

# The distribution of epiphytic lichens on Uludag fir (*Abies nordmanniana* (Steven) Spach subsp. *bornmuelleriana* (Mattf.) Coode & Cullen) forests along an altitudinal gradient (Mt. Uludag, Bursa, Turkey)

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## Abstract

In this study forty six epiphytic lichen species were found on Uludag fir from five localities within an altitudinal range of 1500-1900 m in the Abietum zone on Mt. Uludag and were recorded. The most common species were *Bryoria capillaris*, *B. fuscescens*, *Caloplaca herbidella*, *Hypogymnia tubulosa*, *Lecanora saligna*, *Parmelia sulcata*, *Phlyctis argena*, and *Pseudevernia furfuracea*. The results indicate that the distribution and species composition of epiphytic lichens was related to altitude. *Bacidia globulosa*, *Evernia prunastri*, *Phlyctis argena*, *Ramalina farinacea*, *Rinodina capensis*, *Usnea glabrescens* and *U. rigida* were the characteristic species at 1500-1600 m. *Arthonia mediella*, *Bryoria fuscescens*, *B. implexa*, *Buellia disciformis*, *B. griseovirens*, *Caloplaca herbidella*, *Lecanora saligna* and *Parmeliopsis ambigua* were the characteristic species at 1700-1900 m. Altitude is one of the main factors controlling the diversity and distribution of epiphytic lichens on Uludag fir on Mt. Uludag.

**Keywords:** *Abies nordmanniana* subsp. *bornmuelleriana*, altitudinal gradient, epiphytic lichens, Mt. Uludag.

**Uludağ Göknař (*Abies nordmanniana* (Steven) Spach subsp. *bornmuelleriana* (Mattf.) Coode & Cullen)'ı ormanlarındaki epifitik likenlerin yükseklik gradienti boyunca dağılımı (Uludağ, Bursa, Turkey)**

## Özet

Uludağ'ın Abietum zonunda, 1500-1900 m'lik yükseklik alanı içerisindeki beş lokaliteden Uludağ göknař ağaçları üzerinden kırkaltı epifitik liken kaydedilmiştir. En yaygın türler *Bryoria capillaris*, *B. fuscescens*, *Caloplaca herbidella*, *Hypogymnia tubulosa*, *Lecanora saligna*, *Parmelia sulcata*, *Phlyctis argena* and *Pseudevernia furfuracea*'dir. Sonuçlar epifitik likenlerin dağılımı ve tür kompozisyonunun yükseklikle ilişkili olarak değiştiğini göstermektedir. *Bacidia globulosa*, *Evernia prunastri*, *Phlyctis argena*, *Ramalina farinacea*, *Rinodina capensis*, *Usnea glabrescens* ve *U. rigida* 1500-1600 m'de karakteristik türlerdir. *Arthonia mediella*, *Bryoria fuscescens*, *B. implexa*, *Buellia disciformis*, *B. griseovirens*, *Caloplaca herbidella*, *Lecanora saligna* ve *Parmeliopsis ambigua* 1700-1900 m'lerde karakteristik türlerdir. Yükseklik Uludağ'daki Uludağ Göknař'ı üzerindeki epifitik likenlerin dağılımı ve çeşitliliğini kontrol eden başlıca faktörlerden biridir.

**Anahtar Kelimeler:** *Abies nordmanniana* subsp. *bornmuelleriana*, yükseklik gradienti, epifitik likenler, Uludağ.

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## INTRODUCTION

Lichen communities comprise a major portion of the biomass of a forest with many ecological roles such as nitrogen fixation, nutrient cycling, and provision of food and nesting material for wildlife in the forest ecosystems (Nash III 1996).

Many lichens are long lived organisms with a high habitat specificity so they can be used to estimate species diversity and habitat potential at all

times of the year. Lichens are widespread in a range of habitats from natural to managed environments. They may be found on all types of substrata such as trees, rocks and soil, as well as man-made substrata, allowing their use as biological monitors of the environmental conditions in urban and rural situations, as well as tropical and arctic areas (Nimis et al. 2002). The lichen can obtain water from the atmosphere and nutrients from dust falling on the

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thallus, so it does not depend entirely on the substrate.

