Epiphyll cover on *Asplundia* leaves in the tropical cloud forest

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Abstract

The leaves of plants of the genus *Asplundia* are often densely covered by epiphylls. The aim of the study was to inquiry the potential relationship between the epiphyllic cover, the altitude, and the age of the leaf. Leaves were sampled along altitude gradient from 1180 to 1515 m a.s.l. Sampling sites were chosen in order to ensure diversity of the altitude. Additionally, the physical characteristics of the environment were measured. Significant correlation between the epiphyll cover and altitude (as well as the humidity) for different leaves' age groups were found.

Key words: tropical montane forest, cloud forest, tropics, epiphyll, elevation gradient, *Asplundia*

Introduction

The tropical montane rainforest grows above the altitude of 1000 m a.s.l. and it is characterized by high humidity and precipitation. Therefore another name of this forest is cloud forest. Patches of montane rainforest are often isolated from other parts by valleys and ridges, so they tend to have many endemic species [3]. As a result of high humidity direct sunlight and thus evapotranspiration are reduced [1]. The trees of a typical cloud forest are usually shorter - 15-20 m in height - than those of lowland forest and they are heavily burdened with epiphytes that thrive due to the extremely high humidity [4, 5]. Most obvious features of cloud forest is an abundance of mosses, ferns, orchids and other epiphytic plants on every tree and rock surface [2].

The potential global area of cloud forest is about 380 000 sq. km, which is approximately 0,26 per cent of the Earth's land surface [5]. Cloud forests occur in the Americas, Africa and Asia. There is considerable variation in the altitude at which cloud forests have their limits of occurrence. On large inland mountain systems cloud forests occur between 2000 and 3500 m, whereas in coastal mountains may descend to 1000 m. Under exceptionally humid conditions a cloud forest zone may develop on steep, tropical island or coastal mountains at elevations as low as 500 m [5].

With increasing elevation above sea level the trees become gradually smaller and more 'mossy'. Changing from ca. 10% to 25-50% of moss cover of the bark and 15-35 m tall to 70-80% bryophytic cover and 20-22 m tall in upper montane forest [5]. As it was reported in Cloud Forest Agenda [5], there is a new and substantial evidence from the humid tropics that the number of species of lichens, orchids, bryophytes (mosses and liverworts), shrubs, herbs and ferns increases with elevation. In the past, epiphytes were often discounted or ignored in forest surveys, as their biomass was considered relatively insignificant. But now it is known that epiphytes reach their greatest abundance and diversity in montane cloud forests.

The aim of this study was to asses a potential influence of the altitude (above sea level) and the age of leaves on the speed and level of leaf colonization by epiphylls.

Materials and methods

The research were carried out in the northern part of Venezuela in Cordilliera de la Costa mountain range, Parque Nacional Henri Pittier, which is Venezuela's oldest national park, created in 1937. It has an area of 1078 sq. km. The highest point within the park exceeds 2400 m, and the park extends down to sea level.

Fig.1. The visible cover (epiphylls) on the surface of the leaf of *Asplundia*.

The tropical montane rainforest (adjacent to the Rancho Grande Biological Station [6]) was chosen as the most representative ecosystem for research area. Genus *Asplundia* (the *Cyclanthaceae* family) was chosen for this research because of its visible susceptibility to strong epiphyllic cover [Fig.1]. Moreover, this genus is very common in the study area.
The genus *Asplundia* includes approximately 107 species, distributed in the Neotropical ecozone from southern Mexico to southern Brazil [4]. The taxonomy of *Asplundia* is as follows:

Kingdom: *Plantae* – Plants
Phylum: *Tracheophyta* - Vascular Plants
Class: *Liliopsida*
Order: *Pandanales*
Family: *Curculionoidea*
Genus: *Asplundia*

All measurements were taken between 14th and 19th of July 2008 (days with stable and similar weather conditions) on 19 individuals. The research was carried out in the altitudinal gradient - from 1180 to 1515 m a.s.l. The altitude and geographic coordinates were determined with Garmin GPSmap 60 CSX device.

Number of leaves, geographical orientation and infrared surface temperature (InfraRed & K-Type Voltcraft IR-364 thermometer) were determined in every individual. Moreover, the intensity of light was measured (MS-1300 Light Meter) on the surface of every leaf and above the whole plant. The quotient of these two values was defined here as a normalized intensity of light for leaves. Temperature and relative humidity were monitored (Data Logger Voltcraft DL-120 TH) at the distance up to 1 m of every individual.

Five leaves of every plant were numbered according to age (1 – the youngest, 5 – the oldest). Five squares (1 × 1 cm) were chosen randomly on the surface of every leaf using a template. Each square was examined for the coverage by epiphylls using 7 arbitrary classes: 0 %, 5 %, 10 %, 20 %, 25 %, 50 % i 100 % of covering. Mean cover (called here Epiphyllic Cover Density, ECD) was calculated for a leaf and for and individual plant. A condition of every leaf was also evaluated (1 – without damages, 5 – heavily damaged). The successive classes of leaf condition were: 1 – intact; 2 – frayed / fragmented; 3 – with holes; 4 – frayed / fragmented and full of holes; 5 – very much frayed / fragmented, full of holes and rottening.

Non-parametric statistical tests were used because the data were not normally distributed (W Shapiro normality test). The method being used to discriminate among the means is Fisher's least significant difference (LSD) procedure. All statistical analyses were performed with Statgraphics Centurion computer program.

Results and discussion

Strong correlations between altitude and humidity as well as with temperature were observed [Fig.2].

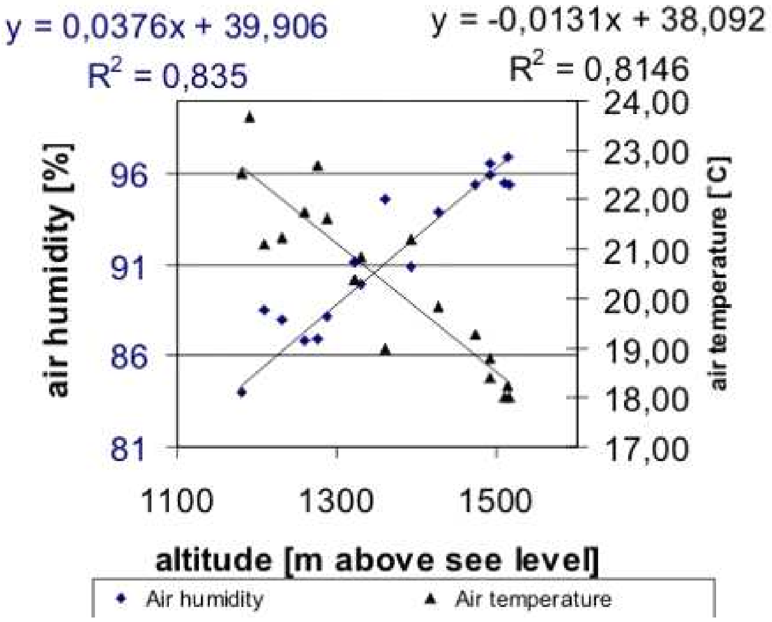

Fig.2. The relationship between altitude and the relative air humidity, and the air temperature (blue – humidity, black – temperature).

A tendency to the epiphyllic cover density (ECD) increasing with age was revealed [Fig. 3] for all plants without regard to elevation. The ECD of the leaves no. 4 and no. 5 differ statistically from the ECD of the leaves no. 2 and 3 (Fisher's LSD). As a result two homogenous groups are identified.

Fig.3. The ECD on leaves of increasing age (1-5). Columns signed with the same letter (a or b) do not differ statistically.

Collected data demonstrate a relationship to exist between the altitude and the ECD on leaves. The significance of correlation for leaves of various ages is different [Table 1, Fig. 4]. The table 1 and Fig.4 show that the occurrence of epiphylls on leaves is dependent on time (the age of leaves). Correlations between the age of the leaves and the altitude were tested. Only for leaf no.2 the correlation was not statistically significant. An inclination of the regression of leaf no. 1 was very low so we decided not to take the data of this leaf to further analysis. Next, data was divided into two groups: leaves 2 + 3 and leaves 4 + 5 because of no significant differences between measurements inside these groups (Fig. 3].

Table 1. Regression equations, determination coefficients and p-values (simple regression) between altitude (x) and epiphyllic cover density (y) of the leaves of different age.

No. of leaf (age)	equation [y=]	coefficient of determination R^2	p-Value
1	0,0058x-7,4	0,2599	0,0257
2	0,0318x-35,513	0,0866	0,2213
3	0,0927x-111,57	0,3938	0,0040
4	0,1378x-145,27	0,18956	0,0479
5	0,1394x-136,01	0,2737	0,0215

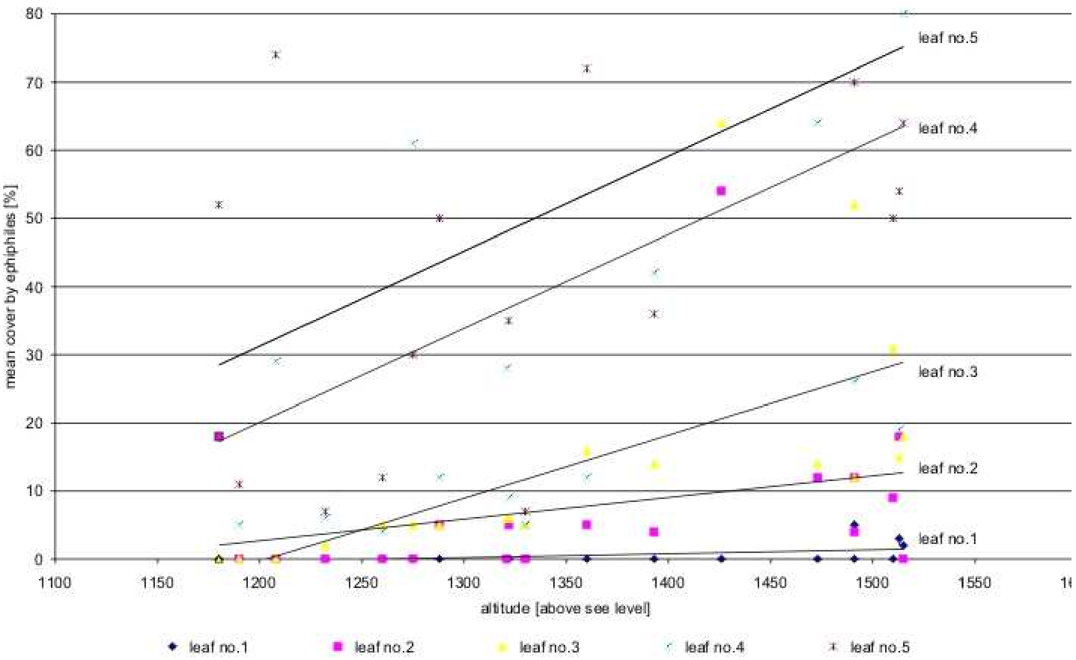

Fig.4. The relationship between the altitude and the mean cover by ephiphiles (for leaves of different ages).

The correlation between the ECD and altitude was found. Within the age gropus (2+3 and 4+5) the relation between altitude and the ECD seems to be curvilinear (Fig. 5].

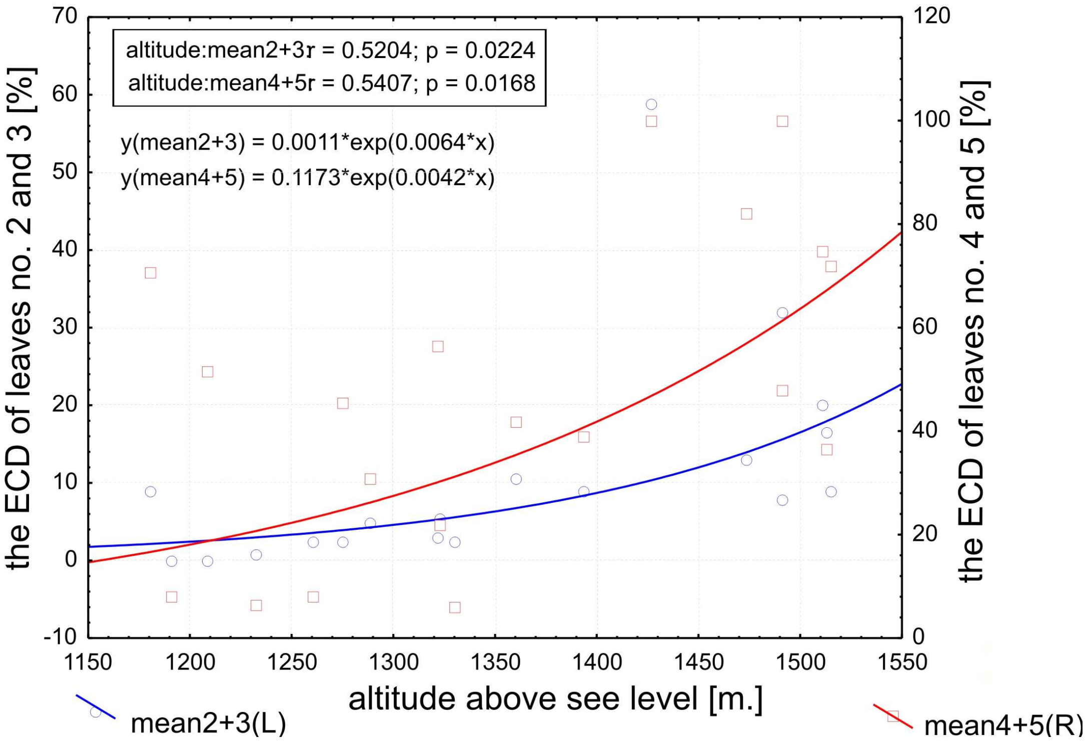

Fig.5. The relationships between the ECD (for both groups) and altitude.

Simultaneously the correlation between the ECD and the humidity is present because the humidity is strongly correlated with the altitude [Fig.2]

It is clear that older leaves (4 and 5) have a bigger cover at the higher elevation than leaves 2 and 3 [Fig. 5]. The main cause of this situation is the time of exposition (leaves 4 and 5 are longer exposed). This difference increases over the almost whole range of altitudes. We tested the correlation between the cover on leaves 2 + 3 with the cover on leaves 4 + 5 [Fig. 6]. It was statistically significant. The colonization speed is noticeably faster above an obtaining of 50% colonization on leaf. It is possible that presence of epiphylls can increase the rate of further colonization (because of changed properties at the leaf surface) [Fig. 6].

