Final report on the
6th Tropical Ecology Field Course
Venezuela 2012

Instytut Nauk o Środowisku Uniwersytetu Jagiellońskiego (INoS UJ)

Muzeum Zoologiczne Uniwersytetu Jagiellońskiego (MZ UJ)

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Kraków – Caracas – Maracay

Respiration rates of large sized Arthropoda of tropical cloud forest, Venezuela

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Report submitted in partial fulfilment of the requirements for the course “Tropical ecology – field course” (WBNZ-850), at the Faculty of Biology and Earth Sciences, Jagiellonian University, 2012.

Abstract

Metabolic levels of large cloud forest invertebrates: diplopods, cricets, opilionids (undefined species), a harlequin beetle (*Acrocinus longimanus*) and another large cerambycid beetle (not determined) were measured as CO_2 production rates. Diplopods have lower metabolic rates than insects (crickets and beetles). The exponent of allometric regression to body mass amounted to 0.6352 and was lower than literature values for Diplopoda. Simple respiration chamber equipped with CO_2 diffusion sensor (a soil respirometer) proved to be reliable and useful for metabolic rate measurements in large invertebrates at field conditions.

Key words: Diplopoda, Cerambycidae, Orthoptera, respiration, cloud forest

1. Introduction

Metabolic rates of invertebrate are studied in connection with the effects of body mass and age (Hack 1997, Reichle 1967), photoperiod (Boccardo and Penteado 1997), temperature (Webb and Telford 1994), etc. Some studies were done only to measure metabolic rates and to find some interspecies differences (Brueggl 1992) or body mass allometry (Frears et al. 1996). Only few of them were done in tropical areas (Frears et al. 1996, Webb and Telford, 1994, Boccardo and Penteado, 1997. Few comparative studies of metabolic rates in various taxa of Arthropoda have been made (e.g. Frears et al. 1996). None of the studies published so far included the gigantic tgropical species belonging to the common taxa. On the other hand, litter and soil dwelling arthropods, including Millipedes, as detrivores have a great influence on soil litter respiration (Brueggl 1992, Kaneko 1999).

The aim of study was to measure the metabolic rates of large Diplopoda, common in montane cloud forest, to find allometric relation to body mass and to compare them with other Arthropoda occurring in the same ecosystem at the same time. Additionally, this attempt was aimed at testing the field soil respirometer as a possible tool to measure metabolic rates of individual, large sized invertebrates at field conditions.

2. Study area and methods

2.1. Study locality

The animals were collected in cloud forest in the neighborhood of Rancho Grande Biological Station in Henri Pittier National Park, , Cordillera de la Costa, Venezuela (10° 21' N, 67° 41' W; Fig. 1). In the forest and also in old buildings of biological station the animals was quite abundant.

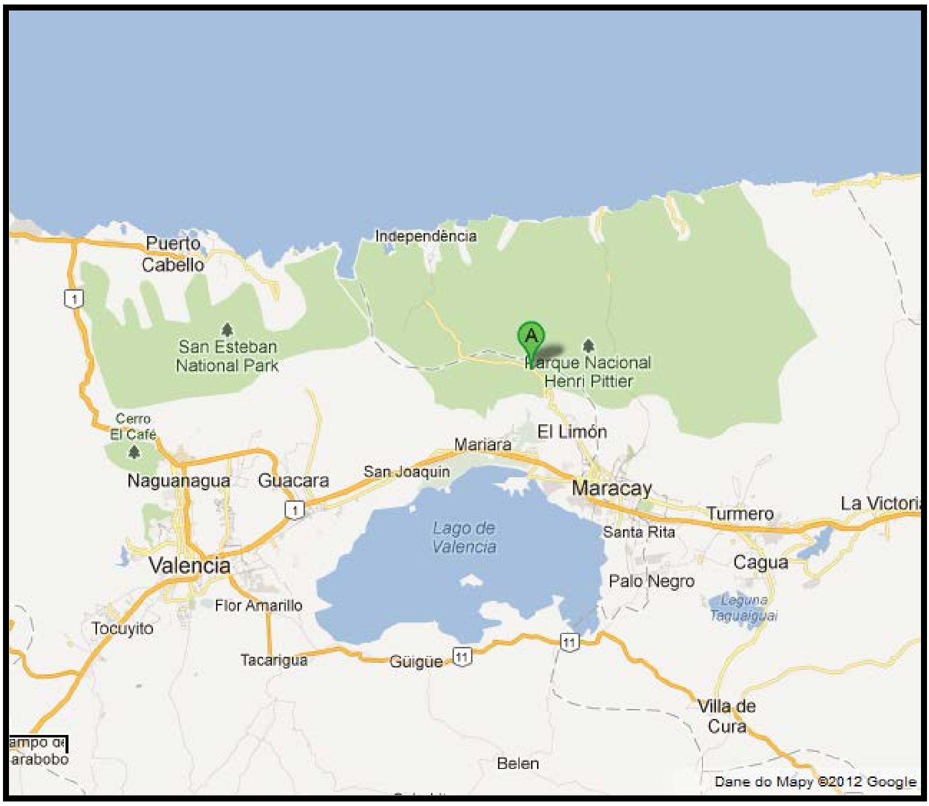

Fig. 1. Situation of Rancho Grande Biological Station (A) in Henri Pittier National Park, Cordillera de la Costa, Venezuela

2.2. Animals studied

In the forest and in the vicinity of buildings 18 large (body mass>4 g) individuals of a single species of Diplopoda, Pselaphognatha (species not determined, Fig. 2) . Additionally, six individuals of large Orthoptera (crickets, species not determined, Fig. 3), five individuals of large Opilionida (not determined, Fig. 4), 3 individuals of *Acrocinus longimanus* (Coleoptera, Ceramnbycide, Fig.5) and one individual of another large beetle from the same family (not determined).

Fig.2. Diplopoda

Fig.3. Orthoptera

Fig. 4. Opilionida

Fig. 5. *Acrocinus longimanus*

2.3. Procedures

All animals were weighed using electronic pocket balance PS500X (Voltcraft) with the accuracy of 0.01 g.

Metabolic rates were measured in terms of CO_2 production using a closed system with VAISALA GMP 343 diffusion CO_2 analyser. Animals were placed in a 3.2 l chamber and the increase of CO_2 concentration in the chamber was recorded on a computer in one-second intervals. The measurements lasted usually for 12 minutes. The temperature in laboratory varied slighty around 21°C (it was impossible to control temperature inside the chamber). The rate of CO_2 production by the animal was computed as a regression slope of the CO_2 concentration increase in the chamber (Fig. 6). Concentration values were recalculated into CO_2 productions rates (ml CO_2/h) taking into account the volume of the chamber. Assuming RQ = 1 (Webb and Telford, 1994), CO_2 production rate is exact equivalent of oxygen consumption.

Respiration of each individual diplopod was measured three times at intervals of at least one day. The individuals were identified by the body mass, which varied only slightly between replications. In further analysis average respiration value and average body weight for each individual were used.

In other animals metabolic rates were measured only once in each individual. In the case of Opilionida measurements were made in 3 individuals of similar body mass, put together into the chamber.

Almost all measurements was done in the evening (when majority of animals begin their activity). Other studies showed that consumption of O_2 by crickets was not affected by time of day (Hack, 1997).

For statistical analysis Microsoft Exel and Statistica were used.

3. Results

3.1 Regression between time and concentration of CO_2

The regressions were significant with R^2 value varying between 0.6534 and 0.9934, most often $R^2 > 0.9$ (Fig. 6).

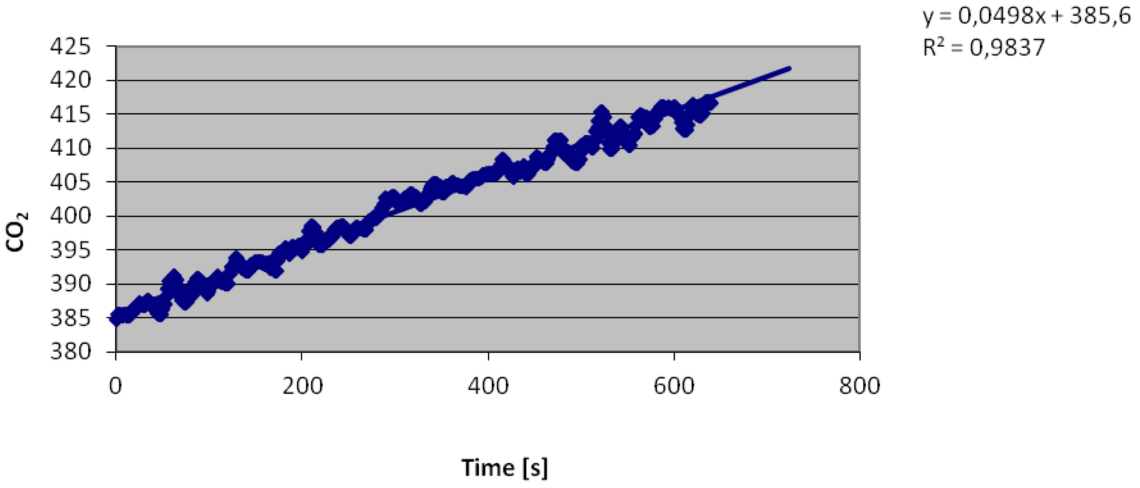

Fig.6. Example of a single measurement record illustrating the linear increase of CO_2 concentration [ppm] in the chamber during measurement The slope coefficient of the regression represents metabolic rate of the animal. The intercept, as expected, did not differ from the CO_2 concentration in ambient atmosphere (ppm).

3.2. Average respiration rates

Average values of respiration for all taxa studied are given in Table 1.

Table1. Average (±SD) respiration rates for all measured taxa, for whole animals and per 1 g of body mass.

Taxon	*Respiration rate (ml CO_2/h)*	*Respiration rate (ml CO_2/h*g)*
Diplopods	0.69±0.27	0.09±0.03
Crickets	0.4±0.15	0.38±0.09
Opilionids	0.73±0.05	0.05±0.05
Acrocinus longimanus	5.46±5.99	0.63±0.57
Other Coleoptera	0.29	0.12

3.3. Relation between body mass and respiration rate

For Diplopoda the relation body mass vs. respiration rate was significant (R^2 = 0.5824) and regression equation on log transformed data was:

$$y = -0.7625 + 0.6352\,x;\;\; r = 0.7632;\; p=0.0002 \;\; \text{(Fig. 7)},$$

where x – log(body mass, g), y – log(metabolic rate, mlCO_2/h), or:

$$Y = 0.1728\,X^{0.6352},$$

where X – body mass (g), Y – metabolic rate (mlCO_2/h).

