inorganic nitrogen compounds, such as nitrate and ammonia (Cantino & Turian 1959). For instance, *Nowakowskiella elegans* and *N. ramosa* are able to metabolize inorganic nitrogen as nutrient source, colonizing substrates with high nitrogen levels (Goldstein 1961). In the case of the aquatic Hyphomycetes, some species such as *Anguillospora longissima* and *A. gigantea* may utilize nitrate as a nitrogen source and sulfates for sulfur requirements (Ranzoni 1951). Nitrogen and lignin content have been positively connected to the diversity of aquatic Hyphomycetes in several streams in Europe (Gessner & Chauvet 1994).

Table 3. Comparisons (two by two) among the means of the mineral content in leaves of *A. triplinervia* (A), *F. microcarpa* (F) and *Q. robur* (Q) submerged in a stream of the Atlantic rainforest in Paranapiacaba, SP, from April to November of 1990, by the the Mann-Whitney (U) - Wilcoxon (W) tests. Z = critical values; * = significative at 5%; $_{NS}$ = not significative.

Mineral elements Comparisons	U	W	Z	Significance
N% (total)				
A x F	17.50	53.5 - 1.5239	0.1275	NS
A x Q	0	36.0 - 3.3607	0.0008	*
F x Q	0	36.0 - 3.3607	0.0008	*
P% (total)				
A x F	21.00	79.0 - 1.1673	0.2431	NS
A x Q	16.00	52.0 - 1.7160	0.0862	NS
F x Q	5.00	41.0 - 2.8674	0.0041	*
K^+ %				
A x F	3.00	97.0 - 3.0546	0.0023	*
A x Q	0	100.0 - 3.3706	0.0008	*
F x Q	24.00	76.0 - 0.8490	0.3959	NS
Ca^{+2} %				
A x F	5.50	41.5 - 2.7913	0.0052	*
A x Q	18.00	54.0 - 1.4834	0.1380	NS
F x Q	24.00	76.0 - 0.8408	0.4005	NS
S^{+3} %				
A x F	19.50	55.5 - 1.4034	0.1605	NS
A x Q	1.00	37.0 - 3.3454	0.0008	*
F x Q	15.50	51.5 - 1.7405	0.0818	NS
Fe^{+3} ppm				
A x F	9.00	91.0 - 2.4155	0.0157	*
A x Q	4.00	96.0 - 2.9406	0.0033	*
F x Q	26.00	74.0 - 0.6301	0.5286	NS
Cu^{+3} ppm				
A x F	6.00	94.0 - 2.7305	0.0063	*
A x Q	18.00	82.0 - 1.4714	0.1412	NS
F x Q	16.00	52.0 - 1.6853	0.0919	NS
Bo ppm				
A x F	0.00	36.0 - 3.5082	0.0005	*
A x Q	2.50	38.5 - 3.2420	0.0012	*
F x Q	1.00	99.0 - 3.2677	0.0011	*
Al^{+3} ppm				
A x F	10.00	90.0 - 2.3105	0.0209	*
A x Q	3.00	97.0 - 3.0456	0.0023	*
F x Q	19.00	81.0 - 1.3653	0.1722	NS

Khulbe & Bhargava (1983) noted a negative relationship between nitrate and sulfate levels and zoosporic fungi frequencies in the Naukuchiyatal lake. Also direct correlation between the availability of phosphate in the aquatic environment and the fungal frequency was observed, suggesting that the decomposition of ammonium and organic acid may fit the nitrogen requirements of aquatic mycota.

Table 4. Total number of occurrences of zoosporic fungi and aquatic Hyphomycetes on leaves of *A. triplinervia, F. microcarpa* and *Q. robur* submerged in a stream of the Atlantic rainforest in Paranapiacaba, SP, from April to November of 1990.

Fungi	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	total
				A. triplinervia					
Zoosporic fungi	6	4	5	1	7	5	1	4	33
Hyphomycetes	7	4	3	0	3	3	1	1	22
				Q. robur					
Zoosporic fungi	6	6	3	3	1	3	3	3	28
Hyphomycetes	6	6	3	3	2	1	3	1	25
				F. microcarpa					
zoosporic fungi	5	4	2	4	5	7	5	2	34
Hyphomycetes	5	4	3	2	2	2	2	2	22

Tendencies for the accumulation or leaching of the phosphorus content of leaves was not observed in the present study (table 1). The values of the element were significantly higher for the *Q. robur* leaves (table 2). It is difficult to understand the relationship between zoosporic fungi and the phosphorus content in substrates, in view of the conflicting results mentioned in the literature. For instance, the presence of *Karlingia asterocysta* may be dependent on the availability of chitin and N-acetil-glucosamine (NAG) and the absence of phosphate (Murray & Lovett 1966). On the other hand, concentrations of 0.01 M of phosphate may promote the growth of colonies of *Cladochytrium replicatum*, while the presence of 0.1 M of the ion was toxic for the same species (Willoughby 1962). The presence of 0.005 M of phosphate was considered ideal for the development of almost all zoosporic fungi (Whiffen 1945), but 0.003 M of the ion showed toxic effects on *Chytridium* sp. and *Macrochytridium botrydioides* (Craseman 1954).