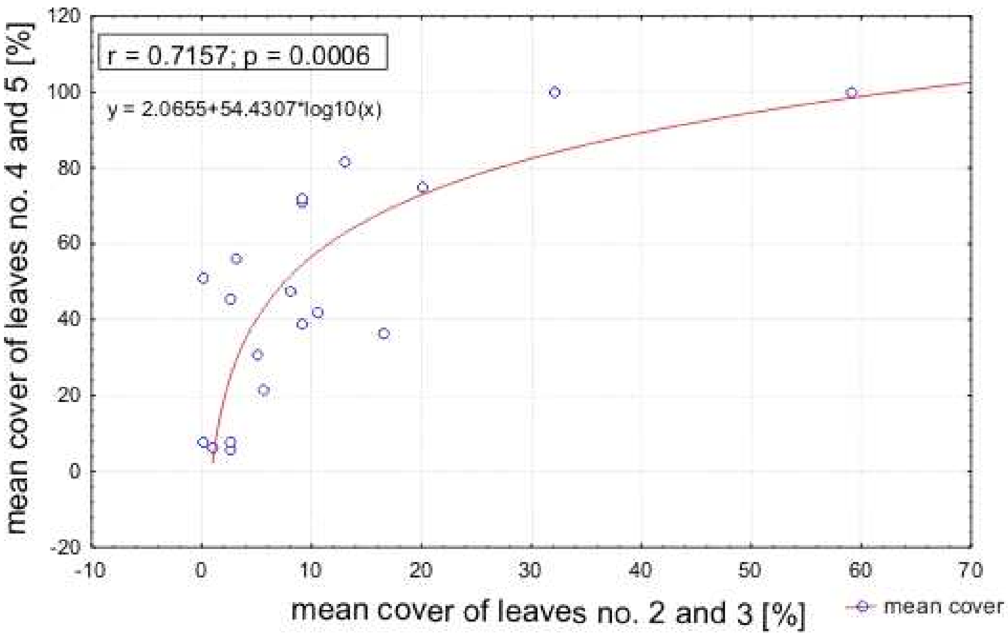

Fig.6. The increasing ECD of older leaves (4 + 5) with the increase of the cover of laves 2 + 3 at the same elevations.

The collected data did not reveal statistically significant correlation between the cover and the condition of leaves. No significant relation was also found between the temperature of leaves and the light intensity. We conclude that the most important factor determining the intensity of epiphyll colonization in the cloud forest is the altitude (with the humidity and temperature as its derivatives). The detected differences in light intensity are to week to determine the temperature of the whole plant or its leaves.

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We wish to thank Professor January Weiner for help with planning the research, statistical analysis and corrections, Dr. Jose Clavijo and Dr. Fred Stauffer for help with determining the genus *Asplundia*.

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The effect of light and slope exposure upon the direction of stilt root growth in *Iriartea fusca* or where to the “walking trees” walk?

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Abstract

The presence of stilt roots in *Iriartea fusca* may enable this palm to translocate. Potentially, translocation might be realized by directional growth of aerial roots, as affected by some environmental conditions. We chose light intensity and slope exposure as the two probably most important. Measurements and observations which had been done at numerous palms show that neither of this two variables can cause a translocation of mature individuals. It was also clear that only young palms are flexible enough to bent their trunk and move towards a more sun-filled habitat.

Introduction

Harsh abiotic conditions, such as water logging, poorly developed soil profile, unstable soil and difficulties in getting enough sunlight may cause various root architectural strategies in tropical rainforest trees. Jenik (1978, cit. after Goldsmith and Zahavi, 2007) identified 25 different models of such strategies. A few genera of palms, commonly referred to as stilt palms, normally produce a few large-diameter roots from the above-ground portion of the root initiation zone. They grow freely in the air until they don’t reach the ground (Kahn and de Granville 1992). These large roots grow downward into the soil, supporting and anchoring the palm stem above ground (Fig. 1). Stilt roots are largely confined to palms within the genera *Iriartea*, *Socratea*, and *Verschafeltia* but they have evolved in many plant families. It was observed that size, number, height, developmental pattern of the roots may differ substantially between individuals.

The function of stilt roots is still poorly understood despite many hypotheses. Kahn and de Granville (1992) connected stilt roots with areas prone to water logging and flooding. Swaine (1983) observed that stilt roots may give trees opportunity to avoid debris and logs. Some studies hypothesis that these roots improve the anchoring of the trunk if the soil is unstable or if the tree grows on a steep or windy slope (Henwood 1973, Jenik 1978, Richter 1984). According to Schatz et al. (1985, cit. after Turner 2001) stilt roots allow palms to gain more height for a given stem diameter than those without stilt roots. Hartshorne (1983) connected stilt roots with rapid growth when light becomes available in the understory. It was observed that in *Iriartea fusca,* which is sometimes called "the walking palm", vertical stem developed earlier than other palms. This hypothesis was considered by Goldsmith and Zahawi (2007), who have also shown connection between the number of stilt and the degree of slope inclination.

According to Bodley and Benson (1980) the aerial stilt roots of *Socratea exorrhiza* from the *Iriartea* family allow this palm literally to move. This situation may occur when immature palm is growing too close to another tree or to a log. It was observed that that new roots grow in the different part of the trunk and the lower part of it and older roots rot away and are left behind. The tree sends out new roots and moves away from its germination point. Also during observations of *Iriartea fusca* in the vicinity Rancho Grande Biological Station, such tendency in very young trees was noted.

For the last 30 years quite a number of studies connected with stilt roots of "walking palms" have been carried out (for a recent review see Goldsmith and Zahavi, 2007), however the question: "where to the walking trees go", and more precisely, if there is any defined directional assymetry of stilt roots' growth still remains unanswered. During the data collection in Rancho Grande we attempted to answer the following questions:

- What conditions may influence stilt roots' growth?
- Is there any defined direction of this growth?
- if there was a defined direction of roots' growth, could it enable translocation of the tree?

Study area and methods

The subject of the research were palms *Iriartea fusca.* Data were collected between 12th and 23th of July 2008 at Henri Pittier National Park in Venezuela. 20 Palms were sampled in cloud forest on the slopes near the Rancho Grande Biological Station (10°21'02''N, 67°41'02''W, ca.1100 m a.s.l.) or on a flat area of the nearby summit Cumbre de Rancho Grande (ca. 1450 m a. s. l)

Because the research site was within a national park, only palms growing close to the path were studied to avoid a possible habitat devastation during data collection. If the palms grew in groups of two or three individuals, one of them was randomly chosen for detailed study.

Only palms between 5 and 12 meters tall were included. This restrain made the object of the research more homogeneous and allowed to collect enough data.

For each individual palm the the light intensity, inclination and exposure of the slope have been measured. Luxometer MS 1300 was applied to measure the intensity of light at 8 points around the tree. These points were nominated according to the cardinal (N,E,S,W) and ordinal (N-E,S-E,S-W,N-W) directions in the distance of one meter from the tree trunk, on the height 2.75 (±0.1) m (Fig. 2). All light measurement were done between 11 a.m and 1 p.m. local time in 4 replicates at each single tree. During one day no more than two replicates have been done. Replicated measurements allowed to minimize the effect of variable weather conditions. Exposition and the inclination of the slope were measured using Ailfa Ranger compass with clinometer.

Other variables were estimated in a more arbitral way. The dominating direction of roots growth (Fig. 3) was defined as a direction to which the largest number of the stilt roots was growing. The angle at which the stilt roots turned aside from the trunk was arbitrarily assessed with the accuracy to the nearest cardinal or ordinal direction. Sometimes it has been observed that close to the trunk roots were growing relatively straight down, then rapidly bent at their end and enter into the ground almost horizontally. This was also considered a directional growth.

If no significant difference in angles at which the roots grow out of the trunk the directional growth was also assumed when a disproportionally large number of stilt roots was noted on one side of the trunk, that was recorded with the accuracy to the nearest cardinal/ordinal direction. Otherwise the directionality of roots growth was assessed as undefined.

Additionally, the total number of stilt roots (separately for the roots that reach the ground, and those which hang in the air), perimeter of the trunk at the heights 30 cm and 50 cm from the base of the youngest stilt root, and the height above ground at which the youngest roots spring out were recorded at each tree sampled.

During the data collection researchers also some more general observations were made concerning young palms (<5 meters tall) and the general description of habitat.

Data analysis

Light intensity measurements were transformed (standarized) in the following way: for each individual tree the averages of 4 replicates for each of the measuring positions (at 8 cardinal/ordinal directions) were calculated, an the ranked from 1 (the highest value of light intensity) to 8 (the lowest).

Data about sunlight intensity and slope exposure are directional, i.e. have a periodic character, thus simple statistical methods of correlation cannot be applied. To enable the testing of association between the variables the following transformation was employed: When the variables under consideration (e.g. slope inclination or sunlight intensity) reached their maximum at the same direction as the direction of dominating growth of roots (“direction of walk”) the association was given the value of 0; for the difference between the directions of 45° the value attributed was 0.25 or -0.25 (resp., clockwise or anticlockwise); for 90° the corresponding values were 0.5 or -0.5, for the angle 135 0.75 or -0.75, respectively, and for the angle 180 it was 1. The hypothesis of random vs. non-random distribution of empirical cases into these 8 categories could have been tested using standard statistical procedures, however, the number of cases studied proved to be insufficient for an exact analysis, therefore only graphical comparisons can be given.

Associations between the other variables studied linear correlations and regressions were tested.

Results

The original data collected for all 20 trees studied are presented in the Appendix.

The results concerning the dependence between light intensity and the roots growth direction and slope exposure are presented the results are presented only on the graphs. (Fig. 4 and 5). While apparently there is no effect of differential light intensity upon the directionality of roots growth (Fig. 4), the tendency may be noted to an association between the slope exposure and stilt roots asymmetry (Fig. 5). Because of the small sample size this tendency cannot be tested statistically.

On the other hand, the correlation coefficients between the slope inclination and the number of the roots, the trunk perimetere and the height above the ground on which the youngest stilt roots start from the trunk proved to be statistically significant (F>4.41; Fig. 6 a – f). A strong correlation was found between the number of roots, perimeter of the trunk, and the height on which the youngest roots start from the trunk (Fig. 6 e – g).

Other bservations

According to our non-quantitative observations, the palms *Iriartea fusca* tend to grow in local habitats of relatively high values of light intensity, if compared with the average conditions in the cloud forest. The “walking palms” occur only on the slopes where no other big trees occur, which may limit the light intensity, or on the flat areas on at higher altitudes atop of montain ridges, with relatively high sunlight intensity. At one occasion an interesting case of a young specimen of *Iriartea fusca* was observed: about 2 meters high, growing on a slope. The trunk of his palm was bent almost horizontally, with the stilt roots protruting from under the trunk nearly vertically down to the ground. The youngest roots never grow on the same side of the trunk, but they bend to the direction of the ground. The angle between two youngest roots is never smaller then 90°. In several cases it has been noted that the stilt roots growing initially (close tothe trunk) in one direction, at their end turn aside in various directions.

Discussion

The measurement and the observations made on the palms *Iriartea fusca* clearly indicate, that the light intensity does not affect much the direction of stilt roots growth, although in general the palms prefer well loighted locations. It is, however, possible, that the light intensity measurements have been made at too low a height above ground (well below the palm crown) to detect any differences and effects.

On the other hand, the effect of the slope inclination and exposure may have a significant effect upon the asymmetry of stilt root growth. Probably the fact, if palm grow on the slope have the actual impact on the direction of stilt roots growth . The roots turn aside from the trunk to a greater extent in the direction of downslope (the angle between the trunk and the stilt root is larger), and often more roots grow on this side of the tree. This tendency could probably be confirmed statistically on a larger sample size.

Our data did not allow for an exact statistical analysis of the connection between slope inclination and the perimeter of the trunk, and direction of the roots growth, however such an association has been shown on a larger and more homogenous sample by Goldsmith and Zahawi (2007).

To sum up, the walking trees do not walk, however, the immature specimens may translocate for small distance from the place of germination. Such translocation may occur on steep slopes. Immature palms searching for the best light conditions bend the trunk to the sun, the stilt roots protect the palm from falling down; this is their actual task, and not the locomotion. Larger individuals of *Iriartea fusca* cannot translocate at all because their trunks are not enough flexible, what would be necessary to move the whole mass of the tree to another position. The ability of the young palms *Iriartea fusca* to find the optimal situation on a slope give them an advantage over other tree species, not equipped with stilt roots.

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FIGURES

Fig. 1. Stilt roots of the palm *Iriartea fusca*

Fig. 2.Taking the measurement of light intensity.

Fig. 3. Asymmetric (directional) growth of stilt roots.

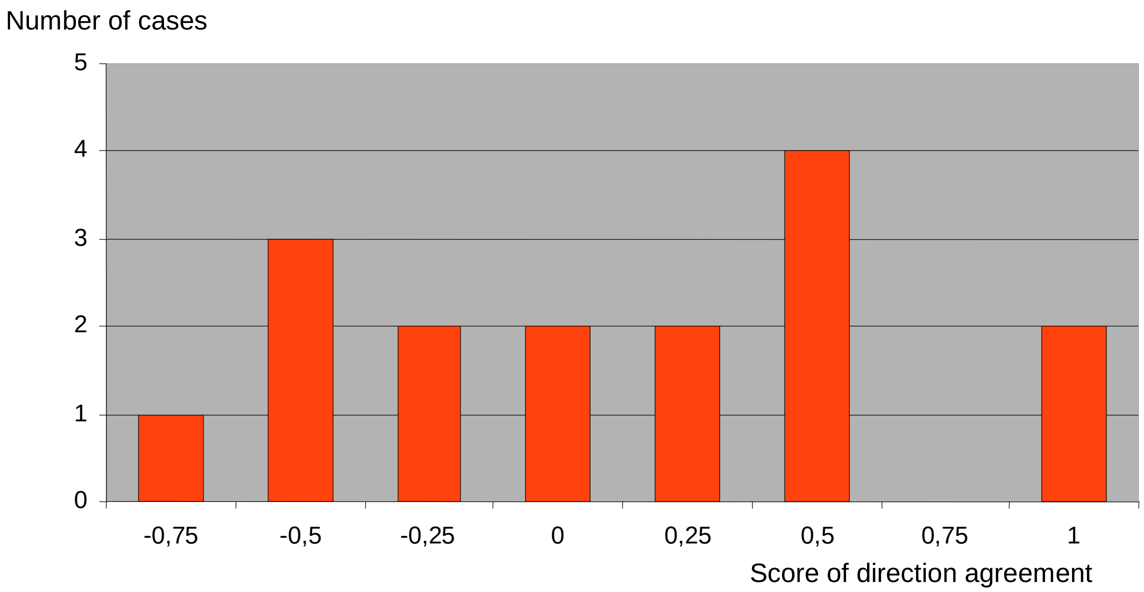

Fig. 4. Distribution of cases into the categories of direction accordance between dominating root growth and light intensity. Scores: 0 – identical direction; 1 – opposite direction.

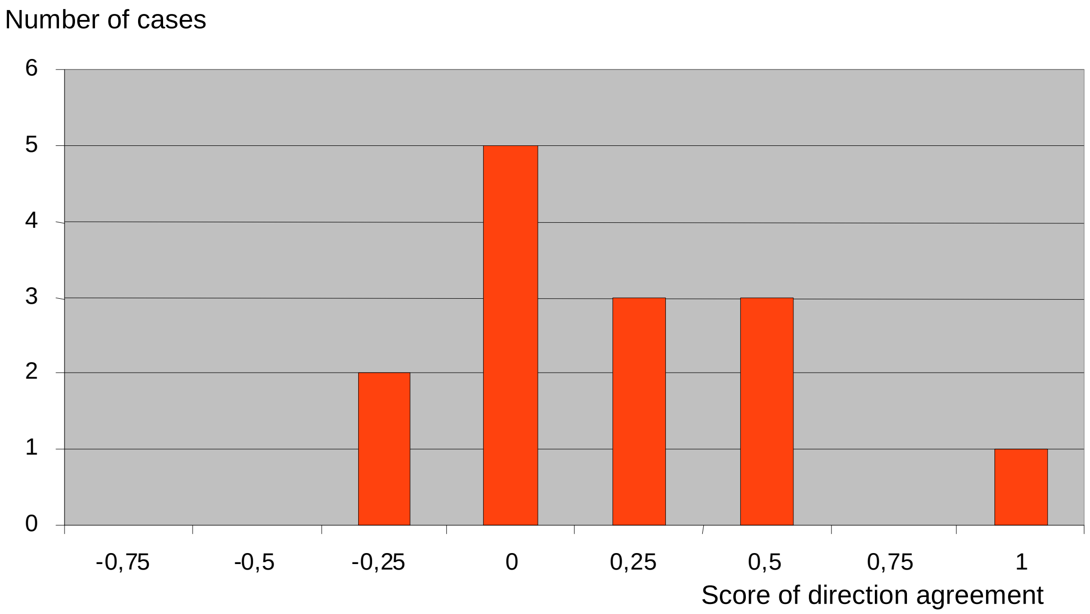

Fig. 5. Distribution of cases into the categories of direction accordance between dominating root growth and slope. Scores; 0 – identical direction; 1 – opposite direction.

