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Analysis of the distribution of epiphytic lichens on *Cedrus libani* in Elmali Research Forest (Antalya, Turkey)

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Abstract: *In order to evaluate environmental factors limiting distribution of species, diversity of epiphytic lichens was studied in 34 sites along an altitudinal gradient from 1300 to 1900 m on north-facing and south-facing slopes of Elmali Cedar Research Forest (Antalya province, Turkey) regarding the dispersion of lichens in different tree-diameter classes (0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and >75 cm). The results showed that the relationship between diameter classes with the number of lichen species was R^2=0.6022. The highest number of species was in the diameter class of 30-45 cm. There was a clear relationship between all parameters, diameter, altitude and aspect, with species richness. Changes in the community structure of the epiphytic lichen vegetation were detected along an altitudinal gradient revealing the highest species richness in the highest zone. The elevation affected both the number and the composition of the lichen communities and the relationship between the altitudinal zones with number of lichen species was designated as R^2=0.6462. The number of species was higher in the north aspects than in the south aspects in all diameter classes. The species number depending on the altitude was also higher in the north-facing slopes than in the south-facing slopes.*

Key words: *Epiphytic lichens, Cedrus libani, Diameter, Forest, Turkey, Environmental factors*
PDF of full length paper is available with author ***(*gcoban@marmara.edu.tr)***

Introduction

Lichens with specific biological structures are known as the best bioindicator organisms of air pollution, due to susceptibility of species to pollutants, especially sulphur dioxide (Hawksworth and Rose, 1970; Nash, 1996; Saxena *et al*., 2007), and also as biomonitors for trace element and heavy metal accumulation and deposition in their thalli (Garty, 2001). However, many lichen species can tolerate extreme environmental conditions, for instance variations in temperature, humidity and light (Hauck *et al.*, 2007; Hilmo and Sastad, 2001).

Basic environmental factors and habitat characteristics may strongly influence distribution of lichen species. Lichens, being poikilohydric organisms, may be very sensitive to microclimatic changes (Nash, 1996). As change in diameter is related to chemical and physical bark properties, lichen occurrence on trees is also affected. For instance, young trees with low diameter have smooth bark, with age, more roughly or cracked bark; on the other hand, old ones have pretty smooth bark. Therefore, factors such as tree diameter and altitude might be important for lichen growth. Precipitation, light intensity and temperature changing along altitudinal gradient and aspect affect the distribution of epiphytic lichens and the number of species. Species richness in the European Alps along the altitudinal gradient was found highest in the upper montane and the lowest in the subalpine belt (Dietrich and Schidegger, 1997). Burgaz *et al.* (1994) examined positive and negative effects of environmental factors such as tree diameter, light exposure, altitude, slope and cover height on trees. Preferences of lichen colonization will be influenced also depending on the changes in bark properties, varying from species to species as well as tree's age with increasing height and diameter. Radies and Coxson (2004) assessed lichen abundance in vertical gradient of canopy with young and old trees and associations with lichen species. Different patterns in vertical distribution of epiphytes are interpreted by Hilmo (1994) as a result of variation in microclimatic conditions and in bark properties. Pirintsos *et al.* (1993, 1995) and Loppi *et al.* (1997) stated distribution of epiphytic lichens along an altitudinal gradient. The factors of susceptibility to toxic substances and the bark pH independently affect the lichen composition (Van Herk, 2001). The relations of species number with increasing diameter also change depending on tree species. The number of microlichen species was found to be significantly higher in pine forests than in deciduous forests, for similar bark area (Ihlen *et al.,* 2001). Stevenson and Enns (1993) stated that the both numbers of individual lichens and surface areas of lichens were correlated with tree diameter (r= 0,867-0,880). Hedenas and Ericson (2000) noted that many species showed positive relationship with increasing mean diameter while some others showed a negative relationship with mean diameter. There is a general increase in species richness with increasing tree diameter, with the trend stronger in the lichens than in the bryophytes (Kantvillas and Jarman, 2004). There was also a positive relationship between occurrence and number of thalli and stem diameter (Rolstad and Rolstad, 1999).