Some aquatic Hyphomycetes may produce enzymes to decompose organic phosphorus compounds, which explains the increase of phosphorus content during leaf decomposition by microbial (input) activity (Suberkropp & Jones 1991).

The calcium content was significantly different among the three species, being higher in *F. microcarpa* at the beginning of the decomposition process (table 1). Calcium levels decreased in all leaf species, probably due to leaching, a common process in submerged leaves (Day 1982).

Table 5. Independence Test for comparisons of association of zoosporic fungi and aquatic Hyphomycetes with the mineral content in leaves of *A. triplinervia* (A), *F. microcarpa* (F) and *Q. robur* (Q) submerged in a stream of the Atlantic rainforest in Paranapiacaba, SP, from April to November of 1990. D = critical values; Rs = Spearman correlation coefficient; * = significant at 5% level.

Species Fungi	Mineral content	D	Significance	Rs
Alchornea triplinervia				
zoosporic	N % total	23.5	0.029*	0.72
	P % total	29.0	0.036*	0.65
	S^{+3} %	28.5	0.049*	0.66
Hyphomycetes	Ca^{+2} %	33.5	0.049*	0.66
Ficus microcarpa				
zoosporic	S^{+3}%	27.0	0.025*	0.68
Hyphomycetes	K^{+}%	28.0	0.043*	0.67
	Ca^{+2}%	24.0	0.036*	0.71
	S^{+3}%	130.5	0.021*	-0.55
	Bo^{+}ppm	24.0	0.035*	0.71
Quercus robur				
zoosporic	Ca^{+2}%	19.0	0.022*	0.77
	Fe^{+3} ppm	129.5	0.021*	-0.54
Hyphomycetes	Ca^{+2}%	14.5	0.014*	0.83
	Mg^{+2} %	10.0	0.009*	0.88
	Fe^{+3} ppm	134.0	0.041*	-0.60
	Mn^{+2} ppm	23.0	0.029*	0.73
	Na^{+2} ppm	23.0	0.029*	0.73
	Al^{+3} ppm	134.0	0.041*	-0.60
	Zn^{+2} ppm	24.0	0.031*	0.71

Willoughby (1962) noted that small amounts of calcium and magnesium, placed into the culture media, promoted only a small development of *Cladochytrium replicatum* colonies. Adding metionine and sulfate, growth increased significantly. Also the input of iron showed a positive effect on fungal growth, as did introducing 5 ppm of calcium and magnesium in the culture media. On the other hand, concentrations below 0.4 mM of calcium and 0.2 mM of magnesium limited the growth of *Catenaria anguillulae* (Nolan 1970).

The high development of colonies of aquatic Hyphomycetes in alkaline environments may be justified by enhancing the production of pectinlyases and pectin esterases in the presence of calcium in the water (Chamier & Dixon 1982). Increased calcium levels in water may also decrease the lethal or toxic effects of cadmium on aquatic Hyphomycetes (Abel & Barlöcher 1984).

Achlya klebsiana usually do not grow without magnesium, calcium, zinc, manganese, iron and sulfate (Reischer 1951). The development of *Allomyces macrogynus* depends on the presence of calcium in the culture media, as in the case of *Allomyces arbuscula* (Ingraham & Emerson 1954). *Aphanomyces cochlioides* depends on the iron content to grow, it is damaged by high copper levels, but is not influenced by variations of other mineral content (Herr 1973).

The sulfur content was significantly higher in *Q. robur* leaves (table 2). The behavior of this element changed according to the type of substrate (table 1). The sulfur levels of the *A. triplinervia* leaves showed little variation during decomposition, while in *F. microcarpa* and especially in *Q. robur* leaves, a tendency for the accumulation of sulfur was observed.

Some chytrids have the ability to reduce sulfates, as sulfur sources for nutrition or enzymatic activators (Cantino & Turian 1959). *Cladochytrium replicatum* grows strongly in the presence of sulfates in a culture media (Willoughby 1962). Some species of Saprolegniales usually depend on the presence of organic sulfate compounds for nutrition (Cantino & Turian 1959).

The leaves of *A. triplinervia* retained a higher level of potassium content after submergence (table 2), in spite of the mobility of the element. Day (1982) observed a decrease of the potassium content in submerged leaves, followed by an accumulation of the nutrient probably explained by microbial metabolism.

The boron content was significantly different among the studied leaves, decreasing sharply on *F. microcarpa* and *Q. robur*, whereas in *A. triplinervia* the level remained fairly the same during decomposition (table 1). *F. microcarpa* leaves contained higher levels of the element followed by *Q. robur* and *A. triplinervia* (table 2).

Alchornea triplinervia retained the highest content of Fe^{+3}, Cu^{+3} and Al^{+3} (table 1). Accumulation of these elements was detected in all substrates, reaching very high levels, when compared with other values (2.000 to 5.000 ppm) mentioned for the Atlantic rainforest (De Vuono et al. 1989). Absorption, precipitation and microbial activity (especially the reduction of sulfates) may be responsible for the accumulation of some metals in soil and leaf litter (Williams & Gray 1974).

It seems possible that aquatic Hyphomycetes may be more sensitive to the variation of the mineral content than the zoosporic fungi, in view of the high correlation coefficients found for the first group with some of the elements. There is little information about their nutrition habits in their environment, due to the extreme limitations on collecting data under such conditions.

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