The respiration rates of each individual was averaged also the body mass. Outliers were removed from analysis. On the averaged data the allometric regression was made.

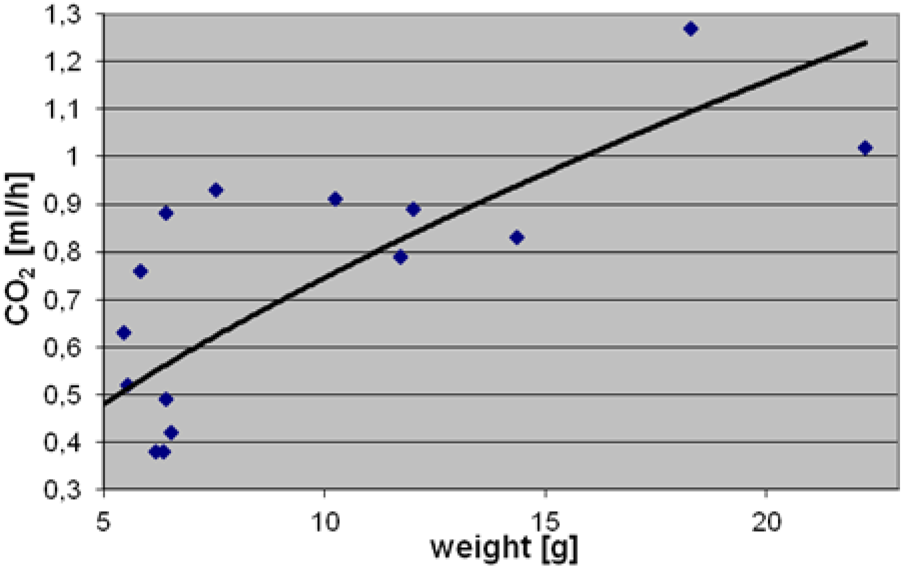

Fig.7. Allometric relation between body mass and respiration in Diplopoda

4. Discussion

4.1. Validation of the results

The use of soil respirometry apparatus to measure metabolic rates of individual proven to be quite satisfactory. The exact linearity and narrow confidence limits of regressions of

CO_2 concentration increase in time, with intercept not differing from expected concentration, allow for a reliable estimate of the respiration rates. Less satisfactory was the measuring protocol. The field conditions did not allow for precise control of ambient temperature nor to record the animals' behavior, therefore the effects of the locomotor activity could not be taken into account.

4.2. Allometry of metabolism in Diplopoda

Value of exponent in allometric regression equation (0.6352) departs from value 0.75 reported as a general approximation for large poikiloterm and homeoterms (Reichle, 1967), and also from the value 0.73 estimated for metabolism of various arthropods taxa, including Myriapoda (Frears et al., 1996). The respiration rate of large Diplopoda differs from that of small ones studied in Alps (Brueggl 1992).

4.3. Comparision between various invertebrate taxa

The paucity of does not allow to calculate allometric regression and uniformly compare all taxa studied. However, if plotted on a graph (Fig. 8) our results show that large Diplopoda have lower respiration rates than the other taxa studied. Among the arthropods investigated here, the highest metabolic rates (at their body size) achieved cerambycid beetles, particularly the Harlequin beetle (A.l), whereas the crickets and Opilionidas demonstrated relatively low metabolic rates.

Other studies showed that centipeds have lower respiration rate than other poikiloterms (Webb and Telford, 1994), however yet another comparision showed no statistically significant differences of respiration rate between millipedes, spiders, ants and beetles. (Frears et al., 1996).

Because the chamber used here was not transparent, it was not possible to observe the activity of studied animals during measurement. Only in case of Harlequin beetle it can be heard that animal was actively moving inside the chamber and this is the case of the extremely high metabolic rate in one specimen (Fig. 8).

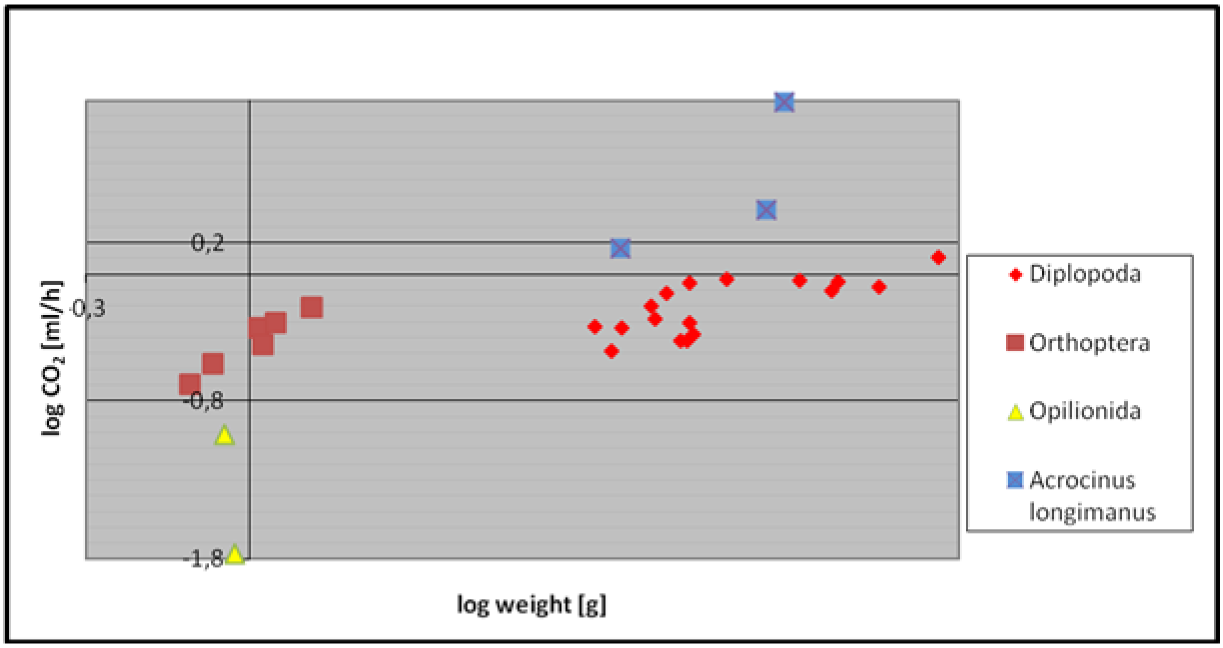

Fig. 8. Comparison between metabolic rates in various taxa of arthropods studied, with regard to body mass.

Conclusions

(1). Diplopoda have lower respiration rate than cerambycid beetles and cricket studied.

(2). The exponent of allometric function among large Diplopoda is smaller than literature value for small Diplopoda.

(3) The method of measurement with closed chamber and diffusion CO_2 analyser proved to be reliable and useful in harsh field conditions, when applied animals (in case of Diplopoda) weighing more than 3 g or Orthoptera more than 1g. In further research transparent chamber should be used to observe the activity of animals.

Acknowledments

The authors want to thank Prof. dr hab. January Weiner for help during the field work and preparing the report.

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Soil respiration in mountain forests of the Henri Pittier National Park.

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Report submitted in partial fulfillment of the requirements for the course “Tropical ecology – field course” (WBNZ-850), at the Faculty of Biology and Earth Sciences, Jagiellonian University.

Abstract:

Soil respiration was measured in four different locations at the elevations of 760, 1174, 1201, 1514 m a.s.l., representing various types of tropical mountain forests and cloud forests near Rancho Grande, in the Henri Pittier National Park, Venezuela. Respiration rates differed between sites, ranging from 0.402 to 0.658 g CO_2 $m^{-2}h^{-1}$, with the maximum at the lowest locality. Repeated measurements at one site demonstrated high spatial and temporal variation of respiration rates.

Key words: soil respiration, tropical cloud forests

Introduction

The CO_2 emission from the soil is an important component of carbon fluxes in forest ecosystems; a detailed knowledge of soil respiration is necessary to cope with environmental and economic issues of today. Soil respiration is a sum of o two processes: root respiration (autotrophic respiration) and litter decomposition by soil organisms (heterotrophic respiration). Numerous studies have shown that many factors affect soil respiration. In temperate regions, temperature is the main factor of variability of CO_2 emission from the soil (Fang, 1998). In the tropics, due to small temperature amplitudes at the ground level, this factor has little influence, but soil moisture and topography are important factors in soil respiration (Pargade, 2000). Some factors act specifically on the autotrophic component of the phenomenon as density and size of the roots (Janssens, 1998). The tropical forests are relatively poorly studied in that respect although they an important sink of carbon.

The aim of this study was make a preliminary investigation in situ in order to get some insight into the patterns of variation of soil respiration in tropical montane forests in connection with the planned more advanced research project in collaboration between the Jagiellonian University and the Central University of Venezuela. It included a preliminary selection of study sites and testing the field equipment.

Materials and Methods

The study was conducted in the National Park Henry Pittier, Cordillera de la Costa (near Maracay, Aragua State, Venezuela) in the area surrounding the biological station Rancho Grande (coordinates : N10°20’58,1” W67°41’03,3”). The station is situated at 1180 m a.s.l and is surrounded by four different vegetation types (semi-deciduous forest, tropical cloud forest transitional, cloud forest *sensu stricto* and high elevation tropical cloud forest; Huber 1986). The climate is defined as a mountain wet tropical one. The annual temperatures fluctuate around 20°C the whole year with low amplitude (averages : 18.4°C in January, 21°C in July). The annul precipitations ranges from 1650 to 1850 mm, depending on local elevation and exposition (Huber 1986).

Four study sites were established: (1) “La Toma “ – close to the station, coordinates N10˚20’55”, W67˚40’55” , elevation 1201 m a.s.l., “Cumbre” (Peak of the Cumbre de Rancho Grande; N10˚21’20”, W67˚41’20”, 1514 m a.s.l.), “Portachuelo” (close to Portachuelo Pass; N10˚20’47”, W67˚41’18”, 1174 m a.s.l.) and “Guamita” (Guamita valley; N10˚20’20”, W67˚39’18”, 760 m a.s.l.). The sites La Toma and Portachuelo are located at approximately the same elevation, but differ in exposition: Portachuelo is exposed to N – NE, while La Toma to S – SW, therefore, they differ in vegetation type. Portachuelo may be regarded a typical cloud forest, while La Toma area was classified by Huber (1986) to cloud forest transitional. “Cumbre” represent high elevation cloud forest, and Guamita is a semi-evergreen forest, with distinctly different vegetation.