Distribution of *Cedrus libani* A.Rich in Turkey generally starts from 1000 m (sometimes from 1500 m) and goes up to 2000-2100 m

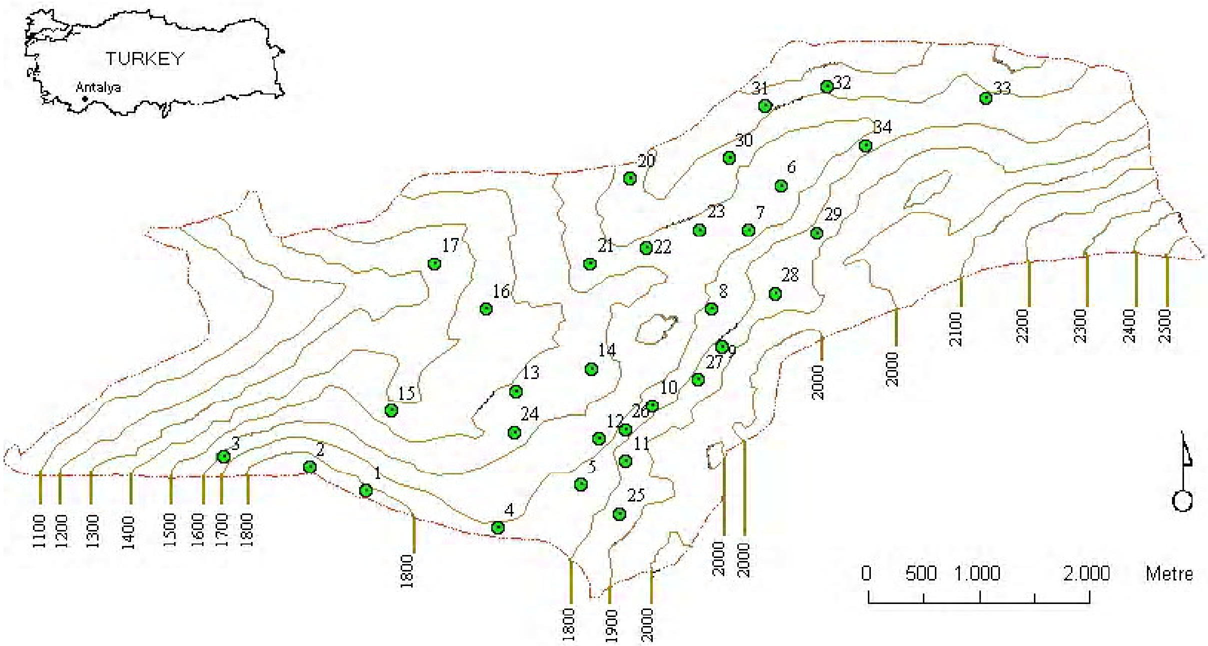


Fig. 1: Positions of the cedar study sites in Elmali Research Forest located in the province Antalya

representing the highest level (Kantarci, 1982, 1985, 1990). Nevertheless small stands of *Cedrus* may appear at 500-600 m in small groups or individually, and rise to 2400 m (Boydak, 2002). Cedar, in a wide range, lies between approximately at 36°16' - 38° 35' latitudes and Bozdag-Engezik Dagi zone at longitudes 29° 02' - 37°19' (Sevim, 1952). Cedar forests in Turkey are grouped into 3 main types, which include one in the Middle and East Taurus (Toroslar) Mountains (Abieti-Cedrion), the other in the West Taurus (Lonicero-Cedrion) and one in the Middle Blacksea region, submediterranean *Pinus sylvestris- Pinus nigra- Cedrus libani* relict forest (Aksoy and Ozalp, 1990).