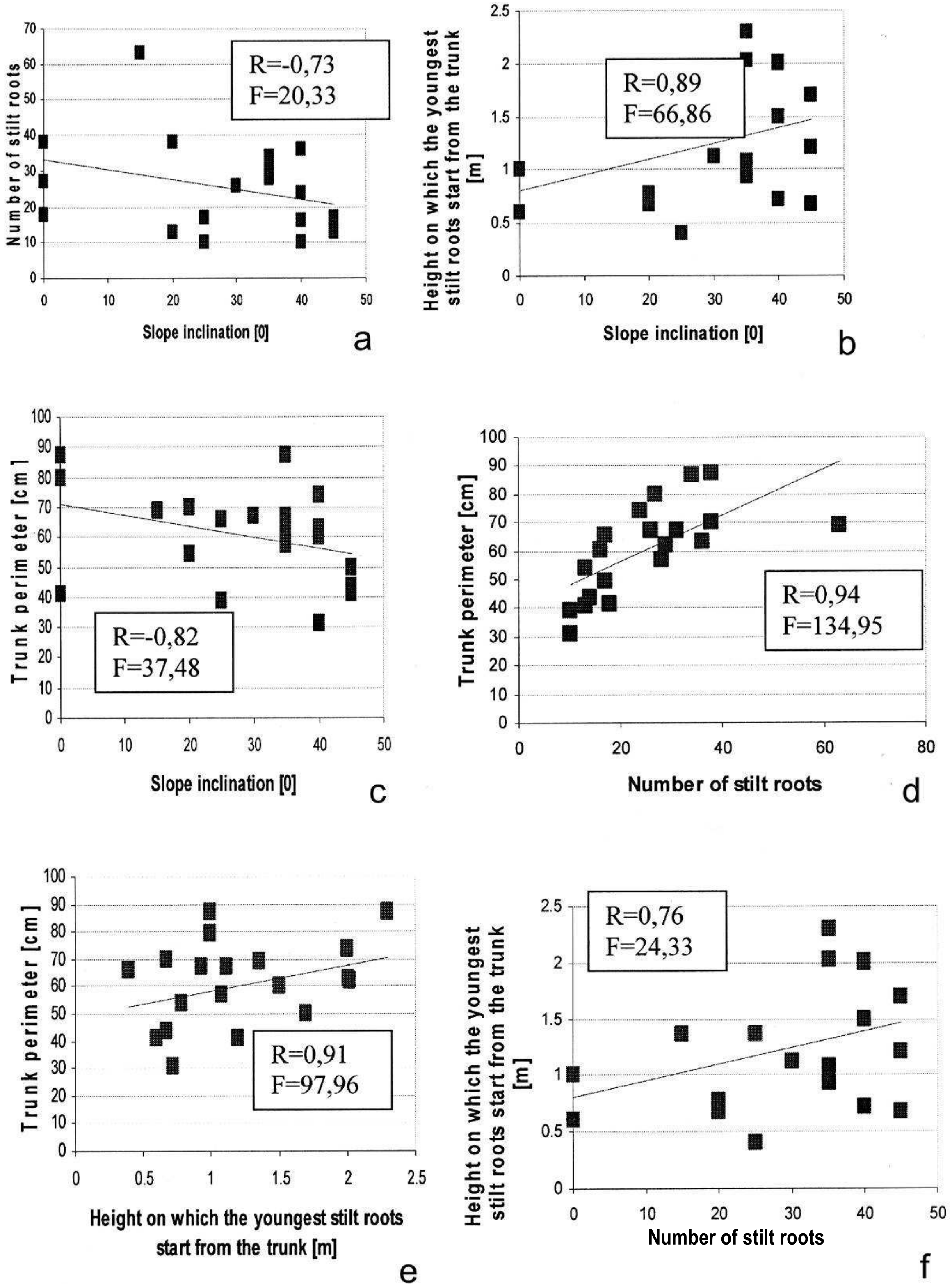

Fig. 6. Correlations and regressions between the variables studied: a – slope inclination and total number of stilt roots; b – slope inclination and the height at which the youngest root starts from the trunkk; c - slope inclination and the perimeter of the trunk; d – total number of stilt roots and the perimeter of trunk; e – height at which the youngest root starts from the trunk and the perimeter of the trunk; f – numetr of the roots and the height at which the youngest root starts from the trunk and the perimeter of the trunk.

APPENDIX

	Light intensity [Lux]								inclination [˚]	exposure	perimeter [cm]		height on which the youngest stilt roots starts from the trunk [m]	number of the stilt roots (Nr)	the youngest stilt roots	the direction of the stilt roots growth
	N	N-E	E	S-E	S	S-W	W	N-W			h=30	h=50				
1	254	244	364	425	426	312	200	185	40	S-W	60,2	64,3	1,5	16(1)	N	S-W
	220	250	230	540	680	1180	1260	980							S-W	
	990	940	960	1380	2060	1720	890	740								
	660	840	1030	1510	1470	1570	330	710								
Average	531	568,5	646	963,75	1159	1195,5	670	653,75								
Rank	8	7	6	3	2	1	4	5								
2	1080	290	80	150	350	1020	720	640	45	S-W	49,7	57	1,7	17(1)	W	N-W
	650	720	440	620	1050	2270	2400	580							E	
	500	2670	310	260	530	940	1330	550								
	740	1750	290	160	340	690	660	910								
Average	742,5	1357,5	280	297,5	567,5	1230	1277,5	670								
Rank	4	1	8	7	6	3	2	5								
3	970	1280	1200	1160	1060	1270	950	982	25	S-W	39	39,8	1,37	10	N	-
	786	1018	1114	1230	981	1160	1006	804							S-E	
	1127	1225	1217	1142	1140	1742	1236	1407							N-W	
	1268	1056	1301	953	1033	1587	1410	1519								
Average	1037,8	1144,8	1208	1121,3	1053,5	1439,8	1150,5	1178								
Rank	8	6	2	7	4	1	5	3								
4	150	130	85	205	200	420	370	220	45	W	43,5	50	0,67	14	E	E
	241	148	301	402	625	700	588	368							N	
	288	199	175	449	780	916	438	415							W	
	415	249	247	309	715	1109	516	607								
Average	273,5	181,5	202	341,25	580	786,25	478	402,5								
Rank	6	8	7	5	2	1	3	4								
5	450	250	350	1500	1710	1880	600	800	40	S-W	31	32	0,72	10	N-W	N-W
	650	370	470	570	660	1400	510	360							S-W	
	106	1330	1510	1420	1230	2270	2040	830								
	720	1070	900	680	1080	1200	310	500								
Average	481,5	755	807,5	1042,5	1170	1687,5	865	622,5								
Rank	8	6	5	3	2	1	4	7								

6	800	1230	1250	550	5000	900	1250	1450	35	S	87	-	2,3	34(5)	N-W	S-E
	4800	3500	13000	8500	1000	6200	4500	7000							S-E	
	2040	1740	1840	3360	4500	780	7150	2800							S-W	
	2750	2040	2140	1690	1410	3140	2900	2510								
Average	2597,5	2127,5	4557,5	3525	2977,5	2755	3950	3440								
Rank	7	8	1	3	5	6	2	4								
7	1080	1670	1300	1670	1600	1840	1020	1030	0	-	41,2	35,8	0,6	18	W	-
	1640	2060	1680	1740	1800	1510	700	1200							N-E	
	800	800	850	720	980	790	880	730								
	600	350	540	860	1270	1030	1050	520								
Average	1030	1220	1092,5	1247,5	1412,5	1292,5	912,5	870								
Rank	6	4	5	3	1	2	7	8								
8	720	950	750	570	510	340	470	680	30	N	67	64	1,12	26	N-W	N
	1000	960	840	250	250	250	570	600							S-W	
	500	500	200	200	200	70	280	260								
	150	130	250	100	70	30	60	70								
Average	592,5	635	510	280	257,5	172,5	345	402,5								
Rank	2	1	3	6	7	8	5	4								
9	1360	1260	700	1200	2400	3900	1600	4020	35	N	57	-	1,08	28	N-E	N-E
	1830	1390	640	750	1070	2040	1800	1370							W	
	1470	950	830	980	1110	1200	1500	1960							N-E	
	270	150	140	100	180	140	30	120								
Average	1232,5	937,5	577,5	757,5	1190	1820	1232,5	1867,5								
Rank	3	6	8	7	5	2	3	1								
10	400	430	420	310	350	180	330	200	20	N	70	67,8	0,67	38(1)	N-W	N-W
	310	600	470	410	360	310	270	270							S-W	
	400	460	260	280	530	370	280	210							N-W	
	280	430	430	340	110	130	150	70								
Average	347,5	480	395	335	337,5	247,5	257,5	187,5								
Rank	3	1	2	5	4	7	6	8								
11	1000	700	1600	1100	1230	1100	1050	1000	20	N	54,1	47,8	0,78	13	S-E	-
	550	700	850	840	830	870	1100	690							S-W	
	330	500	520	570	450	830	490	350								
	470	660	940	700	700	590	540	500								
Average	587,5	640	977,5	802,5	802,5	847,5	795	635								
Rank	8	6	1	3	3	2	5	7								
12	1300	980	980	900	780	550	500	600	0	-	79,8	75	1	27	S-E	E

	450	580	450	470	610	610	470	420							N	
	350	410	300	260	390	210	270	290								
	820	600	600	700	450	350	300	480								
Average	730	642,5	582,5	582,5	557,5	430	385	447,5								
Rank	1	2	3	3	5	7	8	6								
13	1500	1250	1200	800	700	750	1100	1400	15	W	69	65	1,36	63(3)	W	W
	3000	2500	2160	1510	1340	1450	1700	2450							N-W	
	400	340	280	260	560	480	320	350								
	270	260	210	180	170	290	290	260								
Average	1292,5	1087,5	962,5	687,5	692,5	742,5	852,5	1115								
Rank	1	3	4	8	7	6	5	2								
14	620	380	550	580	510	560	600	410	0	-	87,2	83,1	1	38	S-W	S-W(W,S)
	650	390	270	380	310	230	430	340							E	
	420	530	910	760	460	260	330	350								
	380	330	290	360	350	290	290	290								
Average	517,5	407,5	505	520	407,5	335	412,5	347,5								
Rank	2	5	3	1	5	8	4	7								
15	960	350	440	1170	1410	1610	1350	1120	35	W	67,1	65,8	0,93	31(4)	E	W
	580	300	870	980	1150	900	980	630							W	
	1400	380	650	1080	1250	1140	1670	400								
	230	150	476	1340	1900	1360	1210	510								
Average	792,5	295	609	1142,5	1427,5	1252,5	1302,5	665								
Rank	5	8	7	4	1	3	2	6								
16	510	660	460	1380	1500	1550	1460	1550	25	N	65,8	60	0,4	17	N	N-E
	530	570	870	980	2240	3260	3100	2610							S-W	
	1060	1000	1140	1000	1440	1010	740	900								
	2650	1580	1150	1070	1210	1800	1800	2130								
Average	1187,5	952,5	905	1107,5	1597,5	1905	1775	1797,5								
Rank	5	7	8	6	4	1	3	2								
17	7800	9400	7570	5700	3420	1500	5410	9500	45	S-W	41	38,9	1,2	13	E	-
	9050	10450	8500	7000	5630	3800	6070	7250							W	
	13640	17200	10100	9000	7160	3050	7080	19500								
	14460	11200	8270	8300	4600	1630	10100	17360								
Average	11238	12063	8610	7500	5202,5	2495	7165	13403								
Rank	3	2	4	5	7	8	6	1								
18	8120	8050	7900	8900	11700	10200	11800	8900	40	W	74	-	2	24	N-W	W
	5720	5560	5630	6030	7560	12080	4400	6580							S-E	

	13000	77500	99000	99400	93000	98500	72000	20200							S-E	
	63700	74800	91300	80000	53000	95600	94600	91500								
Average	22635	41478	50958	48583	41315	54095	45700	31795								
Rank	8	5	2	3	6	1	4	7								
19	493	612	1045	780	770	1750	1790	905	35	S	62	60	2,02	29	S-E	S-W
	806	765	746	1263	1461	1880	1796	668							W	
	940	1030	860	880	810	1350	1410	810							S	
	1460	1560	1300	1320	4800	7100	3400	1660								
Average	924,75	991,75	987,75	1060,8	1960,3	3020	2099	1010,8								
Rank	8	6	7	4	3	1	2	5								
20	321	296	733	594	678	274	175	245	40	S-W	63	61	2,01	36	S	N-W
	384	991	1050	1260	1207	486	329	288							W	
	445	594	536	688	435	471	533	550							S-W	
	434	704	930	771	812	500	225	301								
Average	396	646,25	812,25	828,25	783	432,75	315,5	346								
Rank	6	4	2	1	3	5	8	7								

Percentage of sprouting seeds of *Gyranthera caribensis* in relation to the distance from the tree.

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Report submitted in partial fulfillment of the requirements for the course “Tropical ecology” (WBNZ 801), at the Faculty of Biology and Earth Sciences, Jagiellonian Univeristy, Kraków, Poland. 2008.

Abstract

The aim of our research was to determine the sprouting rate of *Gyranthera caribensis* seeds in relation to direction and distance from the tree. Researches were made in Henri Pittier National Park near biological station Rancho Grande. No significant correlation has been found between the number of sprouting seeds and the direction and distances of their falling from the tree. The lack of such effect could have been caused by the landform characteristics as well as the fact that the investigations were carried out during the initial seasonal propagation phase of *Gyranthera caribensis*.

Introduction

Henri Pittier National Park is located in ecoregion of Cordillera de la Costa. This mountain range is characterized by very high humidity (about 98% in wet season) [Beebe and Carne, 1947] and it is covered by a cloud forest very rich in biodiversity. In the Park we could see also different habitats like dry semi-deciduous forest, evergreen rain forest, coastal shrub forest, mangroves or savannah. The Park was created in 1937 and it covers 107,800 ha.

Gyranthera caribensis is a species of a giant endemic tree, common in Henri Pittier National Park. A large group of these trees grows near the Rancho Grande Biology Station. The tallest tree reaches the height of 60 m and has huge buttressed roots. Its fruit is about 0,3 m long. Inside the heavy fruit large seeds with long flight feathers (10-15 cm; Fig.1) are densely packed. Their propagation was subject of this research.

The most amazing thing about this species is not incredible dimensions of these trees, but their seeds with enormous flight feathers. This clearly suggest that seeds falling from about 50 m above the ground can use this feature to reach new places and increase their propagation.

Due to our observations in the forest, when a single seed leaves the fruit, at first it keeps falling and after 3-4 m it starts to rotate. The seed turns always in the same direction in a helicopter mode. The flight feather has always regular shape which results in a very regular falling. The main effect of the rotation is slower falling. Without wind the seed falls straight to the ground. The question arises whether the seeds flight feathers do help to increase the distance of dispersed, and whether the probability of sprouting depends on the distance from mother tree.