At La Toma and Portachuelo linear transects were marked out with 20 and 22 measuring stations at 1 m distance. Due to logistic problems a similar transect at Guamita included only 7 measuring stations. At the hilltop of Cumbre, 17 measuring points were randomly selected within appr. 50 m radius from the coordinates indicated, with different slopes and exposition.

At each study site except La Toma respiration neasurements were done only once (Cumbre: July 11, Portachuelo: July 10, Guamita: July 12, 2012); at La Toma measurements were repeated 4 times (July 6, 8, 10 and 14), with measuring chamber placed each time exactly in the same spot.

To measure soil respiration, we used a plastic chamber of the volume of 3.2 l, covering soil surface of 240.2 cm^2 and CO_2 concentration sensor Vaisala GMP343, linked to a computer (Fig.1), recording CO_2 concentration in the chamber at 1 sec intervals. Measurements lasted usually for 2-3 min. To each record a linear regression was fitted, the slope coefficient of which represented the rate of CO_2 concentration increase, which subsequently was recalculated into g $CO_2 \times m^{-2} \times h^{-1}$ using appropriate data on chamber dimensions.

Soil temperature was measured at the depth 5 cm using digital thermometer GTH 175/PT (Greisinger electronic) with accuracy of 0.1˚C.

Fig. 1 Soil respirometer: chamber with the Vaisala GMP 343 CO_2 sensor, interface, and computer.

Results

1. La Toma

The values of respiration measured four times at 20 point localities demonstrated large spatial variation, with statistically significant differences between measuring stations (Fig. 2). Variances were not equal; coefficients of variation of each point averages ranged between 5 and 60% (av. 23%). ANOVA reveals significant differences between locations (Welsh F=3.198, p=0.005).

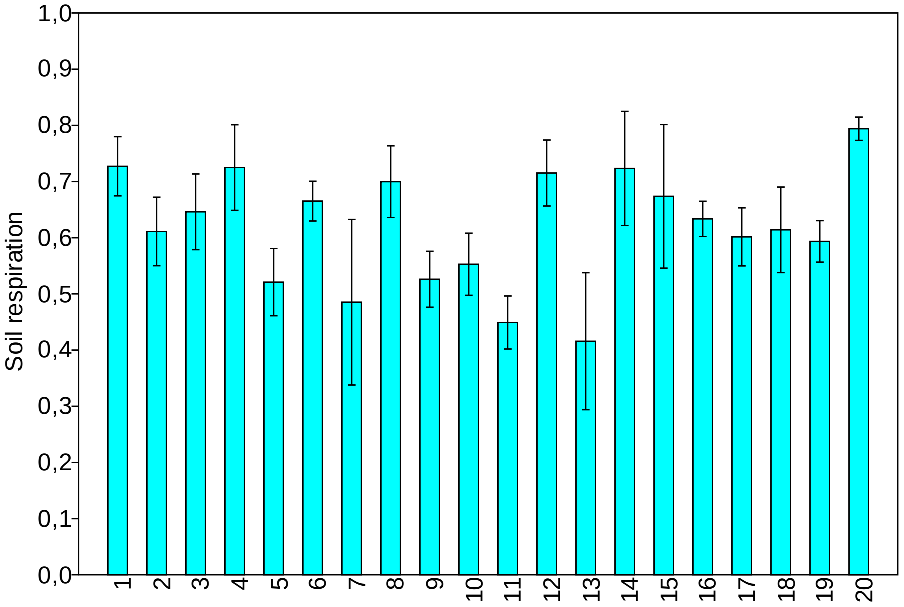

Fig. 2. Soil respiration values (g CO_2 $m^{-2}h^{-1}$) averaged over 4 measurement series at each station of the La Toma transect (Av. ±S.E.)

The variation of respiration rates along spatial gradient does not demonstrate significant autocorrelation (Fig. 3).

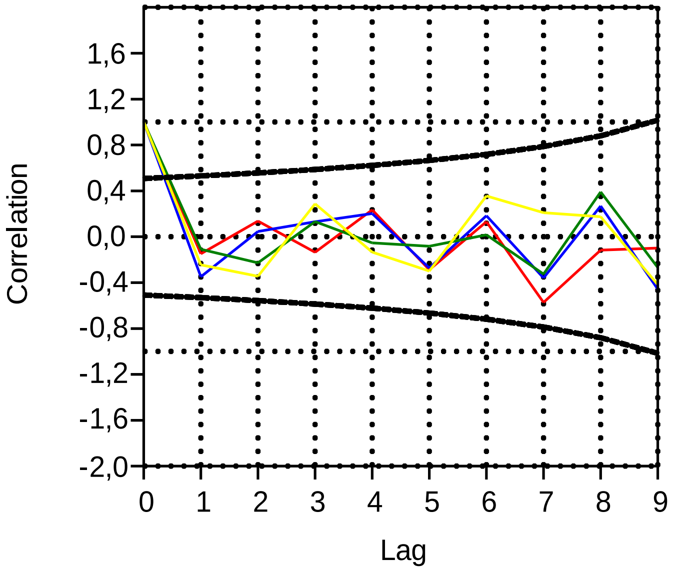

Fig. 3. Autocorrelation diagram for La Toma transect (4 lines represent 4 measurements at 2 – 4 day intervals. Boundary lines indicate 95% confidence interval.

The mean respiration rates averaged over whole transects for each measuring day did not differ significantly (one way ANOVA, Welsh F=0.89, p=0.45, Fig 4; however nonparametric Friedman test *in lieu* of a 2-way ANOVA reveals a significant difference: chi^2=7.38, p=0.06, and pairwise Wilcoxon comparisons indicate a single significant difference between 1 and 2 series of measurements). No significant autocorrelation in time was detected.

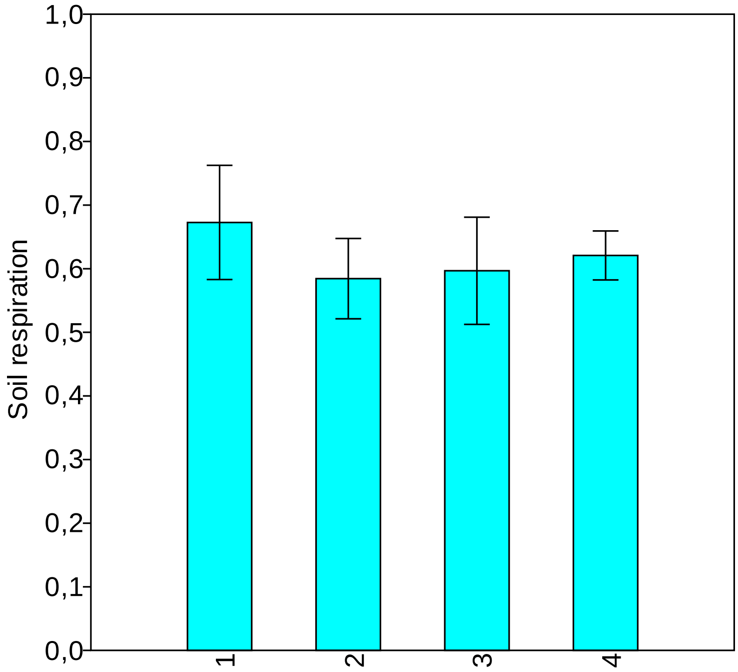

Fig 4. Soil respiration values (g CO_2 $m^{-2}h^{-1}$) at La Toma averaged over 20 transect points in 4 measurement series (av. ± S.E.).

The overall mean respiration rate for the site la Toma is 0.619 (SD = 0.164) g CO_2 $m^{-2}h^{-1}$. Averages for each measuring point (Fig. 2) were used for further comparisons as single values to avoid pseudoreplication.

Soil temperatures at 4 measuring occasions varied between 20 and 20.5 ˚C (av. 20.1˚C).

2. Soil respiration at four sites

The average soil respiration rates differed significantly between the four sites (ANOVA, F=11,74, p<0.00001, Table 1, Fig. 5), although the within site variance was quite high (coefficoent of variation ranging from 16.5 to 38 %). The Tukeys pairwise comparison indicates for significant differences between “Portachuelo” (the lowest value) and “Guamita” and “La Toma” (Fig. 5).

Soil temperatures ranged from 18.3°C (Cumbre) to 21.2°C (Guamita); the lack of replications at two sites does not allow for statistical comparisons.

Table 1. Average values of soil respiration at four sites studied.

SITE	CUMBRE	GUAMITA	PORTACHUELO	LaTOMA
Altitude [m]	1514	760	1174	1201
Soil temperature [°C]	18.3	21.2	19.5	20.1
S.D.	0.76			0.25
Respiration [g CO_2 $m^{-2}h^{-1}$]				
n	16	7	22	20
Mean	**0.524**	**0.658**	**0.402**	**0.619**
S.D.	0.134	0.153	0.152	0.102
S.E.	0.033	0.058	0.033	0.023
Min	0.349	0.442	0.153	0.416
Max	0.757	0.865	0.722	0.794

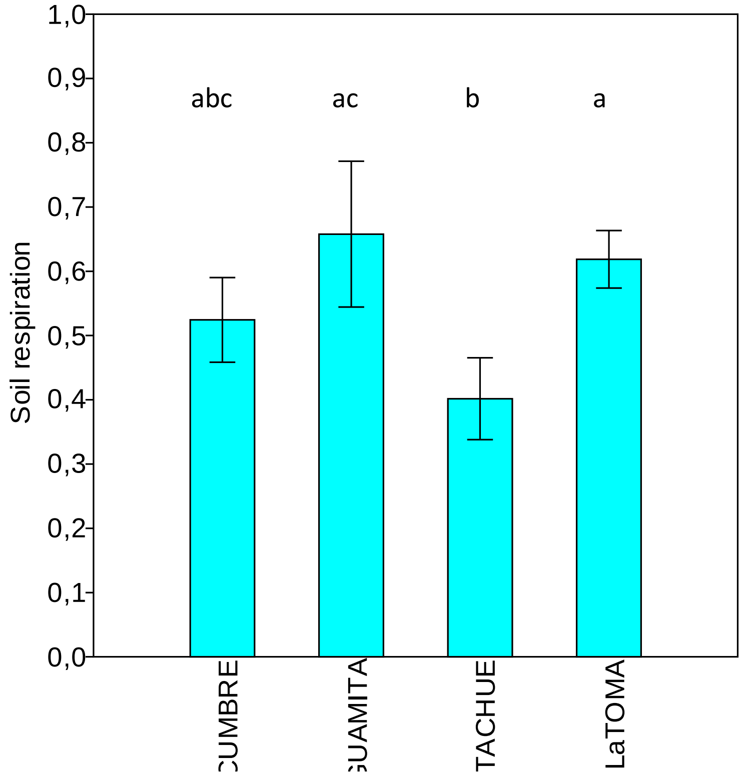

Fig. 5. Soil respiration (g CO_2 $m^{-2}h^{-1}$); site averages ± 95% confidence intervals. Letters above the bars indicate homogenous groups.