Studies on the lichen flora of cedar forests have been carried out very recently (Cobanoglu and Sevgi, 2006). Some epiphytic lichens from the cedar forests were recorded in the earlier studies (John, 1992; Breuss and John, 2004). With the exception of these floristic studies in the last decades, in Turkey, no other papers are presented on ecological comprehensive properties such as the relationship between habitat characteristics and lichen diversity.

This study analyses the diversity and the richness of lichen species in Taurus *Cedrus* in relation to environmental factors such as tree diameter, altitude and aspect. It is important to know limiting factors on lichen growth and distribution, in order to be able to evaluate pollution affects. As lichenology in Turkey is developing in recent decades, this also contributes to the knowledge of the distribution of the lichens as a first step for further ecological studies.

Materials and Methods

Study site: Elmali Cedar Research Forest has maintained a 'research forest' status after transferred to Antalya Research Institution of Station since the date 12.12.1962. It is situated in the province of Antalya and located in the southern part of Central Anatolia. It lies between the latitudes 36° 33' 26" – 36° 36' 18" N and the longitudes 29° 57' 03" – 30° 04' 13" E. The forest covers 2616.9 ha total area, 1586.9 ha of which is productive area, 337.8 ha is destroyed and 692.2 ha is open area (Basaran *et al.,* 2002). The highest elevation of the study area is 1900 m. In between Elmali plain (Avlan Golu) and Camkuyusu Cedar Research Forest *Juniperus*, among *Cedrus*, is widely distributed especially in the range of 1200-1400 m, and *Cedrus* is totally dominant above 1400 m. Heterogeneous stands of *Cedrus* are conspicuous along the altitudinal gradient. The vegetation below 1600 m consists of *Acer hyrcanum, Quercus coccifera, Fraxinus ornus ssp. cilicica, Sytrax officinalis, Juniperus excelsa, Juniperus foettidissima, Lonicera etrusca, Rosa canina, Berberis cretica* entering into *Cedrus libani* forest, whilst above 1600 m *Juniperus foettidissima, Achantolimon oliveri* and *Verbascum lasianthum* occur together with *Cedrus* (Kantarci, 1991). The Mediterranean climate is dominant in the study area. According to seventeen years-data of Elmali-Camkuyusu Cedar Research Forest Meteorology Station (1660 m), annual mean temperature is 7.5°C. The average annual precipitation is about 824.4 mm. The average annual value of relative humidity is 56%, and the average number of snow-covered days is 88. The dominating wind aspect is Southwest (Boydak and Eler, 1990). In the Elmali-Camkuyusu Cedar Research Forest; soil weight changes between 184-643 kg m^{-3}, the soil texture types are sandy clay loam, loamy sand, clay loam and clay. Soil reaction (with water), pH, changes between 7.0-8.1 (Kantarci, 1985).

Sampling methods: All epiphytic lichen materials, on cedar, juniper and oak trees, collected in Elmali Cedar Research Forest during 1 to 6.10.2002, were recorded for floristic data. The lichen samples on cedar (*Cedrus libani* A. Rich) were used for analysis in 34 sampling sites (except 18 and 19 sites) that were designated with having different stand types, tree diameters, altitudes, aspects and slopes (Table 1, Fig. 1). Data for those environmental variables was significantly recorded. Within each sampling site, if present, the epiphytic lichen material were collected on cedar sample trees separated in 6 different diameter classes; 0-15, 15-30, 30-45, 45-60, 60-75 cm and more than 75 cm. The sample trees were given numbers according to diameters in the field. All samples were taken from 0-2 m height from the ground and all around the stem.

Determinations of the collected specimens were made at species level by using standard identification techniques, studied under dissecting microscope (X40) and applied spot tests, with the aid of flora books and keys (Purvis *et al.,* 1992; Wirth, 1995). The nomenclature follows recent literature (Blanco *et al.,* 2004). The specimens are preserved in the Herbarium of the Faculty of Science and Arts, Marmara University, Istanbul and some duplicates in the herbarium of Faculty of Forestry, the University of Istanbul.

