Microbial Respiration and Biomass

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1. Introduction

Microorganisms are the most abundant organisms in soil and litter layers. Their biomass is an important structural element of the soil compartment. In the northern hemisphere more than 80 % of the non-plant biomass of soil is provided by microorganisms. Moreover microorganisms play an important role in the decomposition of organic matter and in the cycling of nutrients, thus fulfil essential ecosystem functions. There are only few data available on the microbial biomass and activity in tropical forest soil and litter (Yang & Insam 1991, Feigl et al. 1995, Wood 1995).
The aim of the study was to determine the microbial biomass and their metabolic activity of soil and plant litter of different tropical forest types: a primary and a secondary forest and an abandoned plantation of rubber trees (Seringueira) which was used as a polyculture forestry research area since 1992.

2. Study sites and methods

Study sites

Study sites were four plots of three different forest systems - one plot of 40 x 40 m in a primary forest (FLO), one plot of 40 x 40 m in a nearby secondary forest (growing since 1984, SEC) and two plots, each 32 x 48 m of polycultures (POA, POC), where 4 different tree species of commercial use have been planted in rows. In the polyculture plots the tolerated secondary vegetation (mainly *Vismia* spp., Guttiferae) still dominated the stand and especially the litter production (Beck et al. 1998; Höfer et al. 1999).

Soil sampling

Every three months twenty soil cores (dia 6.5 cm, length 15 cm) were taken randomly from each experimental site and separated into the layers 0-5 cm and 5-15 cm. In the laboratory soil was sieved (<4 mm) and stored at 6-8° C for max. 2 weeks. Soil respiration was measured before (basal respiration) and after adding glucose (substrate-induced respiration, SIR). From the SIR values microbial biomass was calculated according to the formula described by Anderson and Domsch (1978).

Litter sampling

Leaf litter material was sampled randomly from the surface of the field plots and also from litter bags containing leaf litter of *Vismia spec.* that were exposed on the soil surface of the experimental plots. In the laboratory the litter was cut with scissors into small pieces (approx. 2 cm) and pre-incubated at a water content of 300 % (based on litter dry weight) and 28° C for one week before measurement of respiration.

Respiration Measuring Device:

The respiration of soil and litter samples was determined by measuring the carbon dioxide production over time via infra-red gas analysis in a continuos flow through system at a constant flow rate of 300 mL fresh air per minute.
A portable computerised photosynthesis measuring system HCM-1000 (Heinz Walz GmbH, Effeltrich, Germany) was used. The central unit of the system consists of an infra-red gas analyser (IRGA), a peristaltic air pump, a mass flow meter and is connected to a measuring chamber (cuvette). It works in an open flow mode (differential mode) measuring the difference between the CO_2 concentration of the ambient air before and after passing the cuvette. The system is controlled via a computer. To measure soil respiration the central unit was connected to a specially designed rag containing 17 cuvettes. Each cuvette was connected via tubing and solenoid valves to the central unit. A special software allowed to switch the soil or litter containing cuvettes alternately to the IRGA. Each soil or litter sample was measured once within one hour over a period of up to 24 hours.

Microbial respiration was calculated according to (1):

(1) Respiration [nL CO_2 min^{-1} g^{-1} soil] = $(C * F) / S$

where C = IRGA measured CO_2 –value [ppm]
F = Flow rate through cuvette [mL/min]
S = Soil dry weight [g]

Microbial biomass was calculated according to (2):

(2) Microbial biomass (Cmic) [µg Cmic g^{-1} soil] = $(R * 40.04) + 0.37$

where R = Respiration [µL CO_2 g^{-1} h^{-1}]

3. Results

Soil

The highest "maximum initial response" of substrate-induced respiration (SIR) appeared at a glucose concentration of 8 mg/g soil dry weight (Fig. 1). SIR exceeded the basal respiration (0 mg Glucose) by a factor of approximately 7 (Fig. 1).
Biomass results are summarized in Table 1 for the top soil 0 - 5 cm and in Table 2 for the 5-15 cm soil layer. The overall microbial biomass in the upper soil layer (0-5 cm) appears to be low as compared to forest soils of the temperate zone (e.g. Joergensen et al. 1995). There was no statistically significant difference between the four experimental sites. Also there was no seasonal change in the biomass detectable. The amount of microbial biomass in the lower soil layer (5-15 cm) was about half of the biomass found in the top soil.