Most epiphytic lichens have some degree of substrate specificity. Both forest age and continuity of forest canopy are critical factors for the development of epiphytic lichen communities. Forest soil lichens also vary with soil type. Forest structure affects lichen distribution because the influence on the light and moisture regimes (Wolf et al. 2002). Environmental conditions such as climate, substrate, light and moisture play important roles in the distribution of lichen (Kershaw 1985). Fire is known to shape forest community structure, determine species composition. In the study of the impact of fire on the diversity of epiphytic lichens after the forest fire in Düzlercami area (Antalya) in the Mediterranean region of Turkey was observed to differentiate of the diversity and community structure of epiphytic lichens in damaged forest because of fire (Tufan Cetin and Sumbul 2008).

Similarly, distribution of lichen species and lichen biomass is heterogeneous in forests worldwide because of the importance of small variations in microhabitat characteristics (Ojala et al. 2000, Pharo and Vitt 2000). Various studies have been prepared on these issues (Burgaz et al. 1994, Pirintsos et al. 1995, Loppi et al. 1997).

The aim of the present study was to analyze the distribution of epiphytic lichens in the Uludag fir (*Abies nordmanniana* subsp. *bornmuelleriana*) forests along an altitudinal gradient on Mt. Uludag, Bursa, Turkey. The present study is important because it is the first study about this from Turkey.

## MATERIALS AND METHODS

### Study area

Mt. Uludag is the highest mountain in the Marmara region which includes the whole of European Turkey and North Western Anatolia. The summit of Mt. Uludag is 2543 m. The mountain was previously known as Olympos Mysios, Bithynian Olympos, and Kesis Dagi was renamed Mt. Uludag in 1925. The mountain range is about 40 km long and 15-20 km wide. Geologically, it consists of Palaeozoic granite, gneiss and Mesozoic ophiolite (Çetin 1999). It was made a National Park in 1961 for the protection of the plant cover.

The region has a mild climate. In general, the Mediterranean climate with very cold winters is modified by the climatic conditions of the Black Sea region, and also of the Inner Anatolian region. The

nearest meteorological stations to the study area on Mt. Uludag are Sarıalan (1620 m) and Zirve (1920 m). According to the data of these meteorological stations, the mean annual temperature is 10°C, the maximum mean temperature is 29°C in August, and the minimum mean temperature is 5.8°C in January. The mean annual rainfall is 1330 mm at Sarıalan and 1550 mm at Zirve. Precipitation reaches a maximum in December and a minimum in August (Çetin 1999).

The studied areas are located between 1500 and 1900 m altitude, with an annual average rainfall of 1330 mm and annual average temperature of 10 °C. These climatological features are characteristic of the humid Mediterranean climate with cold winters (Akman 1990). The coniferous forest zone at this elevation is known also as the Abietum zone. The Abietum zone is defined by the dominance of *Abies nordmanniana* subsp. *bornmuelleriana*. The important additional tree species in the Abietum zone are *Fagus orientalis*, *Pinus nigra* subsp. *pallasiana*, *Carpinus betulus* and *Juniperus communis* subsp. *nana*.

The Uludag fir is one of the endemic tree species of Turkey. Its distribution covers the Black Sea region from the west of Kızılırmak to Mt. Uludag and from sea level to 2000 m (Akman 1995, Kaynak et al. 2005).

### Sample collection

The study carried out on the Uludag fir, was 5 study sites in the Abietum Zone of Mt. Uludag. The study sites were located at altitudes of of 1500 m (40°07'08" N-29°05'15" E), 1600 m (40°06'34" N-29°05'48" E), 1700 m (40°06'27" N -29°06'18" E), 1800 m (40°06'37" N-29°07'09" E), and 1900 m (40°06'03" N-29°07'39" E). The lichen samples were taken from ten trees which were close to each other in each locality. Lichens were sampled using a 20x40 cm quadrat divided into 8 subunits of 10x10 cm placed at breast height on the north side of the tree trunks. In total, the lichen samples were collected from 400 sample units. During the sample collection process, the height and circumference of each tree were recorded for each of the sampling localities. The mean height and circumference of the sample trees are given Table 1.