Discussion

The soil temperature decreases linearly with elevation a.s.l. as it can be expected (Fig. 6). The soil temperature elevation gradient is 0.38 deg per 100 m, i.e. less than it usually assumed for air at maximum humidity (0.6 deg/100m). However, the soil respiration rates do not fully with temperature pattern (Fig. 7), as it could have been predicted from the usual exponential dependence of soil respiration rates on temperature (Luo and Zhou, 2006). The lowest soil respiration was recorded at Portachuelo, the highest at Guamita (Table 1, Fig. 7).

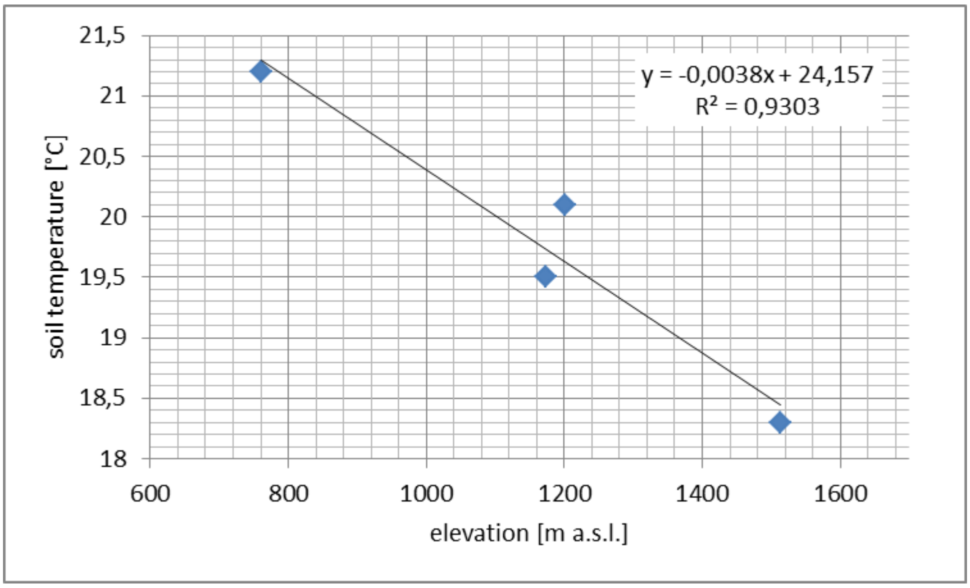

Fig 6. Soil temperature at different elevations a.s.l.

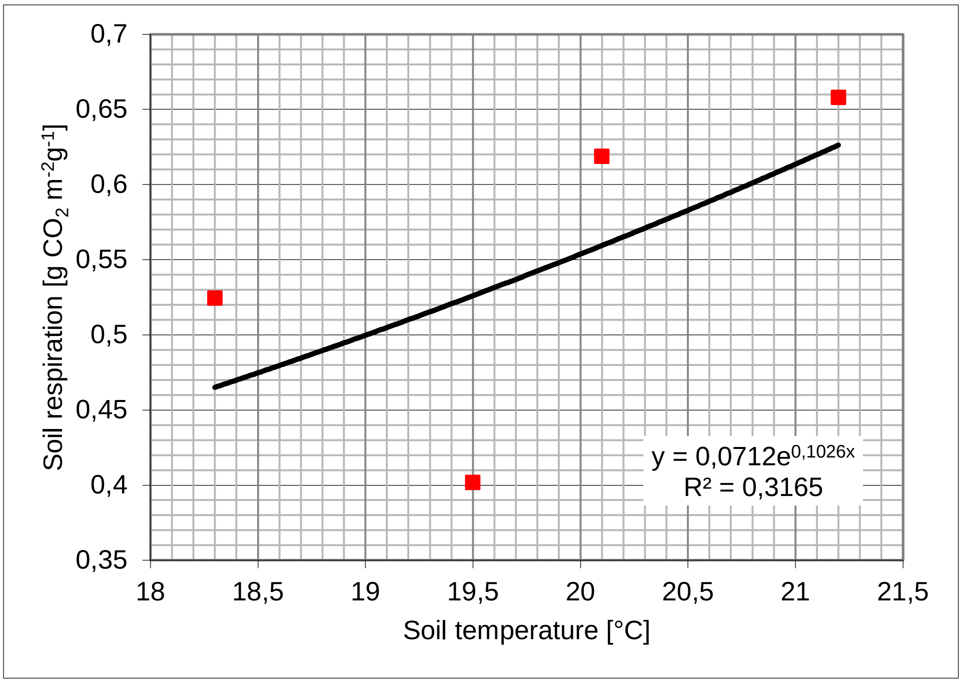

Fig. 7. Soil respiration as related to soil temperature (exponential regression fitted).

The exponential regression fitted to these data yields the exponent 0.1026, which can be translated in a Q_{10} value of 2.79. When excluding the outlying data point for Portachuelo, the exponential regression fits almost exactly to the remaining three points ($R^2 = 0.986$), with the exponent and Q_{10} values equal 0.0795 and 2.21, respectively. These figures are close to those reported for soil respiration data in various climates (Luo and Zhou 2006).

Respiration rates measured in montane and cloud forests of cordillera de la Costa at one point of annual season appear relatively high, as compared to the generalized data published so far for moist tropical forests. E.g., Luo and Zhou 2006 give the value of 1260 g CO_2 $m^{-2}year^{-1}$ (i.e. 0.14 g CO_2 $m^{-2}h^{-1}$) for tropical moist forests. A study performed during one season only (1985/86), at Loma de Hierro (N10˚8’20” , W67˚8’30”, 1350 m a.s.l., about 70 km east from Rancho Grande), using soil respiration estimation by chemical absorption, revealed that the soil respiration demonstrated high variation (av. 0.369 ± 0.180 g CO_2 m^{-2} h^{-1}); a few others single estimates of soil respiration from the same region were similarly varied (La Cumbre de Choroni: 0.346 g CO_2 m^{-2} h^{-1}, Rancho Grande: 0.195 g CO_2 m^{-2} h^{-1}; Medina and Zelwer 1972; after Monedero and Gonzalez 1995), but no attempt was made to explain the sources of this variation.

Our measurement at La Toma site, with four replication, also demonstrate high variation, both in time and in space. Although some pattern of differences between transect points is significant, indicating for existing repeatability of soil respiration rates measured at the same spot over time, it is much less distinct and less stable than analogous patterns in temperate forests in Poland (Matkowska et al., unpubl.).

Conclusions

1. Soil temperature decreases with elevation.
2. Soil respiration differs between the sites located at various elevations, with the highest rate at the lowest and the warmest site.
3. Respiration values are close to previously reported for adjacent areas and similar forest types.
4. Soil respiration dependence on temperature seems to conform with general predictions ($Q_{10} = 2.2$) but more data with longer temperature gradients and covering the whole year are needed.
5. The closed soil respirometry system based on Vaisala GMP 343 CO_2 probe, with a closed chamber, and portable computer proved to be useful and dependable in field conditions.

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Daily activity of leaf cutting ants *Acromyrmex coronatus.*

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Report submitted in partial fulfillment of the requirements for the course “Tropical ecology – field course” (WBNZ-850), at the Faculty of Biology and Earth Sciences, Jagiellonian University.

Abstract

Daily activity patterns, average velocity and the amount of biomass carried by ants *Acromyrmex coronatus* were studied in montane cloud forest in Henri Pitter National Park, Venezuela. The most intense activity was recorded in the morning and in the middle of the day on the 24 hours active path and before midnight on the path used only in the night. The velocity of ants averaged to 0.03 m/sec, and varied with direction of moving, maximum of 0.059 m/sec on vertical path down – hardly with a load. The wet biomass delivered to the nest was estimated at 3.26 kg/day (dry mass content 23.81%).

Key words: *Acromyrmex coronatus,* biomass, activity patterns

1. Introduction

Attini of the genus *Acromyrmex* comprise twenty six leaf cutting ants species, described from throughout the Neotropics (Hölldobler and Wilson, 1990). They are endemic to South and Central America and southern parts of North America. They cut fresh vegetation, which is processed and used as a substrate for their fungus symbiont (Klingenberg et al., 2007). Leaf cutting ants may cause deforestation and strongly affect forest succession on abandoned land (Moutinho et al., 2003). Genus *Acromyrmex* is the most serious agricultural pest of tropical and subtropical America, causing enormous economic damage to the neotropic agriculture industry (cf. Cherrett 1986, after Wirth R., Herz H., Beyschlag W., Holldobler B., 2007). The aim of this study was to monitor the 24 hours activity of ants carrying plant material to determine their average velocity, and to estimate the amount of plant biomass transported into the nest.

2. Materials and methods

2.1. Study area

The project was realized in the field station “Rancho Grande” belonging to the Faculty of Agronomy, Central University of Venezuela, Maracay. Rancho Grande is situated in mountain cloud forest in the Henri Pittier National Park of Aragua, in north central Venezuela (10° 21' N. Lat., 67° 41' W. Long). The study was done in July 2012, during a wet season.

The nest of *Acromyrmex* is located closely to the walls of Rancho Grande field station. We found two active paths. One of them was active 24 hours and ran upon the wall, 9 meters up, to the birds’ feeder. On this path ants used unusual type of food – mainly watermelon, banana and mango, and occasionally the leaves and flowers of *Tabebuia chrysantha*, a tree growing nearly. The second path was used only during night and ran on the trunk of *Tabebuia* tree, where the ants carried almost exclusively *Tabebuia* leaves as a load.