Statistical analysis: The collected lichen samples were grouped into and related with 3 environmental variables; the tree-diameter classes, the altitudinal zones and aspect of the sampling sites. For these 3 variables, each of the lichen species were recorded as present (+) and absent (-) in the tables in computer and then 2x2 tables were created. The Chi-square independence test is applied in these 2x2Tables. This test provides testing the similarity between frequencies in 2x2 type cross tables with theoretical frequencies calculated by the approach of marginal probabilities. This is one of the most easily applied tests in the 2x2 Tables. To make the Interspecific Correlation Analyze, it is necessary to form 2x2 Tables as indicated its general view in Table 2 (Cole, 1949; Ozkan, 2002; Ozdamar, 2002). When relativity of species distribution are remarkable then relativity direction is determined as positive if ad>bc; respectively negative if bc>ad (Poole, 1974). The standard formula for Chi-square test is $X^2=((ad - bc)^2 n/(a+b)(a+c)(c+d)(b+d)$. In case of the number of samples in 2x2 tables, are higher than 25 then Pearson Chi-square test, between 5 and 25 then Corrected Chi-square test, and if lower than 5 then Exact Chi-square tests were applied. Statistical analyses were made by using SPSS (10, 0) package program (Ozdamar, 2002).

Results and Discussion

Diameter class: Totally 52 epiphytic lichen species were recorded during the survey on *Cedrus libani* in 34 sampling sites in the study area. With respect to the tree diameter, which is separated into 6 classes (0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm and >75 cm), the

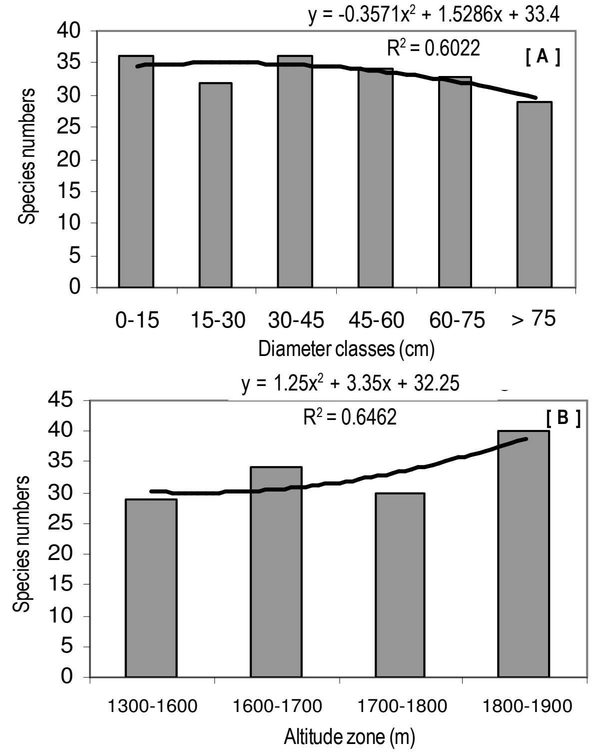


Fig. 2: Distribution of the lichen species in number. A, within 6 diameter classes; B, in altitudinal zones

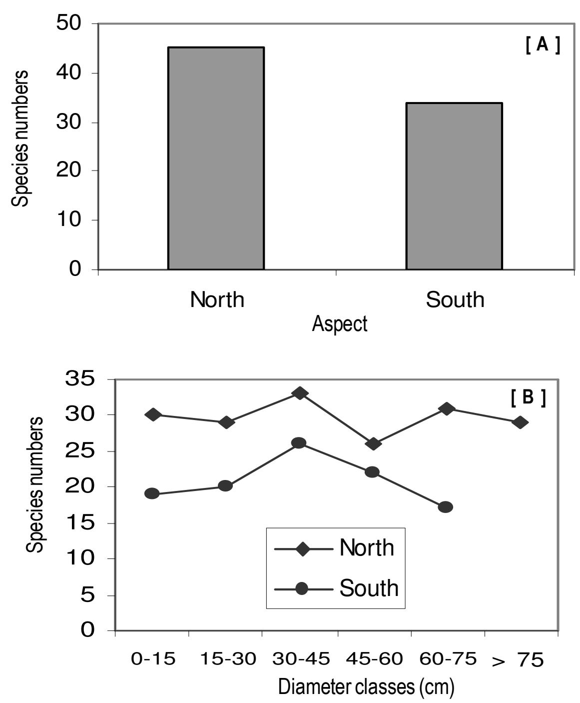


Fig. 3: A - distribution of the lichen species in number according to aspect, B - according to the diameter classes