Lichen samples were quantitatively analyzed for cover and frequency. In data analysis, the importance value is used. The importance value used here is the sum of the relative frequency and relative cover. Relative frequency (RF) and relative

cover (RC) were determined following the method given by Printzos et al. (1993, 1995). In brief,  $RF=100 \times$  (frequency of species  $i$ /sum of frequency values of all species), and  $RC=100 \times$  (cover of species  $i$  /sum of cover values of all species). The maximum value of this index is 200 when all species display 100% cover in all of the sampling units.

#### Statistical Analysis

We studied the relationships between the distribution of the epiphytic lichen and altitude. A total of 46 lichen species with at least two occurrences on 50 sample trees was found (Table 1). The data matrix of 46 species  $\times$  50 samples was investigated to detect the distribution and community structure of the epiphytic lichen along the altitudinal gradient by Detrended Correspondence Analysis (DCA) using the CANOCO for Windows 4.5 (Ter Braak and Smilauer 2002), and multivariate classification techniques (Two Way Indicator Species Analysis= TWINSpan ) (Hill 1979, Hugh and Gauch 1982).

The significant differences between the importance values of species with altitude were determined by one-way ANOVA with Bonferroni correction. Pearson's correlation coefficient was performed to compare the environmental variables (altitude and circumferences of the trunks of trees) and response variables (DCA axis scores, Shannon's diversity based on species density in each of the sampled trees and richness (number of lichen species on each of the sampled trees). All statistical analyses were performed using SPSS for Windows, Version 11.5 (Anonymous 2002) and assessed at the 95% confidence level.

#### RESULTS

A total of 46 lichen species with at least two occurrences on the 50 sample trees were found on the Uludag fir along the altitudinal gradient (Table 1). The common species were *Pseudevernia furfuracea* (98%), *Bryoria capillaris* (94%), *Hypogymnia tubulosa* (76%), *Bryoria fuscescens* (72%), *Phlyctis argena* (58%), *Lecanora saligna* (56%), *Parmelia sulcata* (56%), and *Caloplaca herbidella* (50%). The species were relatively restricted in distribution. Some species such as *Bryoria capillaris*, *B. fuscescens*, *Hypogymnia tubulosa*, *Lecanora carpinea*, *Parmelia sulcata*, *Pseudevernia furfuracea*, and *Usnea filipendula* occurred at all altitudes. Also, some of the other species such as *Bacidia globulosa*, *Hypogymnia farinacea*, *Lecanora symmicta*, *Melanelixia subaurifera*, *Ochrolechia pallescens*,

*Parmelia saxatilis*, *Phaeophyscia orbicularis*, *Ramalina calicaris*, and *Usnea hirta* occurred only at one altitude (Table 1).

DCA ordination showed that the distribution and species composition of epiphytic lichen change was related to altitude (Fig. 1). The epiphytic lichen vegetation of low altitude was clearly different than that of high altitude. DCA of the samples from five different altitudes resulted in values of 0.398 and 0.258 for the first two axes and DCA axis 1 was significantly related to altitude. Species richness and diversity showed a negative correlation related to axis 1 and axis 2 scores (Table 2).

The species and sites were classified using TWINSpan (Hill 1979), with cut levels based on importance values in the data matrix (0, 4, 8, 16, 32), with equal weighting. The TWINSpan classification concluded at level 3 with the production of four groups (Fig. 2).