Fig.1 Non sprouting and sprouting seeds of *Gyranthera caribensis*

Methods

Research was carried out from 12 to 23 July 2008. Area of our researches was situated above the Rancho Grande Biology Station, nearby the educational path from 1100 m a.s.l. to about 1250 m a.s.l. The whole area was a mountain slope with inclination about 30 – 40 grades toward S.

We selected and numbered 28 trees concentrated in a group. At first, under 9 randomly selected trees we set small plots of 1 m^2 between buttressing roots, three per one tree, in a different randomly selected directions. On these plots we carefully examined the forest floor for sprouting / non sprouting seeds and flight feathers.

Next, we selected 11 trees within the group of 28 trees, only the individuals growing at the edge of the group or solitarily (more than 30 m from another closest individual). From these trees we marked out 25 transects in 4 directions (always: NE, NW, SE or SW, but only pointing outside of the group, therefore some trees had only one or two transects). Transects were 40 m long except a few which were shorter because of the terrain obstacles. On each transect plots of 2×2 m were established at distances of 5 m from each other, so that one transect contained 8 plots of 4 m^2 each. On each plot litter was carefully examined to count sprouting seeds, non sprouting seeds and separate flight feathers.

Transects were marked out using a compass and a rope. The measuring tape was used to check the distances from trees and to mark out square plots. Statistical analysis of the data (numbers of seeds per plot) was performed using Kruskal-Wallis nonparametric test instead of ANOVA because the homogeneity condition was not met in most of the data.

Results

No statistically significant differences in average numbers of sprouting seeds and flight feathers were found in all transects. Additionally, there was no statistically significant difference in the sum of seeds and flight feathers collected in points situated at different distances from the tree trunks (Fig. 2). Individual transects significantly differed in the sum of all seeds (sprouting, non sprouting and flight feathers; H=7.773 p=0.0509; Fig. 2) and the average number of non sprouting seeds (H=11.423 p=0.0096; Fig. 3). The sum of all seeds (sprouting, non sprouting and flight feathers) as well as the average number of non sprouting seeds in SE transect was higher than in NW and SW ones. However, there was no statistically significant difference between SE and NE transects.

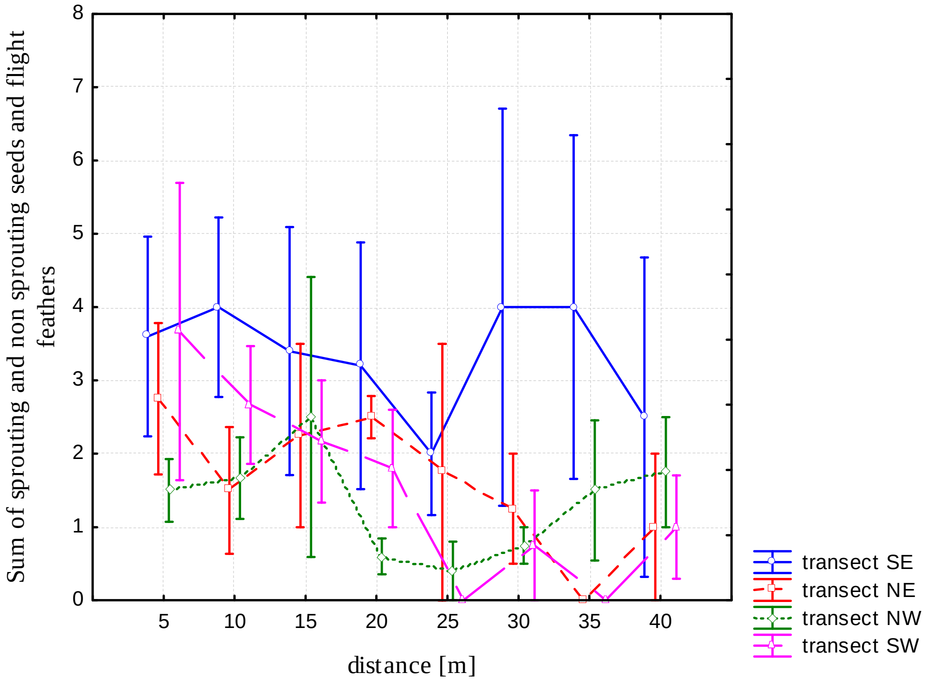

Fig.2. Sum of sprouting and non sprouting seeds and flight feathers on distance from tree trunk in four directions.

Vertical bars denote +/- standard errors

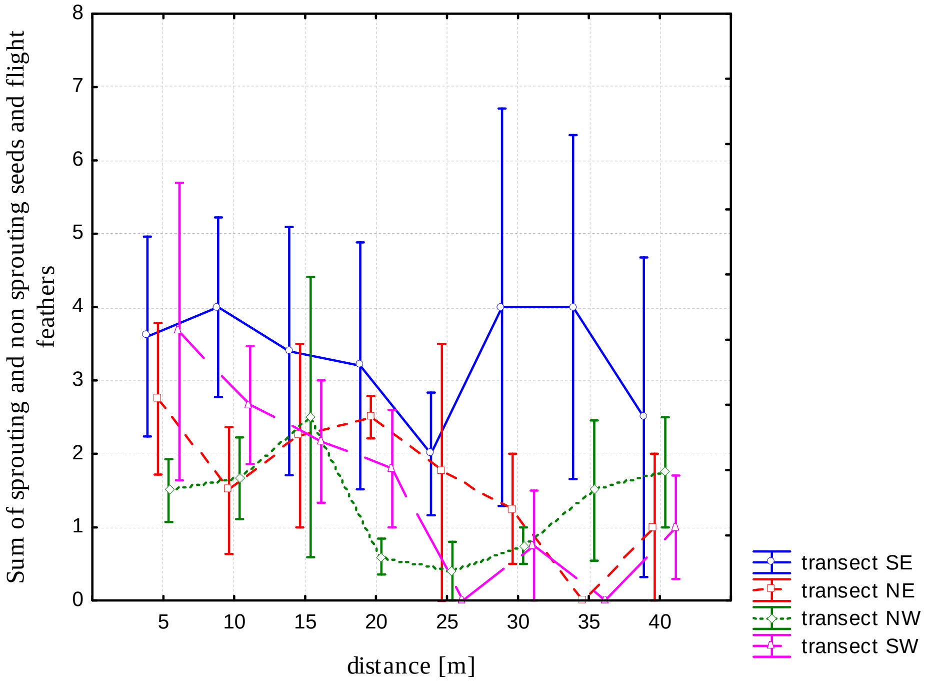

Fig. 3. Average number of non sprouting seeds on distance from tree trunk in four directions. Vertical bars denote +/- standard errors

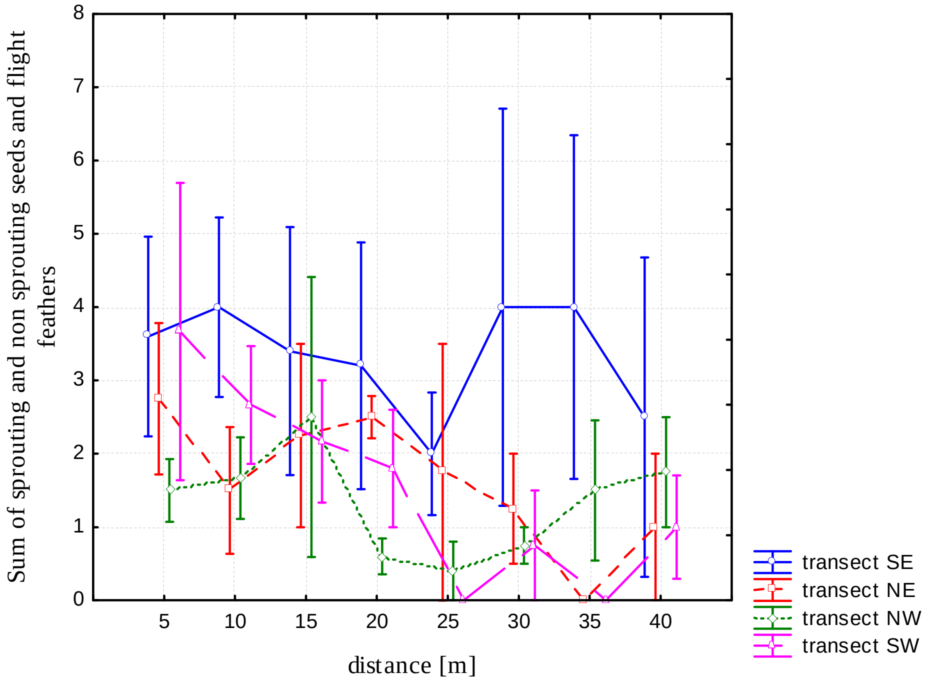

Fig.4 Average number of sprouting seeds on distance from tree trunk in four directions. Vertical bars denote +/- standard errors

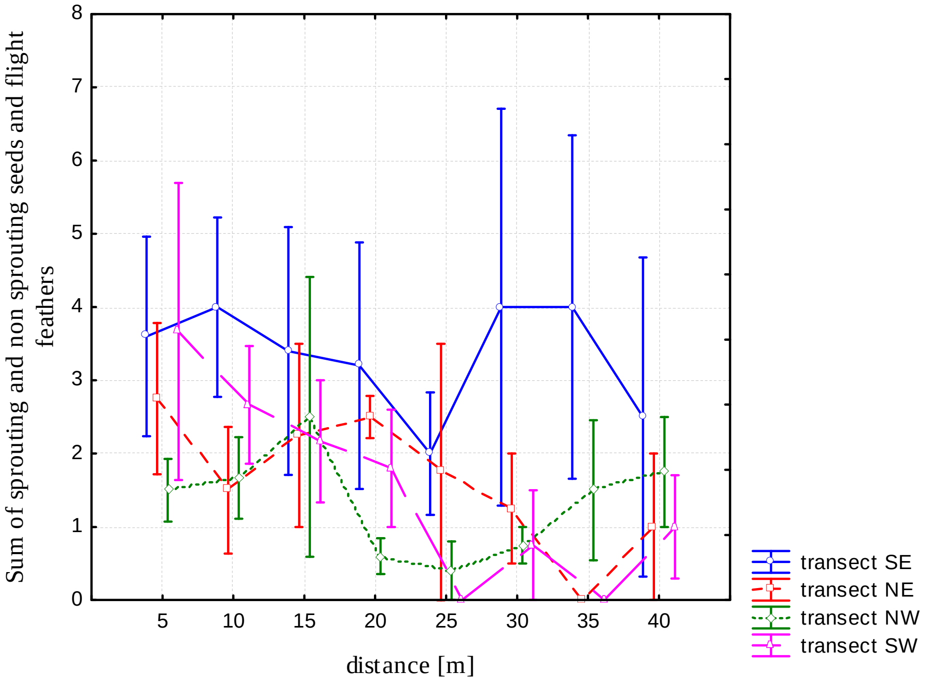

Fig.5 Average number of flight feathers on distance from tree trunk in four directions. Vertical bars denote +/- standard errors.

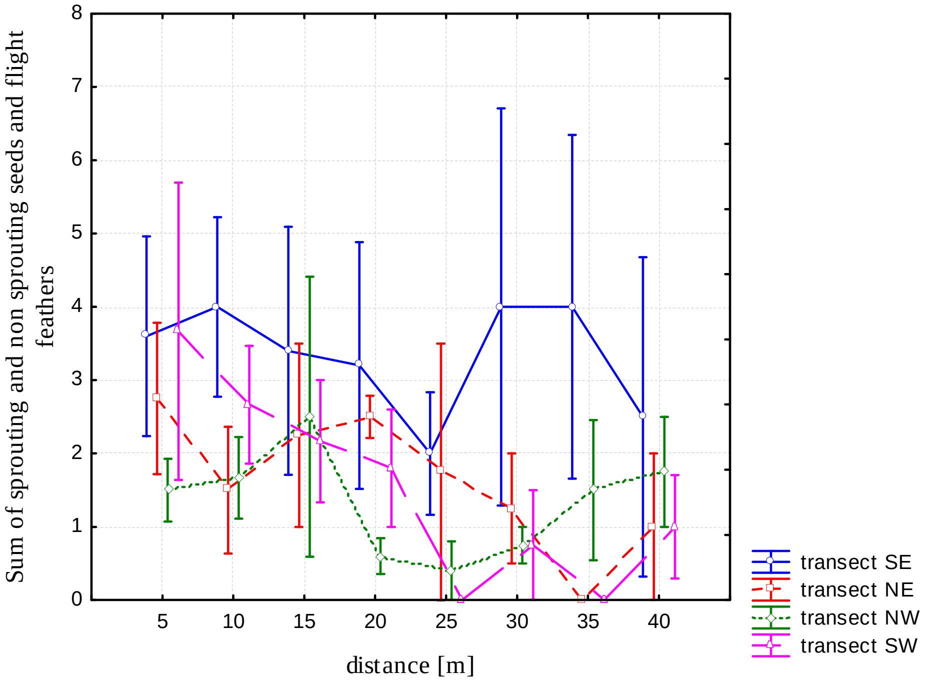

Fig.6 Average percentage of flight feathers, sprouting seeds and non sprouting seeds on individual distance from tree trunk

Discussion

The results show that the distance from tree trunk as well as the direction where *Gyranthera caribensis* seeds fall down do not have any influence on their capability to sprout. *Gyranthera caribensis* seeds are equiped with flight feathers but they provide very poor flight abilities in still weather. This fact causes that the seeds fall down in a close distance from the tree. Probably in windy periods seeds are being carried for longer distances. Unfortunately during our research we were not able to observe this because the winds were not strong enough. Furthermore it was at the beginning of the propagation phase of *Gyranthera caribensis*, so the number of seeds on the ground was still quite low. Supposedly the distances in which *Gyranthera caribensis* trees grow represent the maximum range of seeds scatter (we have not found any tree situated farther than 40 m from another tree of the same species). However we could not recognize *Gyranthera caribensis* plovers which could grow close the trees examined.

We cannot precisely explain statistically significant differences between SE and NW as well as SW transects considering the sum of seeds, flight feathers and non sprouting seeds. We suppose that this fact remains in connection with the landform character since the slopes, where the research has been carried out, were mostly S-oriented. In SE transects the whole sum of seeds, flight feathers and non sprouting seeds was higher than in NW and SW transects. The question arises why in spite of higher sum of seeds and flight feathers in SE transects no more sprouting seeds were found there? More seeds fell down on SE transects due to prevailing slope. However, we were not able to explain why the seeds fell down more often in SE than SW direction, because their number should be nearly the same on each S-oriented slope. It may be the effect of changing wind directions. In Cordillera de la Costa the breezes reported to be variable. During the day the wind was often from SE, changing during the late afternoon to NW [Beebe and Carne, 1947].

It has been shown that autocorrelated turbulent fluctuations in vertical wind velocity are the key mechanism for long-distance dispersal [Soons et al., 2004]. Seed dispersal distances are longest under high wind velocity conditions. The heights of seed release and of the surrounding vegetation play a crucial role in determining seed dispersal. *Gyranthera caribensis* releases seeds from a very high level (up to 60 m) but the surrounding vegetation is also very high. Probably this fact (high level of surrounding vegetation) reduces dispersal distance of *Gyranthera caribensis* seeds.

We assume that the conditions in SE transects were not suitable for sprouting of higher number of seeds than in other transects. That is why the average number of non-sprouting seeds is higher in SE transects.