Table - 1: Features of the sampling sites according to environmental variables (altitude, aspect, slope, tree diameter classes and stand type)

Sample area No	Altitude (m)	Aspect	Slope (%)	Stand type (*)	Diameter class (cm)						Total sampling Tree
					0-15	15-30	30-45	45-60	60-75	>75	
1	1850	N E	40	Ccd1	X	X	X		x	x	5
2	1880	N E	5	Ccd2	X	X	X		X	X	5
3	1610	NW	65	Cd1		X	X		X	X	4
4	1750	N	53	Cbc3		X	X	X			3
5	1760	NW	48	Cbc3	X	X	X				3
6	1640	NW	38	Cd2	X	X	X	X		X	5
7	1690	NW	77	Ccd3	X	X		X			3
8	1710	SW	47	Cc3	X	X	X				3
9	1840	NW	52	Cd2	X	X	X	X		X	5
10	1770	NW	68	Ccd2	X	X	X			X	4
11	1810	W	54	Ccd2	X		X				2
12	1690	NW	63	Ccd3	X	X	X				3
13	1520	N E	26	Cd2	X	X	X	X			4
14	1580	SW	48	Cd1	X	X	X				3
15	1420	N E	43	Ccd1	X	X	X	X			4
16	1480	N E	18	BSJ	X	X	X	X	X		5
17	1320	SW	28	CJd1	X		X	X			3
18	1320	SW	35	JOa1							-
19	1330	SW	41	Oa1							-
20	1770	S E	47	Cc3	X	X	X		X		4
21	1630	SW	43	Cd2	X	X	X		X		4
22	1680	SW	41	Ccd3	X	X	X	X			4
23	1650	S E	47	Cbc1	X	X	X				3
24	1570	W	23	Ccd3	X	X	X	X			4
25	1840	NW	54	Ccd2	X	X	X				3
26	1760	NW	77	Ccd3	X	X	X			X	4
27	1780	NW	76	Cd1		X	X	X	X		4
28	1830	NW	62	Cbc2			X	X			2
29	1840	NW	58	Ccd2		X	X	X			3
30	1760	S E	61	Ccd1	X	X	X				3
31	1830	S E	71	Cd1	X	X	X	X			4
32	1830	S	77	Cd1		X	X	X	X		4
33	1760	SW	52	Cbc2	X	X	X	X	X		5
34	1750	NW	79	Cd2	X	X	X	X			4
Total					**26**	**29**	**31**	**17**	**9**	**7**	**119**

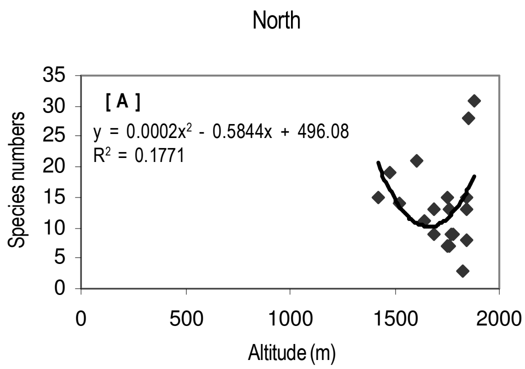
(*) C= Cedar, J= Juniper, O= Oak, B= Degraded, Diameter class (cm); a (0-7,9), b (8-19,9), c (20-35,9), d (36-51,9), e (>52) and Forest canopy cover; 1 (%11-40), 2 (%41-70), 3 (>%71)