The samples were divided into two clusters at the first level. The first cluster includes group I with indicator species *Evernia prunastri*, *Phlyctis argena* and *Usnea rigida* which are characterized by the high importance value at low altitude. The second cluster includes groups II, III and IV with indicator species *Caloplaca herbidella* and *Rinodina exiqua* which are characterized by the high importance value at high altitude. At the second level, group IV consists of the samples from 1900 m with the indicator species *Bryoria fuscescens* which was separated from groups II and III. At the third level, group III consists of the samples from 1800 m where indicator species *Lecanora saligna* was separated from groups II. Consequently, four groups were resolved by the multivariate classification techniques (Twinspan). The groups were significantly related to axis 1 ( $p<0.01$ ) and axis 2 ( $p<0.05$ ) scores (Table 2).

*Evernia prunastri*, *Melanelixia fuliginosa subsp. glabratula*, *Phlyctis argena*, *Ramalina farinacea*, *Rinodina capensis* and *Usnea rigida* were characteristic of group I. The distribution of *Hypogymnia farinacea* and *Lecanora symmicta* were restricted at 1700 m and together with *Micarea globulosella* were characteristic of group II. *Buellia disciformis*, *B. erubescens*, *Hypogymnia tubulosa*, *Lecanora chlorotera*, *L. saligna*, and *Lecidella elaeochroma* were statistically significant for group III. *Arthonia mediella*, *Bryoria fuscescens*, *B. implexa*, *Buellia griseovirens*, *Parmeliopsis ambigua*, and *Pseudevernia furfuracea* were statistically significant for group IV. Although *Lecanora carpinea* and *Parmelia*

**Table 1.** Mean values  $\pm$ SE, F and p-value (one-way ANOVA with Bonferroni Corr.) of the importance values of the species along the altitudinal gradient on Mt. Uludag. The differences is significant at  $p < 0.05$ ,  $p < 0.01$  and  $p < 0.001$ . Results of Bonferroni Corr. are in italic ( $df = 3, n = 10$ ).