Acknowledgments:

We are grateful to Dobrosława Bugajna and Mateusz Buczek for their help in the filed work.

Literature cited:

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Soons M., Heil G., Nathan R., Katul G. (2004) *Determinants of long-distance seed dispersal by wind in grasslands*. Ecology **85**, 3056 - 3068

The relationship between insects diversity and height above sea level nearby Rancho Grande biological station in Henri Pittier National Park (Venezuela).

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Report submitted in partial fulfillment of the requirements for the course "Tropical ecology" (WBNZ 801), at the Faculty of Biology and Earth Sciences, Jagiellonian Univeristy, Kraków, Poland. 2008.

Abstract

Insects were caught in pitfall traps at three posts: 1500, 1300 and 1100masl at the humid mountain cloud forest and transitional zone between humid mountain cloud forest and the high elevation cloud forest. Ants were skipped in this research. The number of specimens and species indicates decline in species richness with increasing elevation, however at the height of 1300masl a small increase of diversity was observed. The dominance D and the eveness indexes are the lowest there as well. Extremely rapid faunal turnover with elevation was shown in this study. The project should be treated as an introduction to further, more precise analysis, which is very important because of the environmental protection.

Introduction

Although the altitudinal and latitudinal clines in diversity studies have a very long history dated back to the origins of biogeography, there is still a lot of controversy and contradiction related to this subject (Lomolino 2001, Brown 2001). Especially the distribution patterns of insects, which are relatively faintly known group of animals, have been constantly tested and their cognition is still incomplete (McCoy 1990, Wolda 1987, Brehn et al. 2003).

Nowadays it is considered that species diversity, with small exceptions, have been declining with elevation (Wolda 1987). However, it is necessary to remember that most of the researches on which this opinion is based were conducted in tropical rain forests (Wolda 1987). What is more, the comparison between diversity gradients in tropical mountain cloud forests and in temperate zone mountains can be very interesting (McCoy 1990). It is also important that, although the decline in species richness with increasing elevation is considered as a general pattern, there are many researches that challenge this opinion (Rahbek 1995).

Such researches are also important as far as the tropical mountain environment protection is concerned. The organisms which live there are very sensitive to every little change in the environment – are exceptionally stenotypical. Tropical species are very conservative in relation to the ecological niche. This results in a very small amount of vertical ranges (and this can stop horizontal spreading) and rapid faunal turnovers with elevation (Huey 1978, Janzen 1967, Pianka 1983, Stevens 1989; after: Olson 1994).

Authors of this project hope to increase understanding of the problem presented above. The research was conducted in an inhabited forest, characterized with almost no disturbance by man. Conclusions, which are very important because of environmental protection not only for Henri Pittier National Park, but for all tropical mountains' ecosystems, can be treated as an introduction to further and more precise analysis.

Materials and methods

Study area

Project was realized in north Venezuela in the neighborhood of Rancho Grande biological station in Henri Pittier National Park, 120km east from Caracas., in the mountains above Lake Valencia and the city of Maracay, Aragua (10°21'N, 67°41'W). Researches were realized at the high of 1100-1500masl, in the humid mountain cloud forests and the transitional zone between humid mountain cloud forest and the high elevation cloud forest.

Field methods

Three posts were set: A at the height of 1500masl, B – 1300masl and C – 1100masl. 10 pitfall traps with poison (car cooling lotion) for 2 days were placed in each of them. After collection the material was divided, according to the key made on the project needs, into morphospecies (tab.1). This is very simple and effective method to use as surrogate for species (Oliver and Beattie 1993, Oliver and Beattie 1996). Ants were not considered.

Table 1. The division of gathered material into morphospecies.

ORTHOPTERA	
1	*Gryllidae*; 15,25mm long; dark brown body with quite many light dots on it; 3rd pair thighs are light only at the bottom.
2	*Gryllidae*; 12,42mm long; dark body with light stripes; 3rd pair tights are light with a few dark dots.
3	*Gryllidae*; 11,9mm long; abdomen covered with stiff wings at 2/3; dark brown body, 3pairs of light limbs, covered with dark stripes at full length.
4	*Tettigoniidae*; 35mm long; long spikes at the end of an abdomen; 3rd pair tights are dark with light stripes.
5	*Caelifera*; 18,5mm long; 3rd pair hips are dark.
BLATTODEA	
6	17,8mm long; bottom part dun with light spots, top – brown; slender body, cerci are leafy shape.
7	24,05mm long; wide and massive body; cerci very short; bottom part light brown, homogenous; top – dark brown, matt.
8	8,65mm long; very slender body; delicate covers; bottom part light brown; top – very dark brown, almost black.
COLEOPTERA	
9	*Staphylinidae*; 8,3mm long; black; abdomen bent into up – looks like scorpion.
10	*Staphylinidae* ; 17,5mm long; black, matt.
11	*Staphylinidae*; 11,4mm long; red head and thorax, black and shiny abdomen and covers.
12	*Elateridae*; 9,1mm long; reddish brown head and thorax, black and shiny abdomen.
13	*Scarabeidae*; 7mm long; covers perforated by longitudinal stripes, black, shiny with bluish green reflection.
14	*Scarabeidae*; 3mm long; black, shiny, smooth covers.
15	*Carabidae* ; 8,45mm long; black wit6h brown reflections; covers perforated by longitudinal stripes.
16	*Carabidae* ; 4,55mm long; dark brown, shiny, white dots at the end of each cover..
17	*Scarabeidae*; 5,95mm long; brown covers with red reflections, perforated by dots.
18	*Scarabeidae*; 5,25mm long; black with brown reflections, covers perforated by longitudinal stripes.
28	*Scarabeidae*; 1mm long; black, shiny.
19	PROTURA; 15,25mm long, light body.
20	HYMENOPTERA; 14, 63 mm long; black with white mark at the end of thorax; small black dots at the first pair of wings (1 dot on each wing).
21	MECOPTERA; 5mm long.
22	MECOPTERA; 3mm long.
23	ZYGENTOMA; 9mm long.
24	COLLEMBOLA; 4mm long.
DIPTERA	
25	2,8mm long.
26	2mm long.
27	1mm long.

Statistical methods

Differences in species diversity between the posts were compared on the basis of the number of specimens and species and also Fisher alpha biodiversity index. Additionally, diversity indexes, which are shown in tab.2, were calculated for each post. Ants were skipped in calculations. The general number of ants is shown in tab.2.

Table 2. An exact characteristic of each of three posts.

morphospecies	**post symbol and the number of specimens**		
	A - 1500	**B - 1300**	**C - 1100**
1	4	0	0
2	17	7	0
3	0	2	1
4	2	0	0
5	0	5	1
6	1	0	0
7	0	1	0
8	0	1	0
9	1	1	30
10	0	0	1
11	0	0	1
12	1	0	0
13	0	4	3
14	0	0	2
15	0	1	0
16	0	2	0
17	0	1	2
18	0	1	0
19	1	0	0
20	1	0	0
21	1	0	0
22	0	0	1
23	0	1	0
24	0	1	0
25	0	0	1
26	0	0	1
27	0	0	1
28	0	1	1

the number of ants' specimens	17	10	49
the number of morphospecies in a post	9	14	13
the number of specimens in a post	29	29	46
Fisher_alpha	4,471	10,65	6,034
Dominance_D	0,3746	0,1272	0,4376
Shannon_H	1,467	2,333	1,479
Simpson_1-D	0,6254	0,8728	0,5624
Evenness_e^H/S	0,482	0,7366	0,3374
Menhinick	1,671	2,6	1,917
Margalef	2,376	3,861	3,134
Equitability_J	0,6679	0,8841	0,5764
Berger-Parker	0,5862	0,2414	0,6522

Results

Figures number 1 and 2 show the dependence between the height above sea level, the number of morphospecies, the number of specimens and Fisher alpha index. The amount of the species is different in post A (1500m) – 9 species and B (1200m), and C (1100m) – slightly 14 and 13 species. The posts B and C differ only in one morphospecies. The post C differs significantly in the number of specimens. 46 specimens of all morphospecies have been collected there (30 specimens belong to morphospecies no9), while in the posts A and B -29 each (tab.3). Fisher alpha index is the highest in the post B: 10.65. The posts A and C differ slightly: 4.471 i 6.034 (tab2).

Diversity indexes:

The dominance index is the highest in the post C, slightly lower but still comparable- in the post A, and clearly lower in the post B. The same rate possesses the eveness index and similar- Shannon index. But these rates change if the number of the specimens is taken into consideration. Menhinick factor has a similar distribution, but its values are more similar in each of the spots. Distribution of the equitability index is similar to Menhinick index.

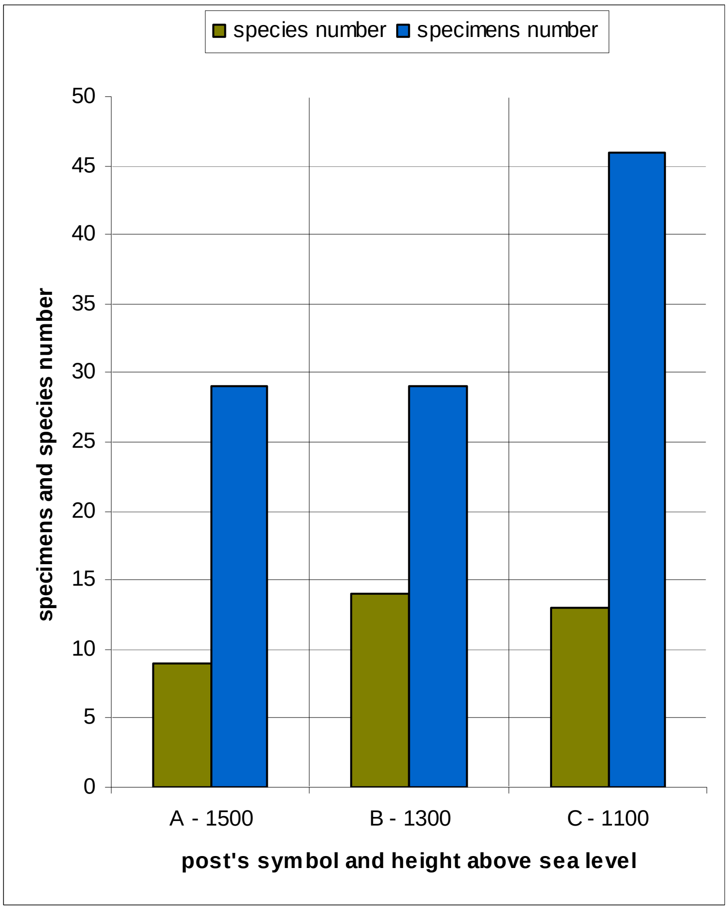

Fig.1. The number of specimens and the number of species in each of three posts.

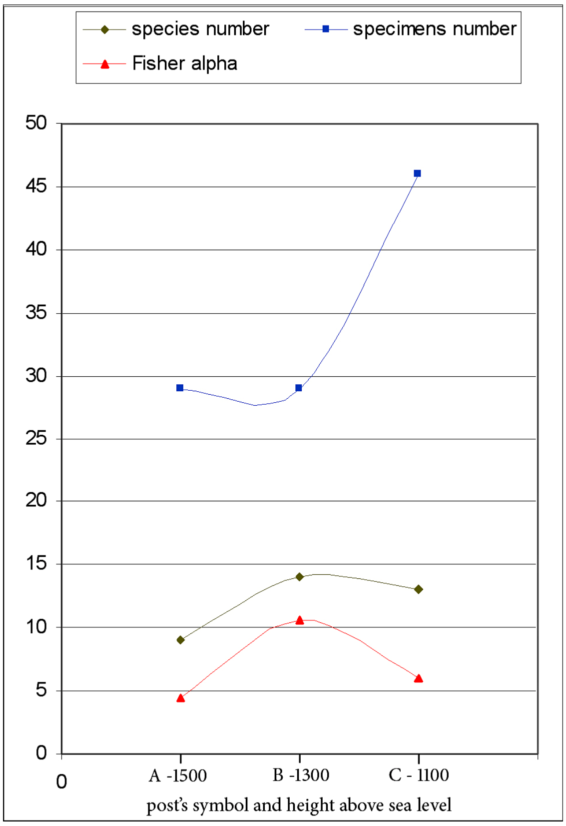

Fig. 2. The relationship between altitude and sample size, the number of species and the Fisher alpha index.

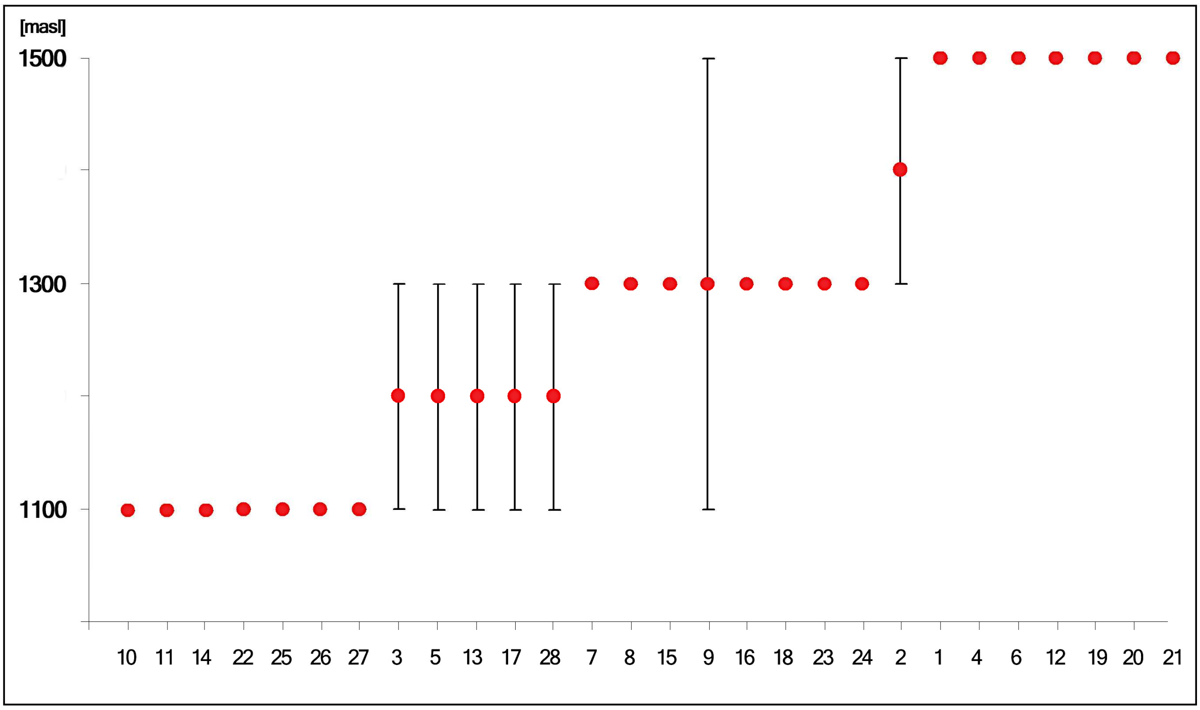

Fig.3. Elevational ranges of 28 morphospecies studied.