2.2. Data collection and analysis

2.2.1. Activity pattern

To determine 24 hours activity of *Acromyrmex* ants, we have recorded ants on their path during 10 minutes using a movie camera. This allowed to count ants moving in both directions in the same time period. The ants were counted on two paths: on the wall and on the tree trunk. To estimate the time of opening and closing the night path we checked the time of first ascending and last descending and repeated this observation three times.

2.2.2. Average velocity

The velocity of ants in different places was measured by using the timer and measuring tape. We made 10 measurements of velocity of ants on the 1 meter distance, for every type of the path: on the tree (in both directions- up and down), on the wall (vertical path- both directions, horizontal path). To compare the velocities of ants measured per one meter distance and on the long path (on the wall), we measured the length of the path from birds feeder to the nest (15.9 m). Then we used nail polish to mark the ants at the starting point and measured the time of the arrival of the marked individuals at the end of the way. We included the information about type of path, direction of moving (horizontal/vertical) and load during measurement velocity on the long day path.

2.2.3. Biomass carried

To determine the weight of wet and dry biomass carried we collected 10 samples of 10 pieces of leaves *Tabebuia* from the path on the tree. We weighed all wet leaves together on the electronic portable balance (Voltcraft PS500X with the accuracy of 0.01 g). We dried the biomass by careful heating and using silica gel to achieve dry mass weight. The calculated weight of single piece of leaf, multiplicated by the number of ants per time period, yielded the quantity of biomass delivered in kilograms per day.

We used “Statistica” and Microsoft Excel programs for statistical analyses.

3. Results

3.1 Activity patterns

The highest activity of ants on the both paths, was observed in the night, before midnight (Fig. 1.). At 11 p.m., we counted 536 ants per 10 minutes, and it was the highest number of ants in this period. After midnight a significant decline was observed (Fig. 1.). At 6 a.m., only a very small number of individuals was noticed.

On the path on the wall, the quantity of ants was the highest in the morning and in the middle of the day. In the night, their activity was stable, but not high. (Fig. 2.).

During night path observation, ants started to be active about 18:00 p.m. (average from three measurements) and they stopped their activity about 05:30 a.m. The highest activity of ants on tree was observed before midnight (Fig. 3.).

3.2 Average velocity

The highest velocity of ants, was observed down the wall, despite loading. The lowest velocity had ants ascending. The results from the path on the tree and on the wall did not differ significantly (Fig. 4.)

Statistical analyses show significant differences ($p<0.005$) for directions of moving. Average velocity of ants moving on the horizontal path on the wall was statistically different from the velocity of ants ascending and descending, on the both paths – on the tree and on the wall (Tab. 1). Type of path was statistically different only for the path on the tree, for the ants moving horizontally and ascending on the wall (Tab. 1.).

Comparing average velocity on short distance to long distance shows that average velocity on long distance was lower than on the short, but that there is no statistically significant difference between the two speeds.

Average velocity on short distance (1 meter) amounts 0.03 +/- 0.005 m/s.

Average velocity on long distance (15.9 meters) amounts 0.025 +/- 0.005 m/s.

3.3. Biomass carried

Wet mass of 100 pieces of leaves was 2.52 g, thus one piece was on average 0.0252 g.

The dry mass of 100 pieces of leaves was 0.60 g., what gives the mass of 0.006 g per piece.

4. Discussion

4.1. Activity patterns

Location of ants nest (close to the station) made it possible to measure 24 hr activity pattern of ants. We have accurate data from the whole day and night. The most intense activity of *Acromyrmex sp.*, recorded in the morning and in the middle of the day on the path on the wall is probably caused by unusual feeding system (feeding by people, mainly fruits). On the tree before midnight a lot of ants were climbing up the tree to get pieces of *Tabebuia's* leaves. During our observation a social behavior was visible. The graph of correlation coefficient between number of ants ascending and descending with the delay of 0 – 4 hours (path on the wall) shows, that ants on the wall need about one hour to ascent and descent. Some ants descent after two hours (Fig. 5.) The ants on the tree needed one hour to go up and down, so they require less time than ants on wall. Probably they have shorter way (Fig. 6).

4.2. Average velocity

Contrary our expectations, loading did not influence the velocity – ants with load or without it had similar speed (comparison on the same type of path; Fig. 4, Tab. 1). The velocity depends the most on the direction of moving - vertical or horizontal (Fig. 4, Tab. 1). The highest velocity occurs down the. The small statistical difference occurs between the speed on the different type of the path (Fig. 4, Tab. 1.). The comparison short and long distance velocity show that velocity from whole path (from feeder to the nest) is lower, but not statistically different. This may be caused by the nail polish used to mark the ants which coul affect the behavior.

4.3. Biomass carried

Ants deliver 3.26 kg of biomass/day, dry mass constitute 23.81% of biomass, thus per 1 day ants are delivering 0.78 kg of dry mass. Recalculated average mass of the load for the whole year (assuming identical activity in all seasons and that there are no other paths) it gives about 1189.9 kg of wet biomass or 284.7 kg of dry mass of plant material. On the base of previous research (Soszka and Zieliński, 2010), we assume that wet biomass of fruits from birds' feeder, amount 31 kg/year, thus gives 1220.9 kg/year of wet biomass carrying from the both paths. They found only one path (24 hours active path on the wall with unusual type of foods) and they did not measured wet biomass from path on the tree. Comparing the result from previous year on *Atta sp.* (Grzech and Grucza, 2008), the biomass of leaves carried into the nest by the ants *Atta cephalotes*), we can see similar amount of wet biomass - 1182 kg/year and 390 kg/year of dry mass of plant, delivered to the nest of *Atta cephalotes*. Differences could be caused by the methods - they were observing ants only in the daytime, and no data are available about the possible night activity of *Atta*. We can suppose that if the study would be 24h the results could be different. In our studies we tried to estimate influence on vegetation by leaf cutting ants, thinking mainly about direct effects caused by defoliation. Colony of *Acromyrmex coronatus* ants can cause serious damage, due to significant amount of using biomass. But ants may have also indirect impact on vegetation. Injuries caused to leaves open the possibility of infection by fungi, bacteria and viruses. On the other hand, indirect effects include soil nutrient enrichment from nest refuse dumps and transferring nutrient to upper soil layers (Weber 1972).

Acknowledgments

We would like to thank Professor January Weiner from Jagiellonian University for his invaluable knowledge and professional advices during our project. Special thanks to the IVIC staff for support and guidance during this course. We wish to thank dr hab. Krzysztof Wiąckowski for sharing his experience and guidance.

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Appendix

Tab. 1. Differences between average velocity of ants at different paths, with or without loading – statistical analyses (Tuckey HSD test). Significant differences marked bold.

Path types	1 –	2 – ˙	3 ↑	4 ↓ ˙	5 ↑	6 ↓ ˙
1 –		0.067232	**0.000142**	**0.000133**	**0.000133**	**0.000133**
2 – ˙	0.067232		0.098638	**0.000171**	**0.000145**	**0.000133**
3 ↑	**0.000142**	0.098638		0.148280	0.079463	**0.000168**
4 ↓ ˙	**0.000133**	**0.000171**	0.148280		0.999777	0.093522
5 ↑	**0.000133**	**0.000145**	0.079463	0.999777		1.171289
6 ↓ ˙	**0.000133**	**0.000133**	**0.000168**	0.093522	1.171289	

1- Horizontal path on the wall; 2- Horizontal path on the wall + load; 3- Vertical path on the wall – up; 4- Vertical path on the wall – down + load; 5- Vertical path on the tree – up; 6- Vertical path on the tree – down + load;

Tab. 3. Weights of 10 samples of the biomass carried (wet and dry mass.)

Sample nr	biomass (g)	drymass (g)
1	0.24	0.057142857
2	0.28	0.066666667
3	0.3	0.071428571
4	0.22	0.052380952
5	0.28	0.066666667
6	0.26	0.061904762
7	0.18	0.042857143
8	0.24	0.057142857
9	0.22	0.052380952
10	0.3	0.071428571
summary	2.52	0.6
variance	0.001528889	8.66717E-05
avarage	0.252	0.06
standard deviation	0.03910101	2.94399382

Tab. 4. Weight of carried biomass and dry mass per different time periods.

	g/1 min	g/1 hour	kg/1 day	kg/1 year
Biomass	2.27	136.2	3.26	1189.9
Dry mass	0.60	32.43	0.78	284.7

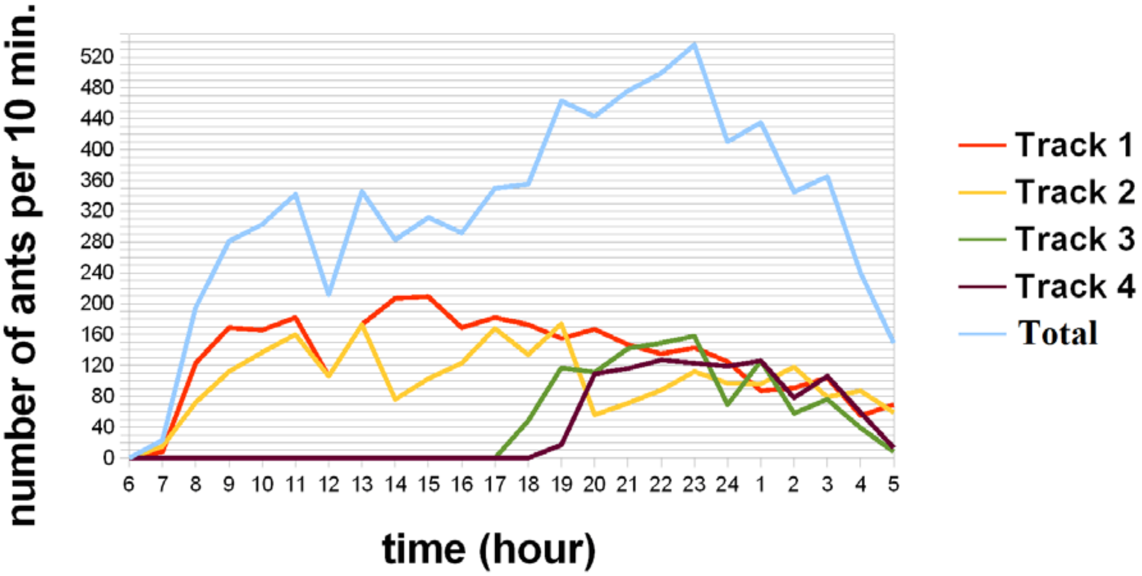

Fig. 1. The average activity of ants for each path (Track 1. Path on the wall up. Track 2. Path on the wall down + load. Track 3. Path on the tree – up. Track 4. Path on the tree down + food)