Altitude (m)		1500	1600	1700	1800	1900		
Mean height of tree (m)		16.2 $\pm$ 0.61	13.3 $\pm$ 0.33	14.9 $\pm$ 0.57	11.6 $\pm$ 0.34	8.7 $\pm$ 0.26		
Mean circumference of tree trunks (cm)		137.6 $\pm$ 4.08	101.5 $\pm$ 8.02	122.4 $\pm$ 8.11	105.9 $\pm$ 5.33	129.3 $\pm$ 5.40	One - Way	
Groups		I		II	III	IV	ANOVA	
Species	Freq.						F	Sig.
<i>Arthonia didyma</i> Körb.	3	0.50 $\pm$ 0.50	0.73 $\pm$ 0.54				1.427	0.247
<i>Arthonia mediella</i> Nyl.	10		0.67 $\pm$ 0.67		2.00 $\pm$ 1.48	<i>12.39<math>\pm</math>4.17</i>	9.562	0.000
<i>Bacidia globulosa</i> (Flörke) Hafellner & V. Wirth	5	<i>4.93<math>\pm</math>2.16</i>					2.059	0.119
<i>Bryoria capillaris</i> (Ach.) Brodo & D. Hawksw.	47	24.07 $\pm$ 3.47	<i>33.02<math>\pm</math>6.00</i>	<i>41.32<math>\pm</math>3.83</i>	13.91 $\pm$ 2.78	15.30 $\pm$ 4.01	9.494	0.000
<i>Bryoria fuscescens</i> (Gyeln.) Brodo & D. Hawksw.	36	5.55 $\pm$ 1.24	5.29 $\pm$ 2.38	2.45 $\pm$ 0.94	4.26 $\pm$ 1.14	<i>28.72<math>\pm</math>4.97</i>	23.97	0.000
<i>Bryoria implexa</i> (Hoffm.) Brodo & D. Hawksw.	15	0.27 $\pm$ 0.27	0.56 $\pm$ 0.56		3.16 $\pm$ 1.20	<i>4.79<math>\pm</math>1.74</i>	6.301	0.001
<i>Buellia disciformis</i> (Fr.) Mudd	13			3.09 $\pm$ 1.27	<i>3.81<math>\pm</math>1.43</i>	0.21 $\pm$ 0.21	6.477	0.001
<i>Buellia erubescens</i> Arnold	5			0.28 $\pm$ 0.28	3.43 $\pm$ 1.95		3.979	0.013
<i>Buellia griseovirens</i> (Turner & Borrer ex Sm.) Almb.	13			0.61 $\pm$ 0.40	1.59 $\pm$ 0.89	<i>5.54<math>\pm</math>2.05</i>	7.133	0.000
<i>Caloplaca herbiddella</i> (Hue) H. Magn.	25			2.74 $\pm$ 0.73	<i>20.57<math>\pm</math>3.00</i>	<i>14.65<math>\pm</math>6.72</i>	11.116	0.000
<i>Candelariella xanthostigma</i> (Ach.) Lettau	5			1.18 $\pm$ 0.49	0.67 $\pm$ 0.67		2.847	0.048
<i>Evernia divaricata</i> (L.) Ach.	9		0.61 $\pm$ 0.61	0.92 $\pm$ 0.62	0.85 $\pm$ 0.45	1.38 $\pm$ 0.81	0.858	0.470
<i>Evernia prunastri</i> (L.) Ach.	12	<i>27.10<math>\pm</math>4.68</i>	1.51 $\pm$ 1.51	0.29 $\pm$ 0.29			6.804	0.001
<i>Hypogymnia farinacea</i> Zopf	3			<i>2.64<math>\pm</math>1.39</i>			4.895	0.005
<i>Hypogymnia physodes</i> (L.) Nyl.	6	1.93 $\pm$ 1.03	2.41 $\pm$ 2.12		0.48 $\pm$ 0.48		1.469	0.235
<i>Hypogymnia tubulosa</i> (Schaer.) Hav.	38	15.69 $\pm$ 3.25	11.36 $\pm$ 2.49	8.91 $\pm$ 3.98	<i>37.11<math>\pm</math>4.79</i>	2.08 $\pm$ 1.09	20.539	0.000
<i>Lecanora argentata</i> (Ach.) Malme	3	0.78 $\pm$ 0.78	0.64 $\pm$ 0.45				1.265	0.298
<i>Lecanora carpinea</i> (L.) Vain.	15	2.70 $\pm$ 0.91	0.75 $\pm$ 0.51	1.09 $\pm$ 1.09	0.94 $\pm$ 0.57	1.26 $\pm$ 0.98	0.238	0.869
<i>Lecanora chlarotera</i> Nyl.	11			0.96 $\pm$ 0.66	<i>4.11<math>\pm</math>1.37</i>	1.09 $\pm$ 0.90	6.197	0.001
<i>Lecanora saligna</i> (Schrad.) Zahlbr.	28	<i>9.59<math>\pm</math>2.60</i>	5.92 $\pm$ 1.90	0.46 $\pm$ 0.46	<i>26.80<math>\pm</math>3.37</i>		35.5	0.000
<i>Lecanora symmicta</i> (Ach.) Ach.	9			<i>14.40<math>\pm</math>3.15</i>			28.516	0.000
<i>Lecidella elaeochroma</i> (Ach.) M. Choisy	13		0.44 $\pm$ 0.44	1.57 $\pm$ 0.85	<i>17.93<math>\pm</math>5.43</i>		13.722	0.000
<i>Melanelixia fuliginosa</i> subsp. <i>glabratula</i> (Lamy) J.R. Laundon,	8	<i>2.92<math>\pm</math>0.71</i>	0.53 $\pm$ 0.53				5.502	0.003
<i>Melanelixia subaurifera</i> (Nyl.) O. Blanco et al.	3			1.71 $\pm$ 1.19			2.823	0.049
<i>Micarea globulosella</i> (Nyl.) Coppins	15			<i>15.43<math>\pm</math>4.56</i>	3.09 $\pm$ 0.96		14.041	0.000

*sulcata* were found at all altitudes, these species were not statistically significant (Table 1).