Table - 2: Arranged of a 2 x 2 Table for testing

		Y		
X	Present	Present	Absent	
	Absent	*a*	*b*	*a+b*
		c	*d*	*c+d*
		a+c	*b+d*	*a+b+c+d=n*

highest number of lichen species was detected in the 0 -15 cm and 30-45 cm diameter classes with 36 species (Fig. 2A). The number of lichen species above 75 cm diameter class is 29 species. The relationship between the number of lichen species with diameter classes is designated as R^2=0.6022 (Fig. 2A). The species preferring 0-15 cm diameter class are *Anaptychia ciliaris, Physcia tenella* and avoiding from this class are *Lecanora saligna, Lecanora varia, Letharia vulpina, Pseudevernia furfuracea* (Table 3). The only species avoiding from the diameter class of 30-45 cm is *Melanohalea exasperatula.* No species is detected preferring or avoiding the diameter classes of 15-30 cm and 45-60 cm. *Hypocenomyce scalaris, Lecania fuscella* and *Ochrolechia androgyna* species prefer 60-75 cm diameter class (Table 3). The preference of the species *Bryoria fuscescens, Caloplaca herbidella, Candelariella xanthostigma, Hypocenomyce scalaris, Letharia vulpina, Ochrolechia turneri, Parmelia saxatilis* and *Platismatia glauca* is the widest diameter class >75 cm (Table 3).

Altitudinal gradient: The elevation in the study area ranging from 1300 to 1900 m is separated into 4 zones. The highest number of lichen species occurs at the highest altitudinal zone, 1800-1900 m, with 40 species. The lowest species number, 29 species, is



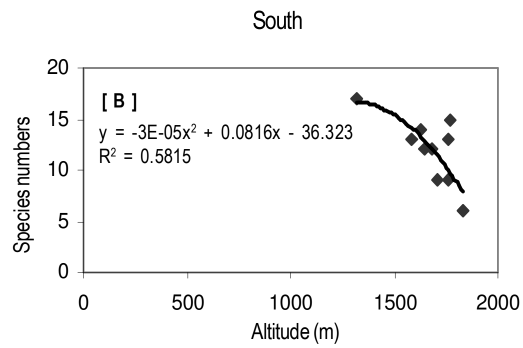


Fig. 4: Distribution of the lichen species in number according to altitude (A) in the North aspect (B) in the south aspect

Table - 3: Relationships of the lichen species with the diameter classes

Species	Diameter class (cm) 0 - 15 n=26	15 - 30 n=29	30 - 45 n=31	45 – 60 n=17	60 - 75 n=9	>75 n=7
Anaptychia ciliaris	0.046(+)	ns	ns	ns	ns	ns
Bryoria fuscescens	ns	ns	ns	ns	ns	0.005(+)
Caloplaca herbidella	ns	ns	ns	ns	ns	0.000(+)
Candelariella xanthostigma	ns	ns	ns	ns	ns	0.042(+)
Hypocenomyce scalaris	ns	ns	ns	ns	0.028(+)	0.017(+)
Lecania fuscella	ns	ns	ns	ns	0.028(+)	ns
Lecanora saligna	0.016(-)	ns	ns	ns	ns	ns
Lecanora varia	0.001(-)	ns	ns	ns	ns	ns
Letharia vulpina	0.022(-)	ns	ns	ns	ns	0.001(+)
Melanohalea exasperatula	ns	ns	0.054(-)	ns	ns	ns
Ochrolechia androgyna	ns	ns	ns	ns	0.035(+)	ns
Ochrolechia turneri	ns	ns	ns	ns	ns	0.004(+)
Parmelia saxatilis	ns	ns	ns	ns	ns	0.004(+)
Physcia tenella	0.058(+)	ns	ns	ns	ns	ns
Platismatia glauca	ns	ns	ns	ns	ns	0.013(+)
Pseudevernia furfuracea	0.006(-)	ns	ns	ns	ns	ns