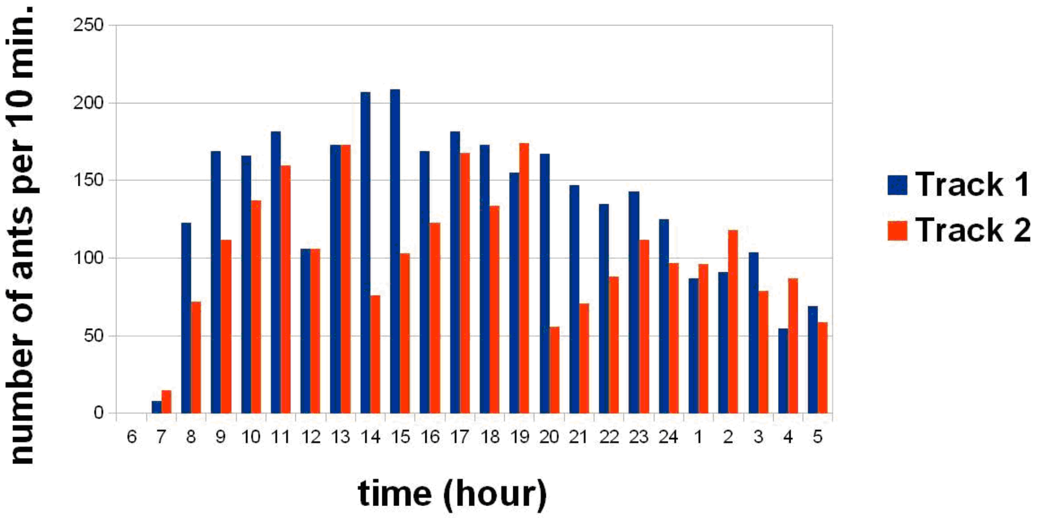

Fig. 2. Average activity of ants on the wall- 24h observation

(Track 1. Path on the wall - up. Track 2. Path on the wall - down)

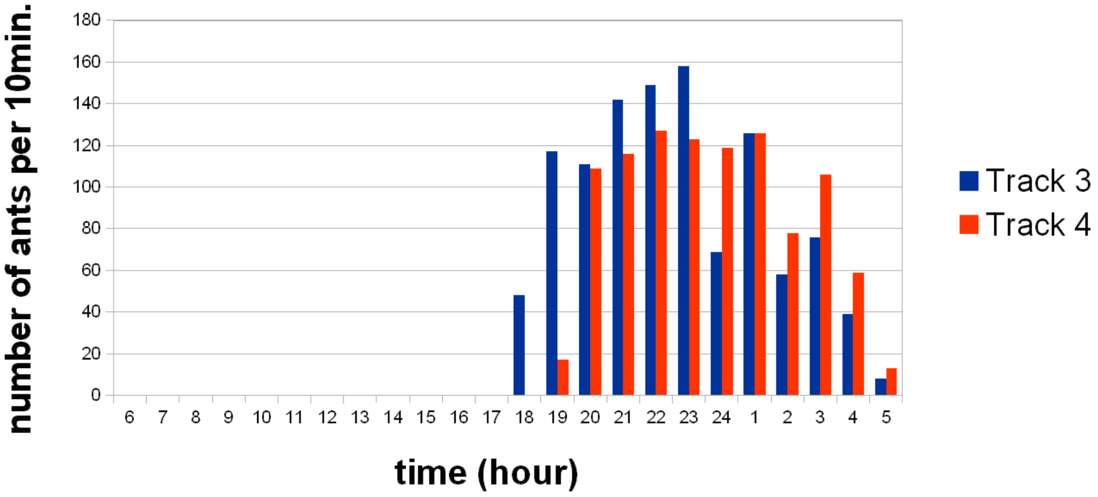

Fig. 3. Average activity of ants on the tree - night observation

(Track 1. Path on the tree - up. Track 2. Path on the tree - down)

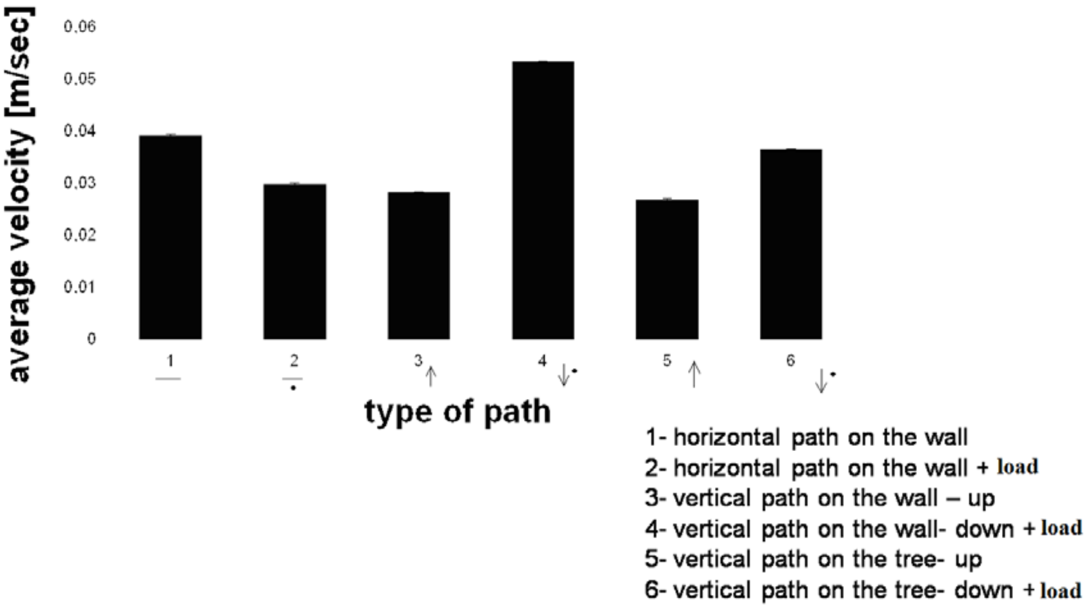

Fig. 4. Average velocities of ants at different paths, with or without loading

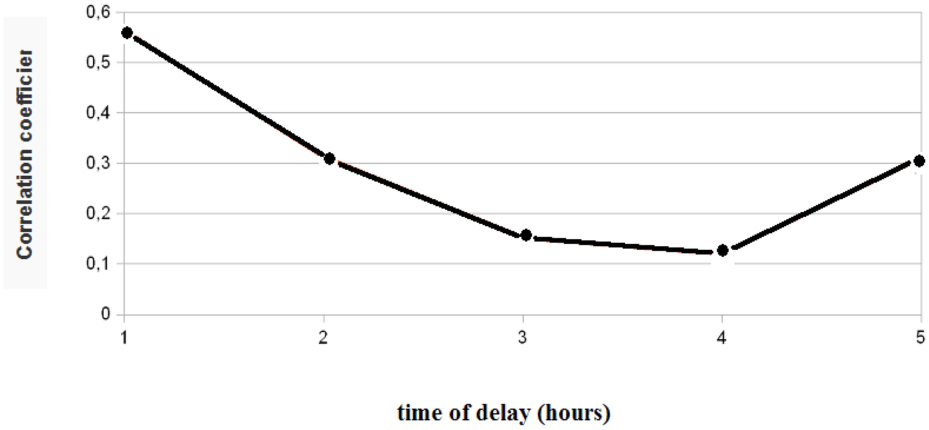

Fig. 5. Coefficients of correlation between the number of ants ascending and descending counted with the delay of 0 – 4 hours (path on the wall)

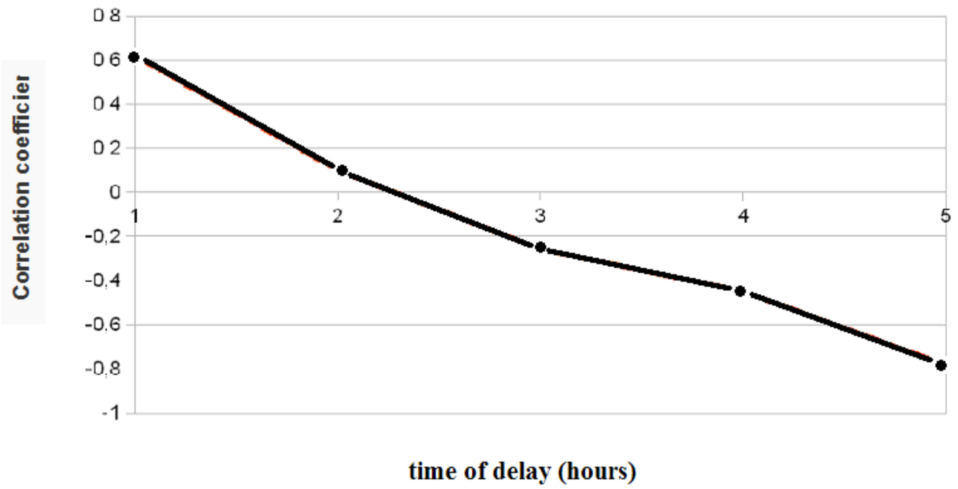

Fig. 6. Coefficients of correlation between the number of ants ascending and descending counted with the delay of 0 – 4 hours (path on the tree)

Light regime preferences in selected plants of neotropical cloud forest.

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Report submitted in partial fulfillment of the requirements for the course Tropical ecology – field course (WBNZ-850) at the Faculty of Biology and Earth Sciences. Jagiellonian University. 2012.

Abstract

The observations done at three open sites and three shadow sites in a montane cloud forest (Cordillera de la Costa. Venezuela) show that the abundance and species composition of epiphyte communities on trees depend on the amount of light available.

Comparative measurements of the amount of sunlight reaching leaves' surface of two species of *Heliconia* show that *H. bihai* prefers more sunny places than *H. revoluta.*

Key words: light regime. epiphytes. *Heliconia* sp.

Introduction

The tropics are warm because the sun's radiation falls more directly. However. cloudiness and higher water vapor content of the air reduce the amount of solar radiation reaching the forest canopy. As the availability of light can limit plant growth. it is interesting to learn how the tropical forest plants adapt to light regime [1.2].