Litter

The highest "maximum initial response" of substrate-induced respiration (SIR) of the litter material appeared at a glucose concentration of 50 mg/g soil dry weight (Fig. 2). SIR of the litter exceeded the basal respiration by a factor of approximately 3. Compared to the soil basal respiration of the litter was up to 70 times higher (Fig. 2). There was no statistically significant difference in the basal respiration activity of the litter exposed on the different fields. Microbial biomass of *Vismia* litter was highest in the medium and fine mesh size litterbags exposed in the primary forest (Fig. 3 – Fig.5). In SEC and POA, there was no difference between the coarse, medium, and fine litterbags.

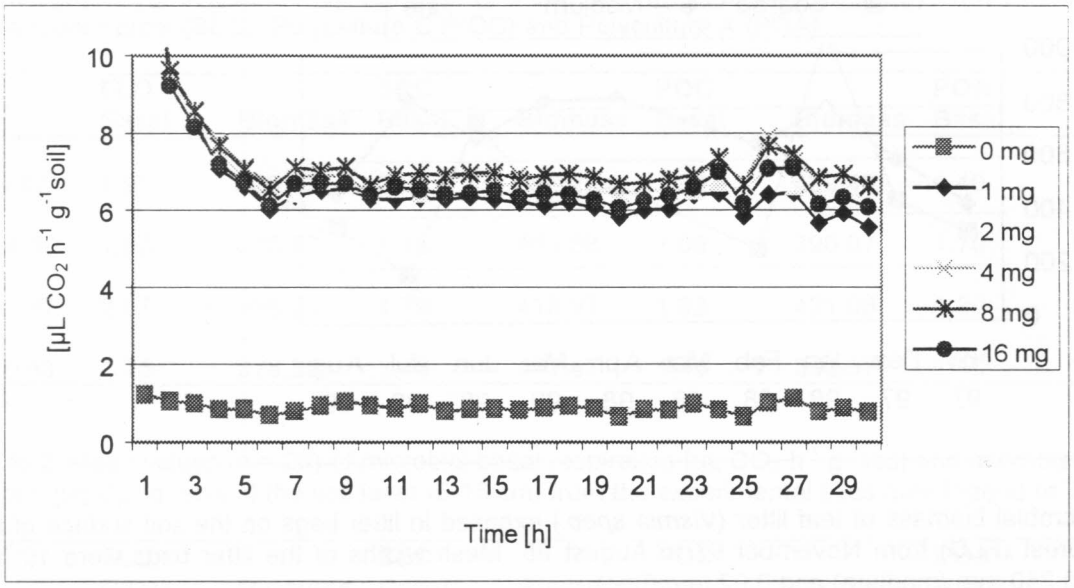

Fig.1: Substrate-induced respiration of soil (0-5 cm) from the primary forest (FLO) after adding different amounts of glucose [mg/g soil dry weight].