ns = Not significant

respectively at the lowest altitudes, 1300-1600 m zone (Fig. 2B). There is a relationship between the altitudinal gradient with the number of epiphytic species and R^2=0.6462 (Fig. 2B). The species preferring 1300-1600 m altitudinal zone are *Anaptychia ciliaris, Caloplaca cerina, Lecanora argentata, Lecidella elaeochroma, Parmelia saxatilis, Pertusaria hemisphaerica* and *Physconia distorta* while the avoiding species from this zone are *Candelariella xanthostigma, Lecanora saligna* and *Ochrolechia turneri* (Table 4). No relationship is found between the lichen species with 1600-1700 m altitudinal level. The species uncommon at the 1700-1800 m altitudinal zone are *Anaptychia ciliaris, Bryoria capillaris, Lecania fuscella, Lecidella elaeochroma, Parmelia sulcata, Physconia distorta* and *Platismatia glauca* (Table 4). The species preferring the altitudinal zone of 1800-1900 m are *Bryoria capillaris, Bryoria fuscescens, Caloplaca herbidella, Candelariella xanthostigma, Lecanora carpinea, Parmeliopsis ambigua* and *Platismatia glauca.* This zone is not preferred by *Pertusaria albescens* (Table 4).

Aspect: Number of epiphytic lichen species is recorded as 45 in the north aspect and 34 at the south aspect (Fig. 3A). The species preferring the north aspect are *Bryoria capillaris, Bryoria fuscescens, Buellia disciformis, Caloplaca herbidella, Lecanora saligna, Lecanora varia, Letharia vulpina, Melanohalea exasperatula, Parmelia saxatilis, Parmeliopsis ambigua, Platismatia glauca* and *Pseudevernia furfuracea* (Table 5). The species preferring the south aspect are *Caloplaca cerina, Lecanora dispersa, Melanohalea exasperata, Ochrolechia androgyna* and *Physcia tenella* (Table 5).

Number of lichen species in all diameter classes at the north aspect is higher than at the south aspect (Fig. 3B). That is the species diversity is higher in the north-facing slopes than in the south-facing slopes in trees with the same diameter class. The highest number of species at the both north and south aspects is recorded in 30-45 cm diameter class (Fig. 3B). The relationship between species number and elevation at the north aspects is R^2=0.1771, while it is R^2=0.5815 at the south aspects (Fig. 4A,B).

Table - 4: Relationships of the lichen species in the altitudinal zones

Species	Altitudinal zones (m) 1300 - 1600 n=23	1600 – 1700 n=26	1700 - 1800 n=37	1800 – 1900 n=33
Anaptychia ciliaris	0.039(+)	ns	0.007(-)	ns
Bryoria capillaris	ns	ns	0.055(-)	0.002(+)
Bryoria fuscescens	ns	ns	ns	0.034(+)
Caloplaca cerina	0.050(+)	ns	ns	ns
Caloplaca herbidella	ns	ns	ns	0.022(+)
Candelariella xanthostigma	0.041(-)	ns	ns	0.001(+)
Lecania fuscella	ns	ns	0.030(-)	ns
Lecanora argentata	0.013(+)	ns	ns	ns
Lecanora carpinea	ns	ns	ns	0.020(+)
Lecanora saligna	0.007(-)	ns	ns	ns
Lecidella elaeochroma	0.029(+)	ns	0.017(-)	ns
Ochrolechia turneri	0.004(-)	ns	ns	ns
Parmelia saxatilis	0.024(+)	ns	ns	ns
Parmelia sulcata	ns	ns	0.017(-)	ns
Parmeliopsis ambigua	ns	ns	ns	0.013(+)
Pertusaria hemisphaerica	0.000(+)	ns	ns	0.027(-)
Physconia distorta	0.000(+)	ns	0.030(-)	ns
Platismatia glauca	ns	ns	0.030(-)	0.005(+)

ns = Not significant

Table - 5: Relationships of the lichen species with the north and the south aspects