Among the growth forms, crustose lichens accounted for 43.48% of the lichen diversity, whereas fruticose lichens represented 41.30% and foliose lichens 15.22%. Fruticose lichens were shown as a negative correlation with altitude (Table 2).

### DISCUSSION

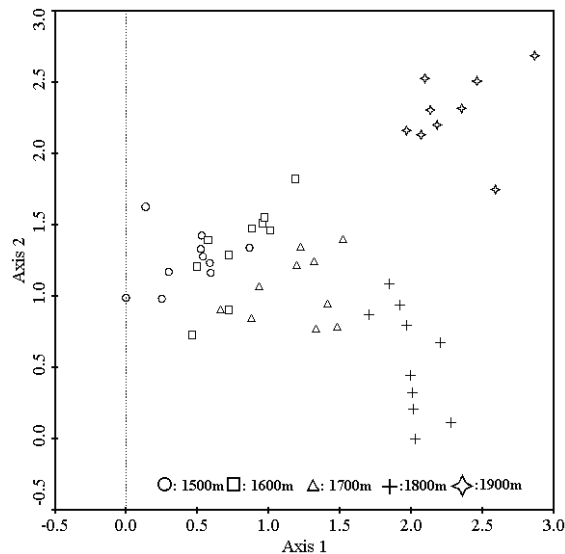
Lichens are generally sensitive to environmental alteration such as changes in air humidity and air pollution (Kricke and Loppi 2002). It is known that the distribution and lichen abundance of epiphytic lichen communities at the same substrate is controlled by environmental conditions such as light, exposure, altitude, moisture and orientation (Brodo et al. 2001). In addition, climatic parameters (i.e. temperature, rainfall, humidity) are known to be closely related to altitude (Loppi et al. 1997) and there is a positive relationship between lichen

biomass and location humidity (Caldiz and Brunet 2006). So, the change in species composition of the communities along the altitudinal gradient might reflect the different ecological conditions of the region.

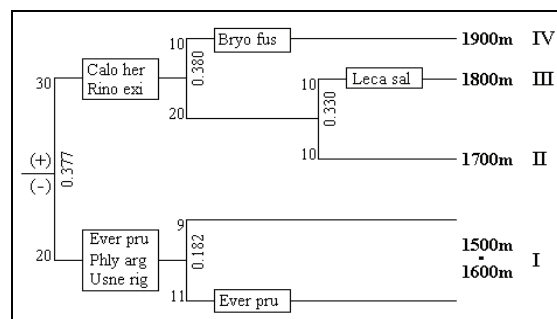
The lichen diversity is not similar on *Abies* trees along the altitudinal gradient on Mt. Uludag. It is a result of the influence of the microclimate on lichen diversity. The common lichen species were determined at five different altitudes. It was observed that the common species have high importance values to altitudes with suitable microclimatic properties. For example, *Bryoria capillaris* at 1700 m, *Hypogymnia tubulosa* at 1800 m, and *Pseudevernia furfuracea* at 1900 m. At the same time, it was observed that some of the common lichen species have high percent values and these are the fruticose lichen (Table 1). Similarly, Pintado et al. (2001) determined that the decrease in lichen