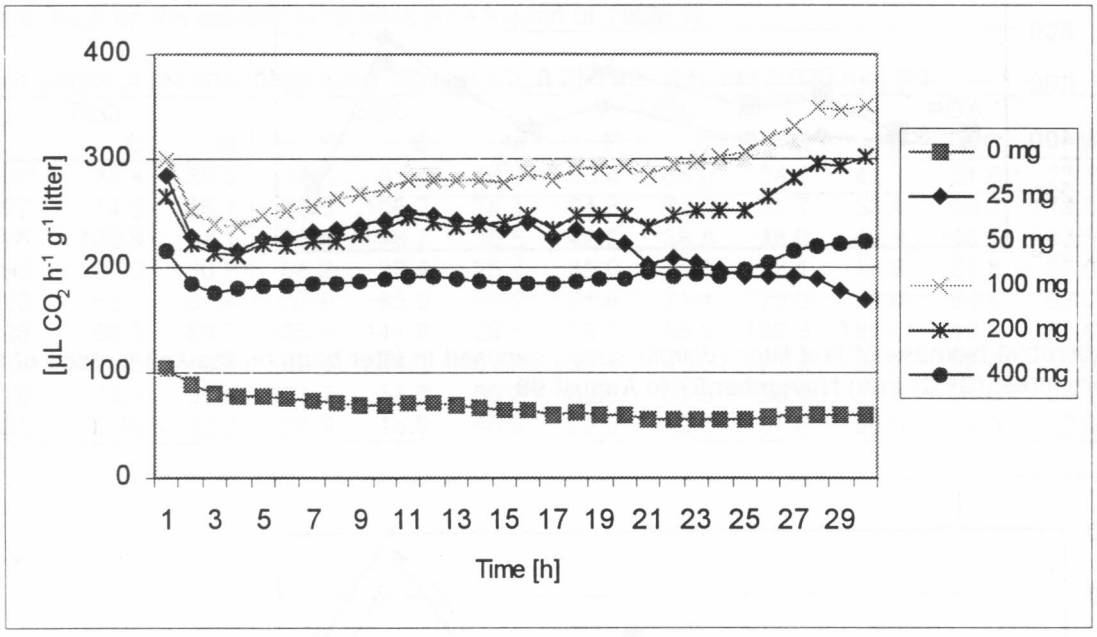

Fig.2: Substrate-induced respiration of litter from the primary forest (FLO) after adding different amounts of glucose [mg/g litter dry weight].

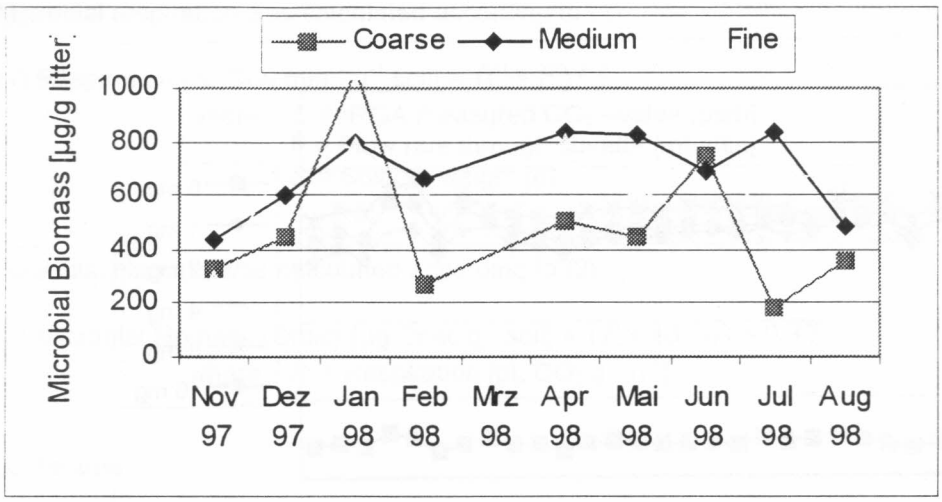

Fig. 3: Microbial biomass of leaf litter (*Vismia spec.*) exposed in litter bags on the soil surface of the primary forest (**FLO**) from November 97 to August 98. Mesh widths of the litter bags were 10 mm (coarse), 0.250 mm (medium) and 0.02 mm (fine).