Species	North aspect (n=73)	South aspect (n=40)
Bryoria capillaris	0.025(+)	0.025(-)
Bryoria fuscescens	0.002(+)	0.002(-)
Buellia disciformis	0.002(+)	0.002(-)
Caloplaca cerina	0.012(-)	0.012(+)
Caloplaca herbidella	0.001(+)	0.001(-)
Lecanora dispersa	0.004(-)	0.004(+)
Lecanora saligna	0.014(+)	0.014(-)
Lecanora varia	0.002(+)	0.002(-)
Letharia vulpina	0.004(+)	0.004(-)
Melanohalea exasperata	0.000(-)	0.000(+)
Melanohalea exasperatula	0.009(+)	0.009(-)
Ochrolechia androgyna	0.030(-)	0.030(+)
Parmelia saxatilis	0.013(+)	0.013(-)
Parmeliopsis ambigua	0.025(+)	0.025(-)
Physcia tenella	0.000(-)	0.000(+)
Platismatia glauca	0.014(+)	0.014(-)
Pseudevernia furfuracea	0.002(+)	0.002(-)

The results of this study indicate a significant relationship between the number of epiphytic lichen species and tree diameter, similar to the number of recent studies mentioning the effect of tree diameter on the distribution and composition of number of lichen species (Stevenson and Enns, 1993; Rolstad and Rolstad, 1999; Hedenas and Ericson, 2000; Kantvillas and Jarman, 2004). A probable reason for the epiphytic lichen diversity showing a high correlation with tree diameter classes may be the changing outer bark properties of cedar trees with age. These may be both chemical and physical changes. The bark pH, roughness and moisture capacity act selectively in variable degrees within a homogeneous forest (Hale, 1952). If the slow-growing feature of lichens is also considered, the colonization of species on trees takes many years that, trees with less than 30 cm diameter are too young for many lichens to reach a visible thallus. Therefore, the epiphytes appear more diverse in 30-45 cm diameter. Why the species number lowers again in the larger diameters then? The bark properties of old trees may explain this question. As tree diameter is increased, the bark pieces replaces with new patches of smoother bark. This may to some extent affect rate of a new colonization.

The elevation is also clearly effective on both the number and the composition of the epiphytic lichen communities. Climatic parameters (*e.g.* temperature, rainfall, evaporation) are known to be closely related to altitude. For this reason, number of species is the most in the highest zone. The preferences of some species were concentrated in 1300-1600 m and 1800-1900 m elevation zones. Moe and Botnea (1997) mentioned that high above sea level was an important environmental factor even though the altitudinal range was not more than 210 m. Significant differences in epiphytic lichen vegetation were detected along the altitudinal gradient in this study, which correspond with the literature (Dietrich and Schidegger, 1997; Pirintsos *et al.*,1993, 1995; Loppi *et al.,* 1997).

The role of aspect in the distribution of lichens species is related to levels of light, temperature and humidity in stands. Light strongly affects temperature, and temperature greatly influences evaporation, rendering it one of the decisive factors of epiphyte environment, although mainly in an indirect way (Barkman, 1958).

In this study, due to decreasing canopy cover on the southern slopes, the number of lichen species was lower in the south sites with higher temperature and more evaporation while the number was higher in the north slopes of the collecting sites at the same conditions (Table 1). Less canopy cover on the south slopes might cause to the occurrence of microclimates. Particularly in infrequent stands, microclimate has more extreme points that are effective on lichen growth (Hauck *et al.,* 2007). When the forest floor is suddenly exposed to direct light as a result of the loss of forest canopy, many lichen species cannot adapt and they soon dry out and die (Miege *et al.,* 2001). However, some old-forest species could adapt to young-forest environmental conditions (Hilmo and Sastad, 2001). There was also a significant effect of "north" aspect in the all diameter classes. The sunlight exposure time is relatively small and therefore the species number and the correlation might become lower in the north slopes. In the south slopes, the period of sunlight exposure time increases with the increasing elevation.

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