Discussion

The present data show a decrease in species richness with increasing altitude, although a small increase of species richness at the middle height (1300masl) was observed. Rapid decline at the higher post was noticed as well (fig.1 and 2, tab.2). It can be result of some measurement and methodological mistakes (too short time of researches, very few posts and traps). But it is also possible that this increase has relationship with existence of the transitional zone between humid mountain cloud forest and the high elevation cloud forest. Olson (1994) said about very clear decrease of species diversity in tropics at the height of 1250-1500masl because of this transitional zone. Anyway, there is different, very interesting reason for this phenomenon. Many studies show sudden increase of species diversity at the middle heights. It was observed at many of insects groups, but also at birds and mammals (Brehm et al. 2003, Pyrcz and Wojtusiak 2002, McCoy 1990, Heaney 2001). Three possibilities of relatopnship between species richness and height above sea level can be found in literature (Rahbek 1995, 1997). It is being written about approximate to straight change, continuous along whole elevational gradient, change approximate to straight but with very rapid decline at the middle heights and about not continuous change, with increase at middle heights and decrease at upper heights. The mid elevation peak can be reflection of very rapid faunal turnover on this height, which is presented below. Previous studies of this subject did not consider this, probably because of too large studying area (data were average out). This phenomenon can be studied precisely in the Rancho Grande neighborhood in the future, basing on the data from the other groups of organisms as well.

In the post A as many as 7 out of 9 morphospecies which have been found do not occur in the lower area (1 morphospecies have been caught in the post B also and one – in all three posts). In the post C as many as 8 out of 13 morphospecies have been found only there (4 in the post B also). In the post B as many as 8 out of 14 morphospecies have been caught only there (fig.3). It testifies to extremely rapid faunal turnover with elevation. So large fluctuation of species on so large heights seems characteristic for tropical areas. The Rapoports Rule, though comes true in the general outline, is disturbed here (Fleishman et al.

1998, Stevens 1992). The authors of this project did not find the evidences of similar faunal turnover in temperate other regions in literature. The reasons of this rapid faunal turnover in the Rancho Grande neighborhood can be studied in the future.

It will be necessary also to study the distribution of species diversity of ants. It will be interesting to divide them, according to the way of fouraging behavior. It is striking, why so many ant specimens were found on the C post, and so few – on the B post. Maybe on the C post carnivorous species are dominating, and that species do not occur in the higher area (McCoy 1990).

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The biomass of leaves carried into the nest by the ants *Atta cephalotes*

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Report submitted in partial fulfillment of the requirements for the course “Tropical ecology” (WBNZ 801), at the Faculty of Biology and Earth Sciences, Jagiellonian Univeristy, Kraków, Poland. 2008.

Abstract

The purpose of the study was to measure the activity of *Atta cephalotes* leaf-cutting ants during daytime and to etimate how much leaves they bring to the nest. We conclude that *Atta cephalotes* ants are mostly nocturnal. Results show the smallest activity during the day. This activity grows in the evening and probably keep going during the night. We have also estimated the biomass of leaves carried into the nest for about 1182 kg of wet mass of leaves annually, i.e. 390 kg of dry mass of leaves.

Introduction

Attini of the genus *Atta* – with a total of 15 species, are the leaf cutting ant species, which are frequently characterized as the major herbivores in the Neotropics (Beyschlag et al., 2007, Agosti et al., 2000). Leaf cutting ants cause deforestration and may have an important effect on forest succession on abandoned land (Moutinho et al., 2003). *Atta cephalotes* cuts green leaves which are prepared and used as substrate for culture of their fungus symbiont, (Klingenberg et al., 2007, Wetterer 1991). The ants may are create long paths in the forest which are connections between leaf sources and nest. Most of the ants bring fresh leaves but some of them also collect dry plant matter or seeds (Klingenberg et al., 2007). During the day they can carry a big numbers of leaves, it depends on widespread physical changes (Lewis et al., 1974). The aim of this study was to monitor the daily activity of ants at the nest and to estimate the amount of plant biomass transported into the nest.

Materials and methods

Field studies were carried out in July 2008 at the Biological Station Rancho Grande of the faculty of Agronomy, Central University of Venezuela, Maracay. Rancho Grande is situated in the Henri Pittier National Park of Aragua, in north central Venezuela (10° 21' N. Lat., 67° 41' W. Long). It is located 80 km west of Caracas at an elevation of 1,100 meters in the undisturbed subtropical cloud forest which covers this part of the Caribbean range of the Andes (Beebe et al., 1947). The researches were taken during a wet season and took one Atta's nest close to the station.

In the beginning we marked all entrances to the nest with active paths of ants that we have found; there were four of them. At each of the four entrances we collected at random 25 pieces of leaves carried by ants (altogether 100 pieces). We weighed all wet leaves together on the electronic portable balance, then we inserted the leaves to the plastic bag filled with silicon gel and dried them for 24 hours. After that we weighed them again and calculated the dry mass of an average piece of a leaf.

The monitoring of ants activity was planned for 5 days of observation, but due to the adverse weather conditions we could only record the activity for two full days (from sunrise to sunset, 6.20 a.m. – 6.45 p.m.). Due to logistic limitations and safety precautions observations could not have been continued overnight. Counted were all ants coming back with leaves to the nest for 3 minutes, at regular intervals of 15 minutes. Two people were watching two entrances for 3 minutes, then moved to other two entrances and also counted ants for 3 minutes, thus in 15 minutes all four entrances were watched. The activity was expressed as the number of ants per 1 minute.

Results and discussion

Biomass of the single piece of leaf

Wet mass of 100 pieces of leaves was 1.82 g, thus one piece was on average 0.0182 g
The dry mass of 100 pieces of leaves was 0.60 g, what gives the mass of 0.006 g per piece.

▪ The activity of ants

The most intense activity of *Atta cephalotes* was recorded in the beginning and in the end of the day (**Fig. 1, 2**). In the early morning (about 5.30 a.m.) a significant decline was observed. From about 7 a.m. to 4 p.m. only a very small number of individuals was noticed. From about 4 p.m. the number of active ants started to rise.

Biomass of leaves transported

We intended to estimate the biomass of leaves brought by the ants to their nest over the whole day. As we did not measure the activity over night, we had to interpolate the values of late evening and early morning. We put the average of our first and last measure, 218 ants per minute, as the activity for all night; however, the activity of ants may rise during the night so our results can only be underestimated. The interpolated values of ants' activity (Table 1) were subsequently used to calculate average activity during the day, which is 124 ants per minute. Multiplied by the average mass of the load it makes 2.249 g biomass.min, or 0.7414 g dry mass/min (Table 2). Recalculated for the day and for the whole year (assuming identical activity in all seasons) it gives about 1182 kg of biomass or 390 kg of dry mass of plant material per nest per day (Table 2).

The estimated biomass annual harvest of biomass may only be regarde a rough approqimation due to the limitations to the study methodology. Recently, as the most effective method of estimating herbivory rates in leaf-cutting ants, short term refuse depostion counts was proposed (Herz et al. 2007).

Acknowledgments

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Tables

Table 1. The activity of ants during daytime dring two days of our measures. **Bold** cells are without our measure data, so we put there an average of neighbour data. 5.00 and 19.00 shows an interpolated data for all night.

Time	**I**	**II**	**III**	**IV**	**All**
5:00	**93**	**63**	**53**	**8**	**218**
5:15	85	67	70	0	221
5:30	95	66	73	0	234
5:45	48	35	42	0	124
6:00	47	34	39	0	119
6:15	10	32	25	0	67
6:30	6	16	20	0	42
6:45	4	9	17	0	29
7:00	4	6	9	0	19
7:15	3	5	7	0	15
7:30	**1**	**3**	**4**	**0**	**8**
7:45	**1**	**3**	**4**	**0**	**8**
8:00	**1**	**3**	**4**	**0**	**8**
8:15	**1**	**3**	**4**	**0**	**8**
8:30	**1**	**3**	**4**	**0**	**8**
8:45	0	1	0	0	2
9:00	0	2	0	0	2
9:15	4	3	1	1	9
9:30	5	1	0	2	9
9:45	4	5	0	2	10
10:00	6	4	0	2	13
10:15	4	8	1	3	16
10:30	5	6	2	1	15
10:45	7	6	1	5	19
11:00	8	2	1	3	14
11:15	8	7	1	4	20
11:30	7	6	1	4	17
11:45	9	9	2	5	25
12:00	**10**	**8**	**2**	**6**	**25**
12:15	**10**	**8**	**2**	**6**	**25**
12:30	10	7	1	6	25
12:45	7	9	1	5	23
13:00	11	7	1	3	21
13:15	9	9	1	8	28
13:30	5	13	1	5	24
13:45	7	10	2	8	27
14:00	**11**	**9**	**2**	**7**	**28**
14:15	15	7	1	5	29
14:30	9	8	2	8	27
14:45	13	10	2	10	35
15:00	11	14	4	9	37
15:15	15	11	3	17	46
15:30	14	12	3	15	45
15:45	14	11	4	16	45
16:00	25	18	2	19	63
16:15	21	17	6	16	60
16:30	30	27	7	23	87
16:45	30	36	5	29	101

17:00	32	29	9	22	92
17:15	35	33	5	20	93
17:30	31	35	8	19	92
17:45	28	38	11	21	98
18:00	36	58	13	20	126
18:15	75	58	21	19	173
18:30	63	49	29	21	163
18:45	102	60	37	16	214
19:00	**93**	**63**	**53**	**8**	**218**

Table 2. The fresh and dried biomass bringing by ants to their nest.

	g/min	g/hour	kg/day	kg/year
Biomass	2.25	134.9	3.24	**1182**
Dry mass	0.74	44.5	1.07	**390**

Figures

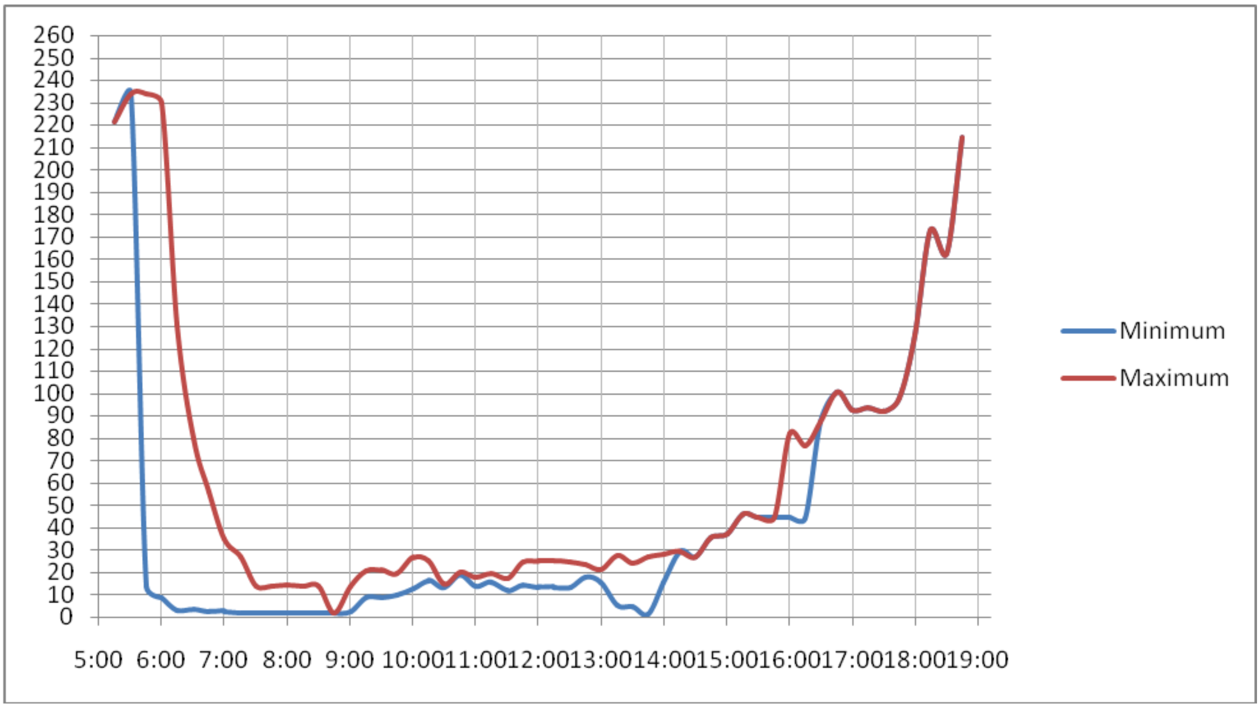

Fig. 1. The minimum and maximum activity of ants in daytime (number of ants counted per 1 min period).

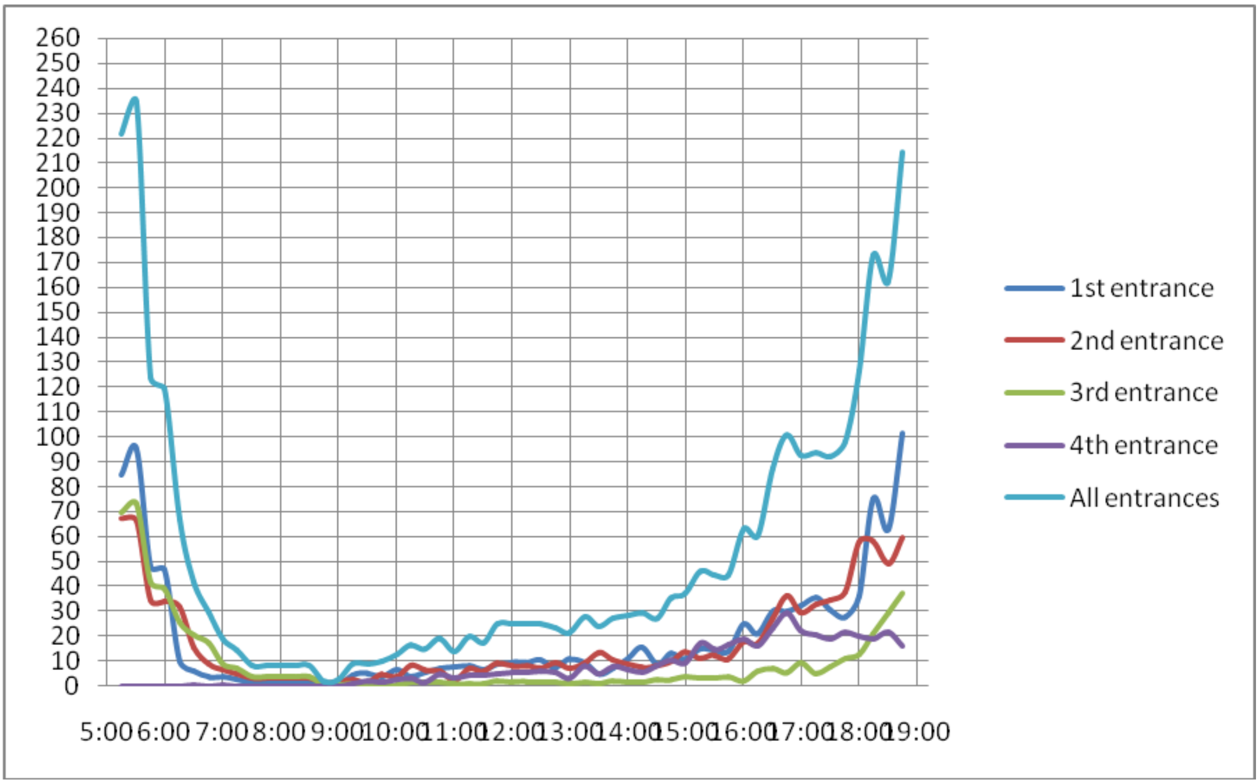

Fig. 2. The average activity of ants (number of ants counted per 1 min period) for each entrance, and the sum for all entrances.