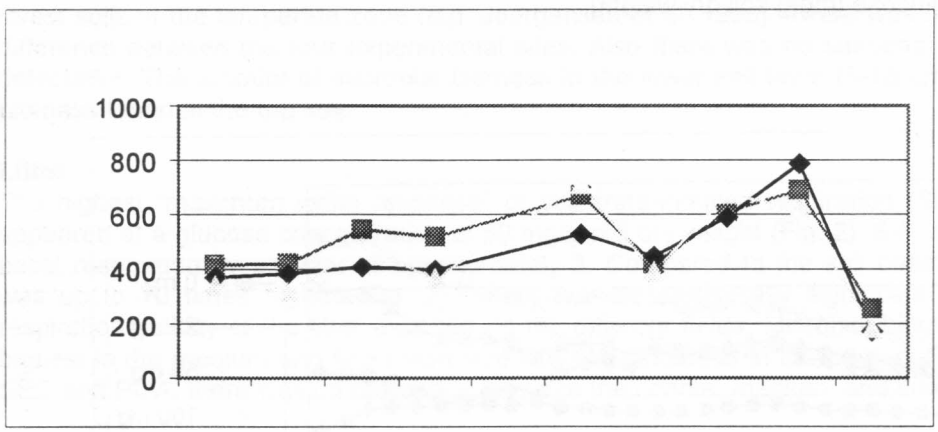

Fig. 4: Microbial biomass of leaf litter (*Vismia spec.*) exposed in litter bags on the soil surface of the secondary forest (**SEC**) from November 97 to August 98.

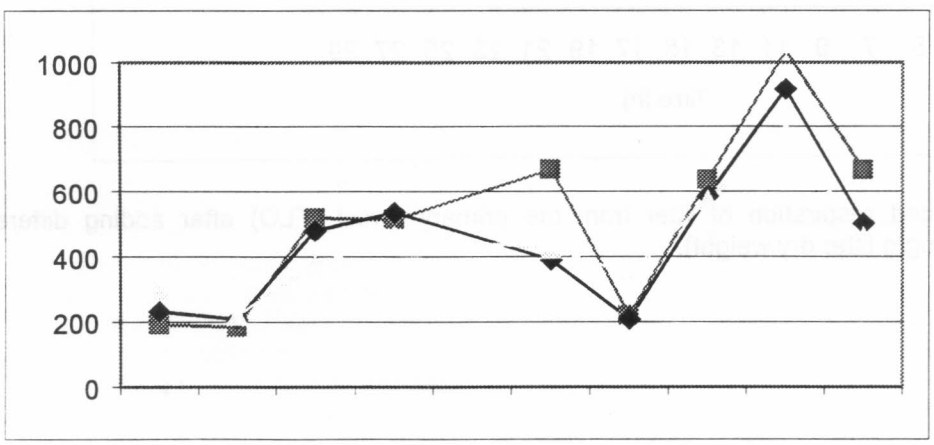

Fig. 5: Microbial biomass of leaf litter (*Vismia spec.*) exposed in litter bags on the soil surface of the polyculture (**POA**) from November 97 to August 98.

Table 1: Mean values (n = 20) of microbial basal respiration [µL CO_2 h^{-1} g^{-1}soil] and microbial biomass carbon [µg C_{mic} g^{-1}soil] of the top soil layer (0-5 cm) from the experimental sites Primary Forest (FLO), Secondary Forest (SEC), Polyculture C (POC) and Polyculture A (POA).

	FLO		SEC		POC		POA	
	Basal	Biomass	Basal	Biomass	Basal	Biomass	Basal	Biomass
July 97	1.91	426.13	2.07	398.29	1.99	429.46	1.40	454.82
Sept. 97	1.52	385.63	1.13	464.88	1.09	390.07	1.70	503.71
Dec. 97	2.07	396.23	1.79	418.97	1.62	421.08	1.90	510.26
Mar. 98	1.75	378.80	1.48	411.47	1.40	393.37	1.48	370.30

Table 2: Mean values (n = 20) of microbial basal respiration [µL CO_2 h^{-1} g^{-1}soil] and microbial biomass carbon [µg C_{mic} g^{-1}soil] of the soil layer (5-15 cm) from the experimental sites (see legend of Table 1).

	FLO		SEC		POC		POA	
	Basal	Biomass	Basal	Biomass	Basal	Biomass	Basal	Biomass
07/97	0,95	231,32	0,98	217,90	0,91	247,98	0,80	275,05
09/ 97	0,62	200,06	0,23	182,93	0,43	227,97	0,96	289,08
12/97	0,71	195,38	0,67	203,37	0,48	233,97	0,64	261,52
03/98	2,40	225,78	1,80	214,91	0,71	235,69	3,42	211,17

Table 3: Mean values of microbial basal respiration [µL CO_2 h^{-1} g^{-1}litter] of *Vismia spec.* litter exposed in litter bags on the experimental sites (see legend of Table 1).