Epiphytes are plants which grow above the ground surface. They are not rooted in the soil. By growing on other plants. the epiphytes can reach positions where there is more light available or where they can avoid competition for light [3.4.5]. What is important. epiphytes use their host plants only as platforms [1.3]. Majority plants use solar radiation as source of energy for photosynthesis. and also to regulate their process of growth and development. Despite their high local diversity and abundance. epiphytes grow relatively slowly [6]. Slow growth is probably caused by poor and irregular availability of water and nutrients. The light intensity is another ecological factor influencing plant growth [6]. On the other hand. high irradiance will lead to increased temperature which may influence the plant growth due to overheating and desiccation.

As the epiphytes do not have direct access to moisture. they reduce their water loss on several ways. Many epiphytes close their stomata during the day. Orchids contain bulbous stems in which they store water. Bromeliads form of their leaves a kind of a water container. Some groups of plants. such as ferns. Bromeliaceae (Fig.1) and Orchidaceae are particularly abundant in neotropical epiphyte communities [3-5].

Light availability in tropical forests varies at different heights. It looks differently deep in the forest, on the forest floor, than in the canopy above. Plant of the understory may differ in light preferences, some grow well in the shade. while most grow best in sunny places and in open areas. For instance, it has been reported that *Heliconia bihai* is growing in conditions with full sun to 40% shade [7] while other species may do well in shadow. *Heliconia bihai* (Fig.2) and *Heliconia revoluta* (Fig.3) are perennial herbs typically growing taller than 1.5 m, characterized by long. curved inflorescences. and colorful bracts surrounding little flowers, adapted to avian, especially hummingbird pollination [3.4]. *Heliconia's bihai* inflorescences are standing up (Fig. 2),. constituting water tanks protecting their seeds against insects and a source of water for animals. In contrast, *H. revoluta* has the inflorescences reversed, hanging down (Fig. 3). The species are sympatric, but they may differ with habitat preferences.

The goals of this study were: (1) to check if the abundance and species composition of epiphyte communities depend on light regime, and (2) to estimate the light regime preferences of two related plants species: *H. bihai* and *H. revoluta* differ.

Fig. 1. A group of Bromeliaceae epiphytes. Photo was made in La Toma area.

Fig. 2. *Heliconia bihai*.

Fig. 3. *Heliconia revoluta*.

Materials and methods

The present study was carried out in the northern part of Venezuela in Cordillera de la Costa, Parque Nacional Henri Pittier. The studies were carried out at the biological field station Rancho Grande and its closest surroundings: the path called “La Toma” and education pathway called “Sendero Andrew Field”.

Epiphytes

The research sites (three exposed and three shadowed ones) were selected, marked in the field and their position was recorded using a GPS. At each of these sites three to six trees with epiphytes were chosen for detailed scrutiny. Using binoculars, the morphotaxa of epiphytes were determined. We have taken into account the following morphotaxa: ferns, Araceae, “Philodendron”, *Vriesea plathynema* – “big” Bromeliaceae, “small” Bromeliaceae, *Rhipsalis* sp., *Epifilum* sp., *Vanilla* sp., Orchidaceae.

Plants of understory

Seven clusters of *Heliconia revoluta* and seven of *Heliconia bihai* were selected and marked in the Sendero Andrew Fields and La Toma. Intensity of light was measured immediately at the surface of leaves, during two days 9th and 10th of July.

All statistical analyses were performed with Statistica.

Protocol

Alltogether, nine series of measurements of light intensity at selected stations for epiphytes were done in various times of day. Measurements were made at a distance of 6-10 meters from the observed trees, in one special point at each site. All measurements were done with luxmeter MS-1300

During the measurements the cloud cover was observed and recorded. using arbitrary numerical scale of discrete degrees (Tab.1). Since the measurements were done at various cloudiness, and at various day hours, a standardization of the light intensity was attempted. To that purpose to each degree of cloudiness we have attached an index of the average reduction of light intensity (Tab.2), involving also the time of the day when measurements *in situ* were done.

Tab.1. The scale of cloud cover.

Degree of cloud cover	Description
I	full light, blue sky, shadows sharply visible
II	the outline of the sun visible through the clouds, a blue border around the sun,sharp shadows
III	Lightly cloudy, the sun flashes through the clouds
IV	Overcast, no shadows, sun invisible

Tab.2. Light reduction index for each cloud cover index and time of the day.

The degree of cloud cover	Light reduction index
I	1
II	0.81
III	0.31
IV 6:00-9:45	0.12
IV 9:45 - 13:30	0.21
IV 13:30-17:15	0.07

The index values were estimated by fitting sinusoidal curves to the light intensity measurements done at open stand on the roof terrace of Rancho Grande Station at various hours and by various cloud covers, assuming a maximum value of 1 at noon by the open sky.
The multivariate analysis was done with PAST (Fig.6), while calculation of variance and ANOVA were done with Statistica.

Results

Epiphytes

The average number of epiphytes on trees in three exposed sites was significantly higher than on the trees in shadow (Fig.4). Similarly, the average number of morphotaxa of epiphytes at exposed sites was higher than in shadowed ones (Fig.5). although the number of morphotaxa in the open site number 2 is close to the number of morphotaxa in shadowed places.

The morphotaxonomic composition of epiphyte communities is presented in Tab.3.

The site 1 contains the largest amount of ferns and the minimum abundance of *Vriesea plathynema*. Site 2 had the lowest number of morphotaxa. On the trees at the site 3 no bromeliads were found. and the abundance of ferns was low. Trees from site 4 do not host any Pteridophyta.

also they have 2-4 epiphytes from morphotaxon Bromeliaceae. Site 5 contains the largest number of individuals of Araceae. The trees of site 6 contain the largest number of Bromeliacea (Tab.3).

The multivariate cluster analysis classified the epiphyte communities into six clusters (Fig.6). with a clear segregation of communities in shadowed sites (cluster 2) and those from exposed localities (clusters 4. 5.6).

The results of light intensity measurements at epiphyte sites did not give a clear pattern. The average light intensity values (raw) did not differ significantly between the open and the shadowed sites. The standardization with the model including cloud cover only did reduce the intra group variance (Tab. 4). but the averages for the sites defined as open and shadowed did not differ statistically in average light intensities.

Plants of understory

The average light intensities measured at the stands of the both *Heliconia* species differed statistically (Fig.7). with *H. revoluta* preferring darker sites.

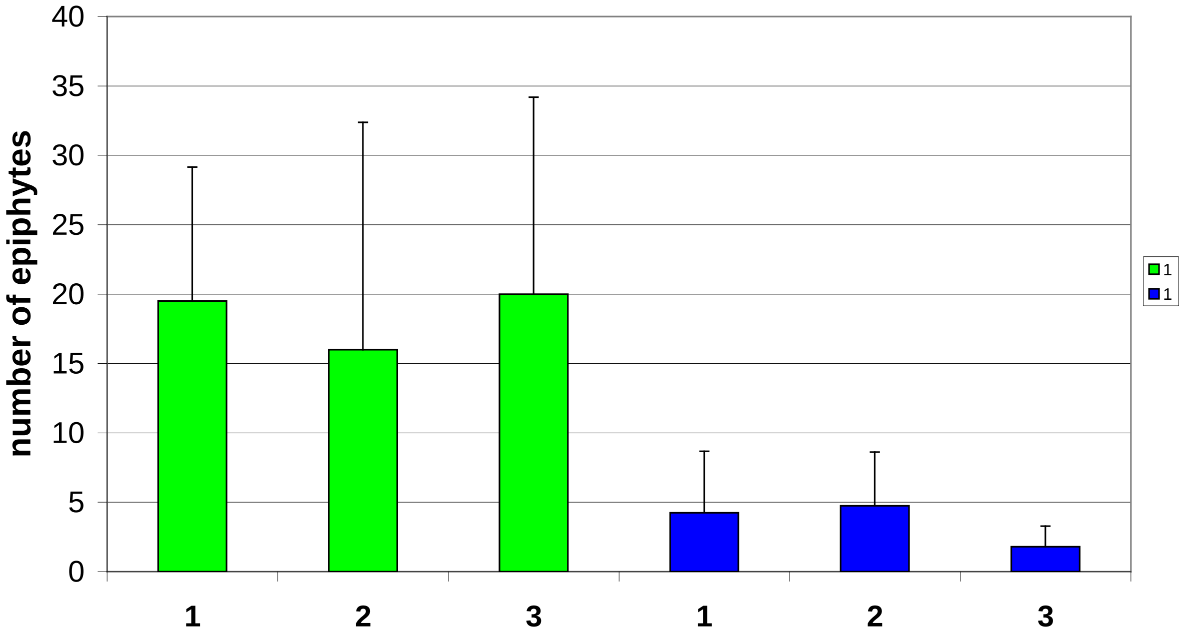

Fig. 4. The average numbers of epiphytes on trees in three open and three dark sites (green – open sites. blue – dark sites). Average ± SD.

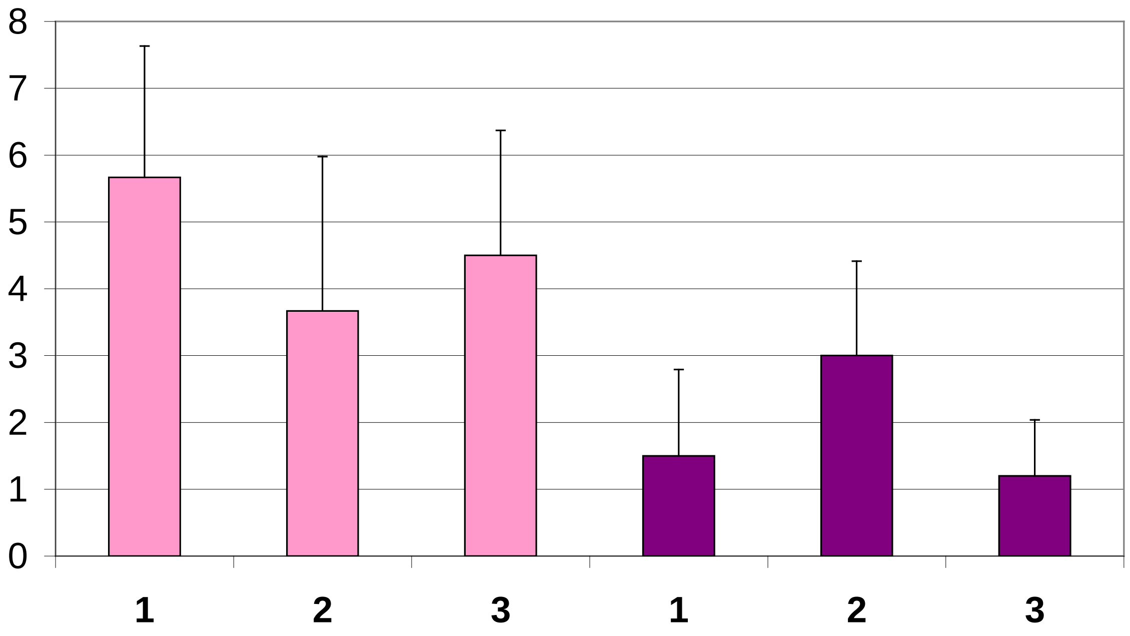

Fig. 5. The average numbers of morphotaxa of epiphytes at each site (pink – open sites; violet – dark sites). Average ± SD.