Temperature changes in tropical Sphinx moths (Sphingidae) from Rancho Grande biological stationof venezuelan Henri Pittier National Park

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ABSTRACT

Studied were sphinx moths from Venezuelan tropical montane cloud forest. During two consecutive nights temperatures of different moths’ body parts were monitored at various situations: rest, shiver and after flight. Temperature of insects’ body was measured by means of infra-red radiation thermometer (IR-364 Voltcraft) at four points: head, thorax, abdomen and wing. It was noted that, temperature of moth's body decrease about 5,5˚C in rest time (it takes from 20 to 50 minutes). During shivering time, which takes from 10 to 20 minutes, average temperature increase amounts to 1,5-3˚C. The studies reveal also that for head and thorax the differences of temperatures between periods after flight and rest are positively correlated with body weight. It follows that the larger the body weight, the larger temperature amplitude for individual body parts of moths.

Key words: tropical sphinx moths, tropical montane cloud forest, endothermy, temperature changes, shivering thermogenesis

INTRODUCTION

Studies were carried out in tropical montane cloud forest at Rancho Grande Biological Station located in Parque Nacional Henri Pittier. This national park is Venezuela's oldest one, it was created in 1937. It has an area of 1078 sq. km and occupies the State of Aragua's portion of the Cordillera de la Costa. The park has a very high diversity of plant and animal life. The total number of insect species in the park is unknown but surely it reaches tens of thousands.

Portachuelo Pass is located near Rancho Grande and it is a flyway through the mountains for migrating insects and birds. The broad range of altitudes and the exposure of the terrain result in differentiated precipitation, temperature and insolation, which is important for the local richness of biodiversity. Climate of Rancho Grande is moist and cool and the whole place is often in clouds. Its average humidity amounts to 85,5%.

On the terrace of Rancho Grande biological station vast biodiversity of tropical insects may be attracted to light, of which moths constitute the largest part. Sphingid moths are largest of all which can be seen there.

Sphingid moths (Sphingidae) are a family of moths that includes about 1,200 species (Grimaldi and Engel, 2005). They are moderate to large in size and are distinguished among moths for their rapid, sustained flying ability (Scoble, 1995). Their narrow wings and streamlined abdomen are clearly adaptations for rapid flight.

Sphinx moths are ones from few poikilotherm organisms capable of maintaining constant body temperature. The mechanism of active metabolic maintenance animals' body temperature regardless of ambient temperature is called endothermy. Endothermic are birds and mammals and also some "cold-blooded" animals (tuna fish, some moths and bumblebees). Endothermic insects are capable of raising their thorax and flight muscles temperature, and therefore they may be active at low ambient temperatures. Endothermy can be the result of increased activity of muscles called shivering thermogenesis or it is due to catabolism of specific brown fatty tissue. Sphinx moths are capable of raising their flight muscles temperature owing to shivering thermogenesis. Thermogenesis of insects with synchronous flight muscles like moths consist in simultaneous contraction of antagonistic muscles, which are alternatively activated. Result of this is fast vibration or shiver of wings as a result of incomplete muscles synchronization, resulting in heat production without actual movement of wings (Migula, 1990). Maintaining a raised flight muscles temperature makes it possible for these large moths to start flying even at low ambient temperatures. Sphinx moths' thorax and abdomen are covered with hairs which make up an insulating layer helping to maintain the raised temperature of flight muscles and of the whole body.

The aim of this study was to find out, using a non invasive measuring technique, how quickly the temperature changes in tropical sphingid moths may follow and if the rate of temperature change is related to body size.

MATERIALS AND METHODS

Observations have been done on the terrace of Rancho Grande biological station. To attract insects we used white sheet about 250 × 400 cm in size spread to form rectangular flat area and a white (UV-enriched) high pressure mercury lamp (Fig. 1). The observations were made during two nights: 18/19.07.08 and 19/20.07.08. We started the observations at 21:30 and finished at 3:30 each night. To measure surface temperature of moths we used infra-red radiation thermometer (IR-364 Voltcraft), which can measure heat radiated from each surface at the point indicated by laser beam. We assumed standard radiation emissivity of the studied material as 0,95. We took value of temperature with IR thermometer from four parts of insect body: head, thorax, abdomen and wing. The measuring distance was approximately 40 cm, thus the diameter of temperature measured was approximately 13,3 mm. The background temperature was measured the same way on the white fabric close to the insect under study.

To measure insects' body weight and length we used portable electronic laboratory balance (Pocket Scale PS250/PS500) and calipers. In order to measure average air humidity used USB humidity/temp logger DL-120 TH.

Most of sphingid moths resting on the white sheet were studied each night. During the first one we measured temperature changes in time for consequent individuals. Next we checked the temperature of the same individuals in various thermal situations: rest, shiver and immediately after flight. During the second night we measured the dependence between body weight and temperature changes of the four measured body parts in three situations: rest, shiver and after flight (Tab. 1).

During the observations we used Canon 350D digital camera to take the insects' pictures, which were used for distinguishing individuals and for working documentation. The photographs can be used for species identification; until that will be done we distinguish morphospecies named with arbitrary numbers.

RESULTS AND DISCUSSION

During two nights we studied about 24 Sphingid moths belonging to 10 morphospecies (Fig. 2 – 11). At the first night we checked temperature changes of consecutive sphingid moths in time (Fig. 2, 3, 4), in four established body parts (Fig. 12) and we noted that when an insect sits on the sheet to rest after flight, the temperature of its body starts decrease down to some level characteristic for each insect (Fig. 13, 14, 15). The amplitude of head temperature is significantly higher than amplitudes of abdomen and wing, which change significantly less (Fig. 13, 14). The temperature of a resting moth change very little (Fig. 15), until the insect starts to shiver; then the temperature grows to reach the level similar to that after flight (Fig. 13). At this moment muscles are warm enough to enable flight and the moth usually takes off.

The differences between the temperatures of the head and of other parts of the body have been better demonstrated in the second part of observations during the first night (Fig. 17, 18). Especially it is visible at the moment immediately after flight, when the temperature of head significantly differs from thorax, abdomen, and wing temperatures (Fig. 18).

Many insects exhibit elevated thoracic temperatures during flight due to the heat produced as a by-product of the flight effort (Casey and Joos, 1983). In our case, the head is the hottest point of moth’s body because flight muscles are located very close to moth’s head (Fig. 19), so in the after-flight period the point of temperature measurement on head had higher temperature then other points of measurement, because the largest amount of heat produced by flight muscles became radiated in head direction. On the other hand, the insulation layer of hairs on the head is much thinner and therefore the temperature gradient between the head and the surface (at which the temperature is measured) is smaller.

The maximum body temperature that an insect can attain or regulate during flight is a function of its size and cooling rate (Bartholomew, 1981) as well as its rate of energy expenditure and the operating ambient temperature (Heinrich, 1981). Difference between head temperature and other parts of moths’ body temperatures is not so big during shivering period (Fig. 17), and it is quite the same as in other body parts during rest (Fig. 16).

During the second night we checked dependence between body weight and temperature changes in selected body parts in three situations: rest, shiver and after flight, for seven individuals of Sphingid moths, belonging to seven morphospecies differing in size (Fig. 5-11). We noticed that for head and thorax the difference of temperatures between periods after flight and rest is positively correlated with body weight (Tab. 1, Fig. 20). It means that heavier moths lose heat more slowly, in accord with the principle that the bigger an insect, the larger its thermal inertia, thus the insect more slowly warms up and more slowly cools down. According to Casey and Joos (1983) “thoracic conductance is clearly related to body size, because as body size decreases, the surface-to-volume ratio increases, thereby facilitating an increased mass-specific thoracic conductance and therefore also the cooling rate in smaller insects. It is likely also that heat production during flight increases with body mass”. It can be an answer to the question, why difference of temperatures between periods after flight and rest are positively related to body weight. We noted also a tendency for abdomen and wing differences of temperatures between periods after flight and rest to decrease with larger body weight (Tab. 1, Fig. 20). This would be difficult to explain; however, all the observed patterns of body temperature changes are only indicative; no statistical significance could have been attained because the data sets are too small due to logistic limitations.

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TABLES AND FIGURES

Table 1. Lengths, weights and temperatures of seven consequent Sphinx moths studied during second night.

number of insect	head temp. ºC	thorax temp. ºC	abdomen temp. ºC	wing temp. ºC	background temp. ºC	behavior	time	body weight [g]	body lenght [mm]
4	10	10.2	10.1	10	9.1	rest	21.55	0.62	45.7
	15.6	15.3	14.7	14.5	14.7	shiver	00.17		
	17	13.1	12.2	12	12.2	after flight	00.20		
5	11.7	11.2	11.1	11.1	11	rest	22.12	0.82	46.1
	12.5	11.5	11	11	10.5	shiver	00.25		
	11.3	9.2	9.5	9.5	8.6	after flight	00.30		
6	12.7	11.6	12	12	11.6	rest	22.22	0.88	48.2
	-	-	-	-	-	shiver	-		
	16	9.2	9	9	9.3	after flight	22.30		
7	11.1	11.1	11.1	11.1	11.1	rest	22.37	2.56	62.9
	13.2	10	8.6	8.1	8.5	shiver	00.33		
	17.6	13.5	8.2	8.5	8.6	after flight	00.35		
8	13.5	13.2	13.3	13.1	12.8	rest	00.55	0.94	33.8
	15	12.8	12.6	12.6	12.1	shiver	00.58		
	18.2	13.6	13.3	13.1	13.1	after flight	00.41		
9	11.5	11.5	11.5	11.5	11.3	rest	00.43	1.22	50.9
	16.2	12	12	11.8	11.7	shiver	23.56		
	18	14	13.2	13.2	13.1	after flight	00.49		
10	13.3	13.2	13.1	13	12.1	rest	1.28	1.46	50.2
	14.6	11.6	10.1	10.1	9.5	shiver	1.33		
	20	13	11.5	11.6	11.5	after flight	1.06		

Fig. 1. Collecting sheet.

Fig. 2. Moth number 1.

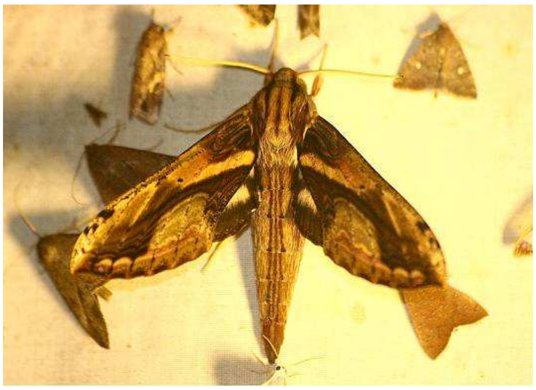

Fig. 3. Moth number 2.

Fig. 4. Moth number 3.

Fig. 5. Moth number 4.

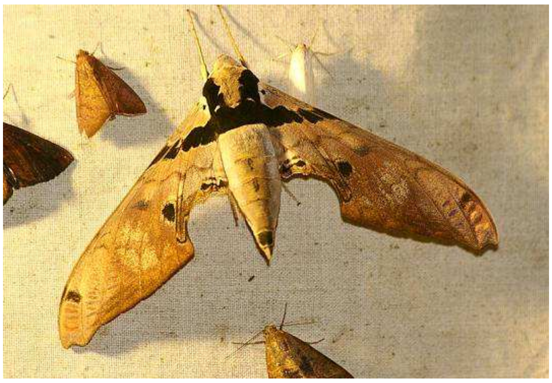

Fig. 6. Moth number 5.

Fig. 7. Moth number 6.

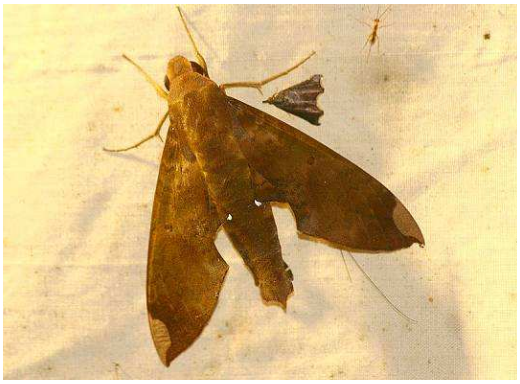

Fig. 8. Moth number 7.

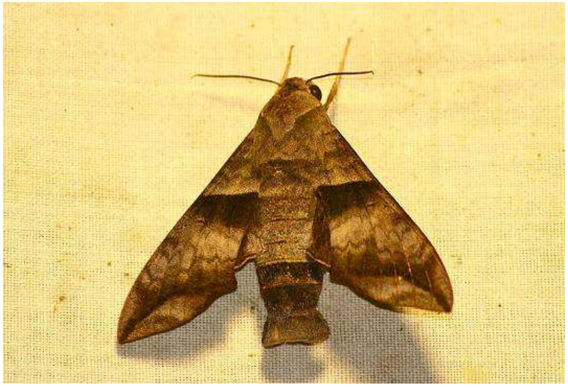

Fig. 9. Moth number 8.

Fig. 10. Moth number 9.

Fig. 11. Moth number 10.

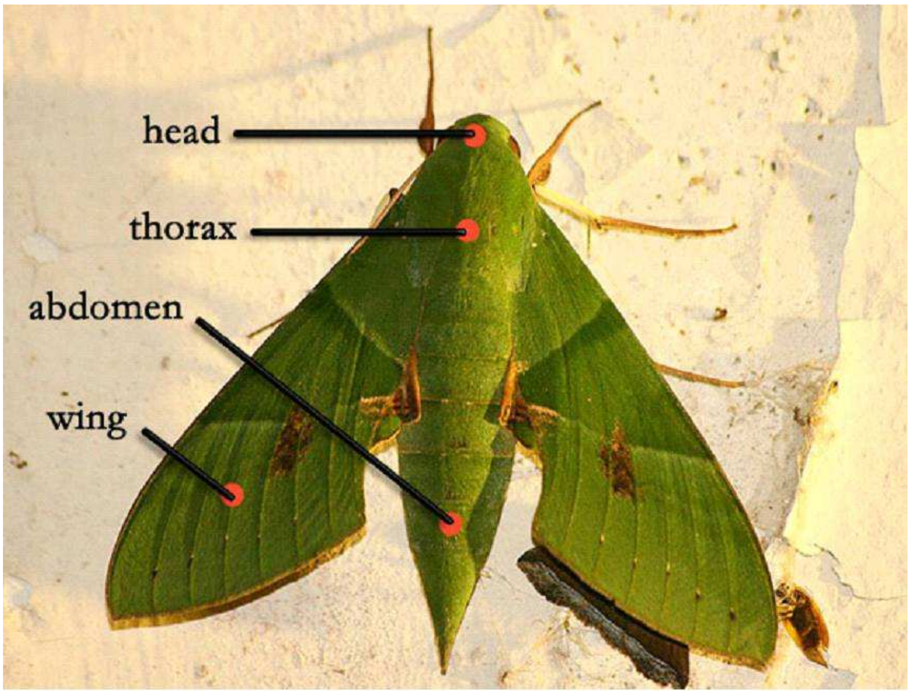

Fig. 12. Four parts of insect body in which temperature was measured.