Mesh widths of the litter bags were: 10 mm (C), 0.250 mm (M) and 0.020 mm (F).

	FLO			SEC			POC			POA		
	C	M	F	C	M	F	C	M	F	C	M	F
11/ 97	36.4	38.5	34.3	67.4	60.4	55.4	68.0	64.1	42.7	24.0	23.1	27.8
12/97	74.5	86.7	86.3	106.3	74.1	94.3	74.9	81.7	53.4	66.2	119.8	120.1
01/98	132.9	84.1	86.9	48.7	35.6	42.2	39.8	38.6	42.3	46.5	43.5	44.4
02/98	27.0	50.7	58.2	38.4	25.7	35.9	21.8	38.1	18.8	27.8	38.0	37.5
04/98	61.1	61.4	67.9	53.0	44.6	61.4	71.4	79.0	80.0	64.4	63.0	64.8
05/98	63.5	89.7	126.0	147.9	129.1	156.1	138.0	122.3	181.4	119.2	85.6	81.7
06/98	62.6	46.0	67.9	54.3	61.4	60.1	41.3	71.2	84.3	62.4	86.6	81.3
07/98	24.8	95.6	71.7	55.3	56.2	52.5	51.3	56.4	81.8	61.6	88.1	91.3
08/98	1.16	22.3	28.9	15.0	45.6	22.9	42.6	31.0	35.6	32.5	2.0	43.9

4. Discussion

It is assumed that the low amounts of soil microbial biomass found in the investigated plots are assumed are due to the low pH of the soil. Microbial biomass of the top soil (0-5 cm) was higher compared to the lower soil layer (5-15 cm). This could be expected since the amount of organic material and nutrients in soil also decreases with the depth. Microbial biomass did not differ significantly between the 4 investigated forest types. Therefore all calculations given below are based on the average microbial biomass of 422 µg g^{-1} soil of the 0-5 cm soil profile. Assuming an average soil density of 1g cm^{-3} and an average carbon content of 3.5% the microbial biomass carbon (Cmic) in the 0-5 cm soil layer comprises 21.1 g C m^{-2}. This would represent 1.2% of the C-stock in soil. Compared to the results of Feigl et al. (1995) who found the ratio to be 3-4% for soils of the same region the values reported here seem to be small. The reason for this is not clear.

For temperate soils the ratio between organic carbon (Corg) and Cmic usually is in the range of 1-4 % (Domsch 1992). Grisi et al (1998) found that the organic matter was mineralised more rapidly in temperate than in the tropical soils and concluded from this, that the organic matter in tropical soils was more degraded or humified than in temperate soils.

Respiration of the litter was measured under standardized moisture conditions. Under field conditions, differences in respiration activity may occur due to spatial and temporal differences in the actual moisture of the litter.

The average microbial respiration activity (basal respiration) was 7 g CO_2 –C a^{-1} kg^{-1} dry mass for the top soil (0-5 cm) and 319 g CO_2 –C a^{-1} kg^{-1} dry mass for the leaf litter Thus, the yearly loss of C via soil respiration can roughly be calculated to be 359 g m^{-2} yr^{-1}. This value is in accordance with Medina et al. (1980) who measured soil respiration in the field and calculated the C-loss of an Amazonian laterite forest soil to be 273 g m^{-2} yr^{-1}. For a tropical forest soil in India the C-loss via soil respiration was calculated to be 683 g m^{-2} yr^{-1} (Rajvanshi & Gupta, 1986).

5. Conclusions and outlook

The most important results gained so far when investigating the microbial biomass and respiration of the four EMBRAPA plots can be summarized as follows:

The differences between the four investigated plots (FLO, SEC, POA, POC) with regards to the microbial biomass were found to be negligible. Biomass of the soil and of the litter as determined via the SIR method was relatively low. Due to the low pH of the investigated soil, the fungal part of the microbial biomass may be more important than bacteria.

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