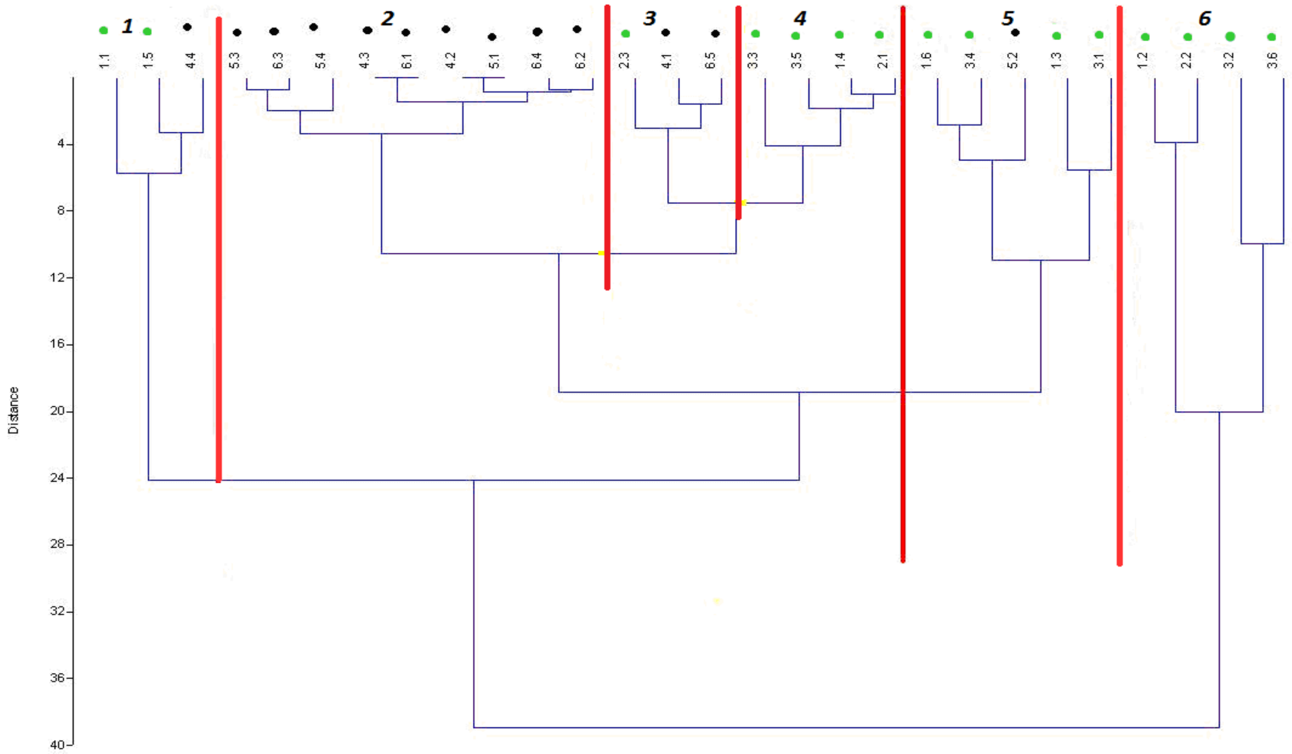

Fig. 6. The multivariate classification of epiphyte communities (Ward’s method). Six clusters (1-6). Green dots – trees from exposed places, black dots – trees from shadowed places.

Tab.3. The number of morfotaxa of epiphytes on each observed tree.

Site number	Tree number	Morfotaxa of epiphytes										
		Epiphites	Small-leaves fern	Fern	Araceae	*Vriesea plathynema* „big” Bromielaceae	"small" Bromeliaceae	Epifilum hokera	Rhipsalis	Orchidaceae	Vanilla	Sum
1	1.1		2	10	0	3	4	2	1	4	0	26
1	1.2		0	2	2	4	18	0	2	2	0	30
1	1.3		1	3	3	5	8	4	0	1	0	25
1	1.4		0	0	0	1	3	0	0	0	0	4
1	1.5		1	9	2	0	3	1	2	1	0	19
1	1.6		0	4	4	3	1	1	0	0	0	13
2	2.1		0	0	0	0	2	0	0	0	0	2
2	2.2		0	4	3	8	16	0	3	0	0	34
2	2.3		0	2	2	6	0	0	0	1	1	12
3	3.1		2	4	2	9	3	0	0	0	0	20
3	3.2		3	3	4	15	4	7	8	0	0	44
3	3.3		0	0	0	5	4	0	0	0	0	9
3	3.4		0	1	5	4	3	0	0	0	0	13
3	3.5		0	0	1	2	3	0	0	0	0	6
3	3.6		1	3	1	13	2	0	0	8	0	28
4	4.1		0	1	2	4	0	0	0	0	0	7
4	4.2		0	0	1	0	0	0	0	0	0	1
4	4.3		0	0	0	0	0	0	0	0	0	0
4	4.4		0	8	0	1	0	0	0	0	0	9
5	5.1		0	0	1	0	0	0	0	0	0	1
5	5.2		0	1	8	1	0	0	0	0	0	10
5	5.3		0	0	2	1	0	0	0	0	0	3
5	5.4		1	0	2	0	2	0	0	0	0	5
6	6.1		0	0	0	0	0	0	0	0	0	0
6	6.2		0	0	1	0	0	0	0	1	0	2
6	6.3		0	0	2	0	0	0	0	0	0	2
6	6.4		0	0	1	0	0	0	0	0	0	1
6	6.5		0	1	0	3	0	0	0	0	0	4

Tab.4. Variances of light intensity averages measured at six sites with and without standardization.

Sites	exposed sites			shadowed sites		
	1	2	3	1	2	3
Raw data	111.6	83.4	71.7	99.1	78.1	47.1
Cloud cover only	67.9	48.1	37.9	69.6	55.3	77.8
cloud cover and day time	73.5	90.2	75.5	62.7	56.3	70.3

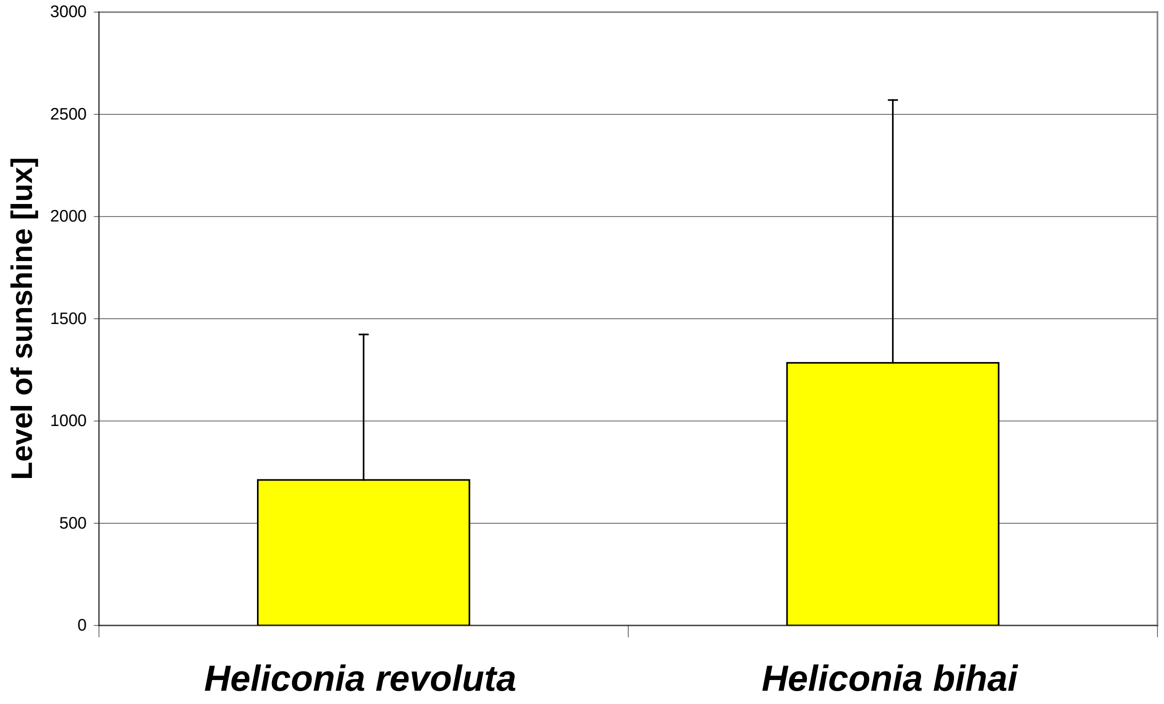

Fig.7. Average light intensities measured at leaves' surfaces of *Heliconia revoluta* and *Heliconia bihai*. Average ± SD.

Discussion

The observations made on epiphytes indicate that the different morphotaxa of epiphytes prefer exposed and sunny sites. The abundance and diversity was the highest in the open sites.

The intensity of sunlight is very variable. To offset the rapid changes in light intensity measurements we used arbitrary scale of cloud cover and attempted a further correction factor accounting for the changes in sunlight intensity with diurnal cycle. However, this attempts failed. This may be related to insufficient number of measurements at various times of the day an cloud cover, and also to the distances between measuring points and the actual situation of epiphytes on the trees.

In the second part of our study. we checked if *Heliconia bihai* prefers more sites with higher light intensity than *Heliconia revoluta*. As in this case we can measure level of sunlight directly on leaves' surface. the results are more reliable.

Conclusions:

(1) the biodiversity and abundance of epiphytes differ depending on light regime. However methods and equipment used for measuring level of light concerning the epiphytes on the trees was inadequate.

(2) We proved that *Heliconia bihai* prefers lighter places than *Heliconia revoluta*

Acknowledgements

We would like to thank prof. January Weiner for advices during field work and help with statistical analyses.

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