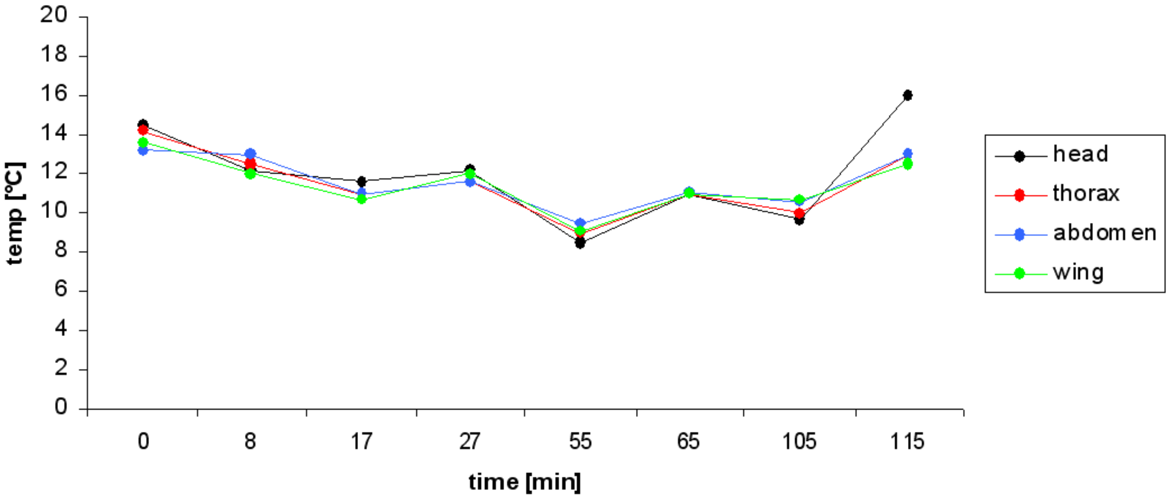

Fig. 13. Temperature changes in time for the moth number 1.

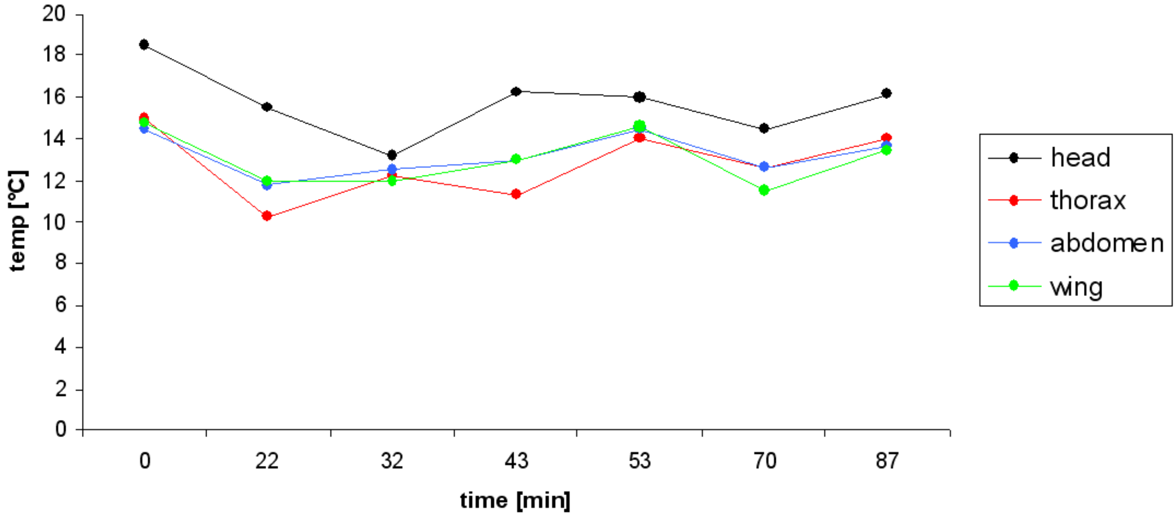

Fig. 14. Temperature changes in time for the moth number 2.

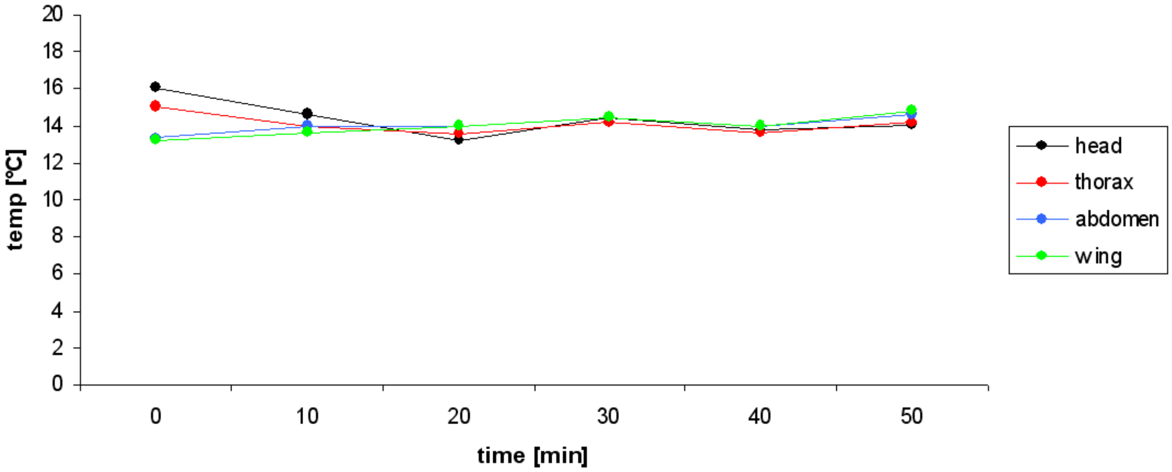

Fig. 15. Temperature changes in time for the moth number 3.

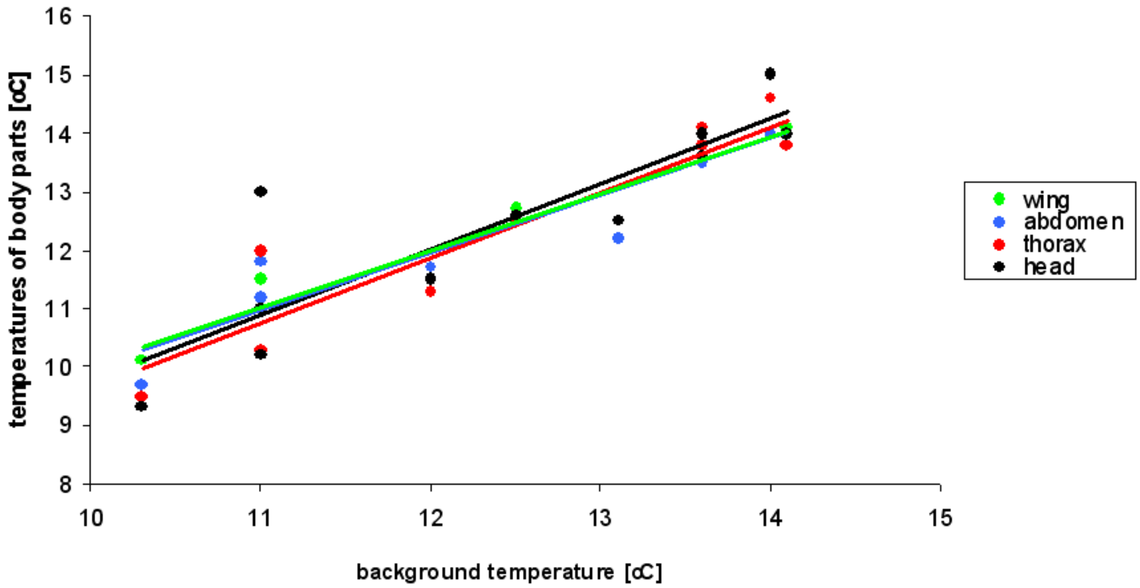

Fig. 16. Linear regression of temperatures for four selected moth's body points and background temperatures during rest.

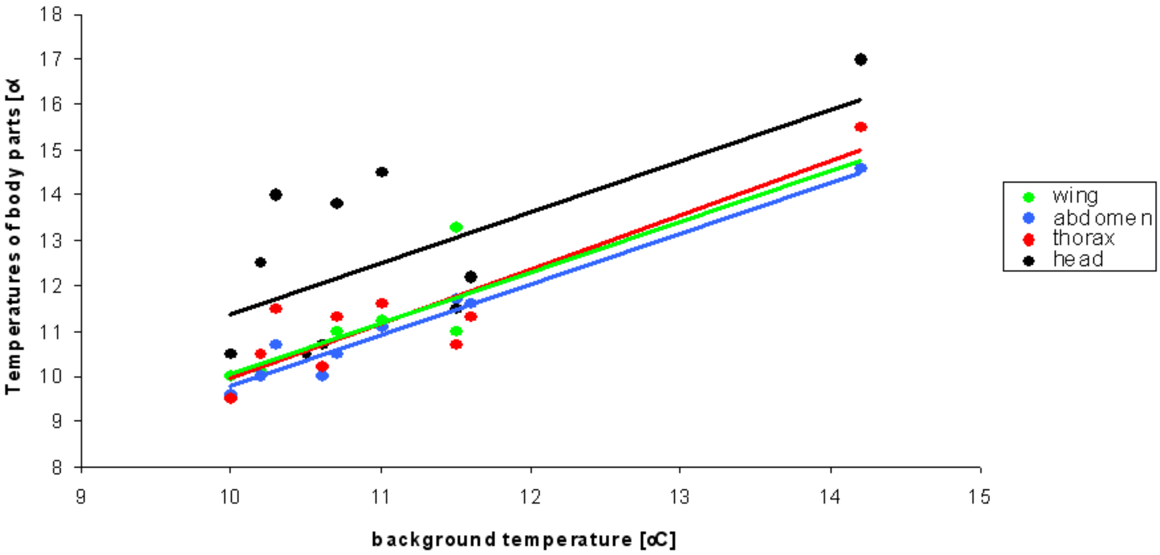

Fig. 17. Linear regression of temperatures for four selected moth's body points and background temperatures during shiver.

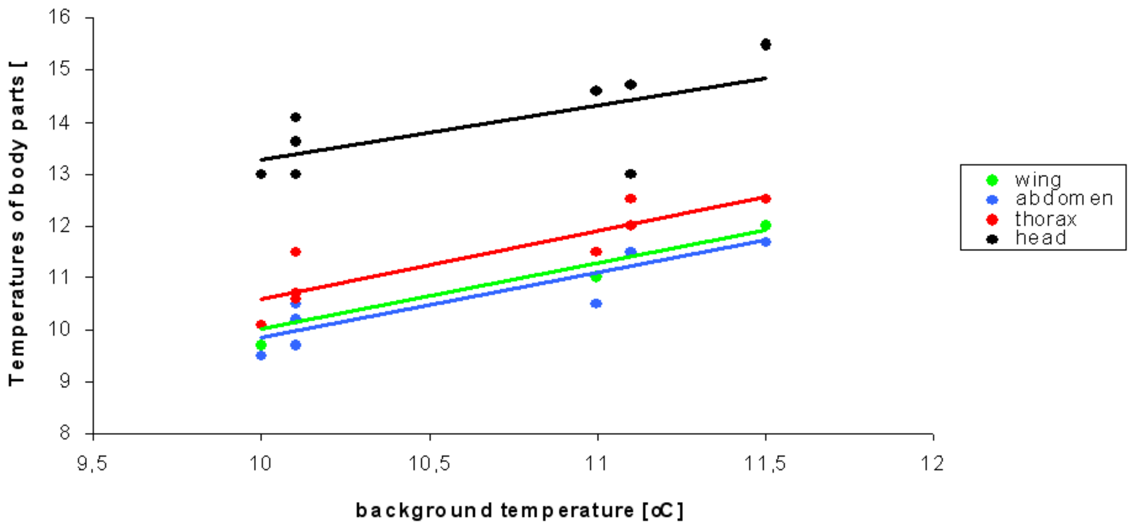

Fig. 18. Linear regression of temperatures for four selected moth's body points and background temperatures during after flight period of time.

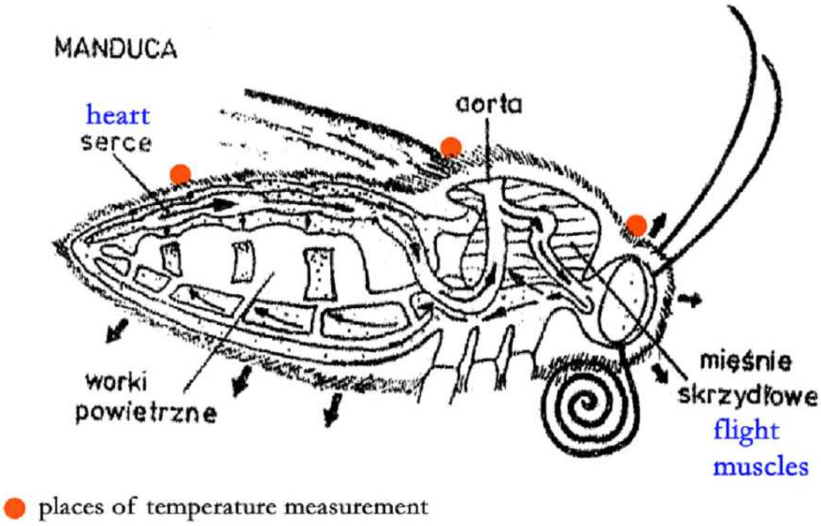

Fig. 19. Longitudinal section of a Sphingid moth (Migula, 1990)

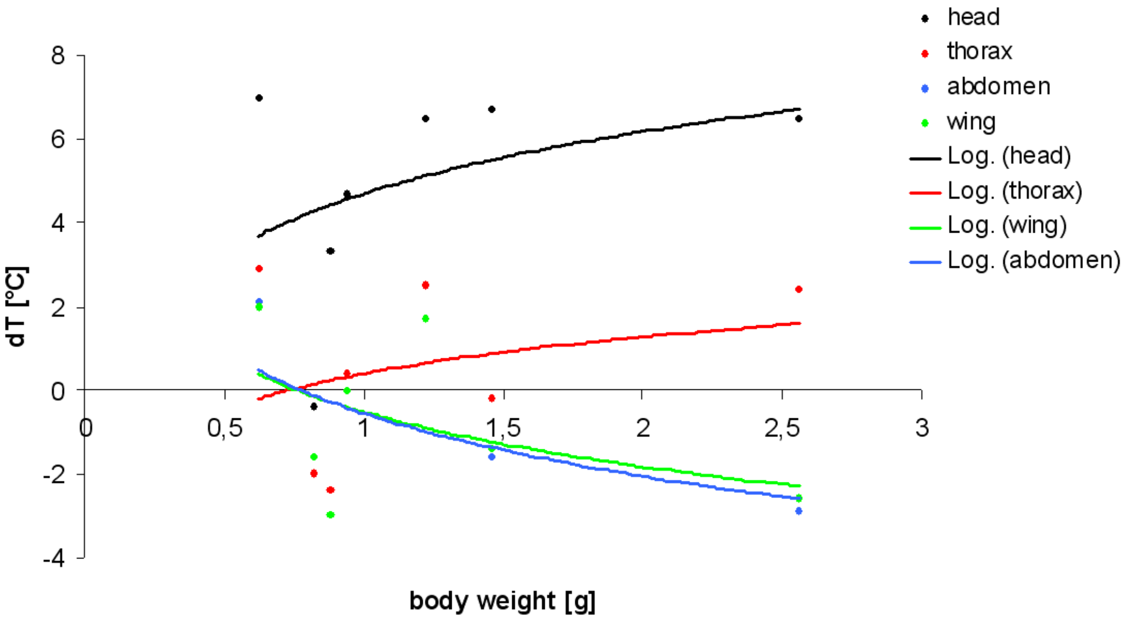

Fig. 20. Logarithmic regression showing dependence of body weight and temperature distinction (dT) between periods, after flight and rest.