**Table 1.** Continued.

Altitude (m)		1500	1600	1700	1800	1900		
Mean height of tree (m)		16.2±0.61	13.3±0.33	14.9±0.57	11.6±0.34	8.7±0.26		
Mean circumference of tree trunks (cm)		137.6±4.08	101.5±8.02	122.4±8.11	105.9±5.33	129.3±5.40	One - Way	
Groups		I		II	III	IV	ANOVA	
Species	Freq.						F	Sig.
<i>Ochrolechia pallescens</i> (L.) A. Massal.	2	0.71±0.49					0.959	0.420
<i>Parmelia saxatilis</i> (L.) Ach.	2	1.95±1.58					0.719	0.546
<i>Parmelia sulcata</i> Taylor	28	6.32±3.38	12.59±4.85	8.71±3.08	2.99±0.96	0.37±0.37	2.564	0.066
<i>Parmeliopsis ambigua</i> (Wulfen) Nyl.	15		0.31±0.31		1.61±0.59	11.39±3.04	17.021	0.000
<i>Pertusaria albescens</i> (Huds.) M. Choisy & Werner	3	1.00±1.00			1.76±1.44		1.136	0.344
<i>Phaeophyscia orbicularis</i> (Neck.) Moberg	2				0.47±0.32		3.022	0.039
<i>Phlyctis argena</i> (Spreng.) Flot.	29	21.01±5.27	33.10±8.07	15.18±6.57	2.09±0.83		7.986	0.000
<i>Pleurosticta acetabulum</i> (Neck.) Elix & Lumbsch	2		0.60±0.60		0.20±0.20		0.373	0.773
<i>Pseudevernia furfuracea</i> (L.) Zopf	49	31.09±3.60	45.82±6.83	38.98±6.59	27.09±3.89	68.97±10.86	6.748	0.001
<i>Ramalina calicaris</i> (L.) Fr.	2			0.77±0.52			2.983	0.041
<i>Ramalina farinacea</i> (L.) Ach.	17	7.53±2.19	3.46±1.95	1.32±0.45			5.575	0.002
<i>Ramalina fraxinea</i> (L.) Ach.	6	4.55±1.78	1.82±1.82				2.999	0.040
<i>Ramalina pollinaria</i> (Westr.) Ach.	2	1.94±1.94		0.29±0.29			0.407	0.748
<i>Rinodina capensis</i> Hampe	15	1.54±0.76	5.82±1.02		0.37±0.25		9.599	0.000
<i>Rinodina exigua</i> Gray	24		0.25±0.25	15.62±2.65	10.47±2.11	6.66±4.45	9.805	0.000
<i>Tuckermannopsis chlorophylla</i> (Willd.) Hale	3	0.22±0.22	0.32±0.32	0.28±0.28			0.662	0.579
<i>Usnea cavernosa</i> Tuck.	5		1.61±1.08		2.02±1.06		1.911	0.141
<i>Usnea filipendula</i> Stirt.	15	0.33±0.33	3.93±2.13	7.40±4.56	3.46±0.91	0.19±0.19	1.825	0.156
<i>Usnea glabrescens</i> (Nyl. ex Vain.) Vain.	21	11.45±4.04	4.14±1.93	6.54±3.02	1.98±0.86		2.689	0.057
<i>Usnea hirta</i> (L.) F. H. Wigg.	2			0.74±0.57			2.247	0.095
<i>Usnea rigida</i> Vain.	15	12.45±3.32	8.85±3.13		0.47±0.47		10.351	0.000



**Fig 1.** DCA ordination of 50 sample trees at five different altitudes depending on the variation of importance value of 46 lichen species with at least two occurrences. Total inertia in species data: 2.66. Eigenvalues: 0.398 (axis 1), 0.258 (axis 2). Length of gradient: 2.87 (axis 1), 2.69 (axis 2).



**Fig 2.** Dendrogram of TWINSPLAN analysis of lichen samples. Bryo fus: Bryoria fuscescens, Calo her: Caloplaca herbidella, Ever pru: Evernia prunastri, Leca sal: Lecanora saligna, Phly arg: Phlyctis argena, Rino exi: Rinodina exigua, Usne rig: Usnea rigida.

diversity and biomass was found with increasing altitude which correlated with a decrease in temperature.

*Hypogymnia farinacea*, *Lecanora symmicta*, *Melanelixia subaurifera*, *Ramalina calicaris*, and *Usnea hirta* were only observed at 1700 m. The second group composed of the samples from 1700 m is

**Table 2.** Pearson's Correlation coefficients between DCA axes and selected variables.

	AX1	AX2	ALT	CIR	GR	DIV	RIC	CRU	FOL
AX2	0.215								
ALT	0.936(**)	0.253							
CIR	-0.175	0.220	-0.082						
GR	0.925(**)	0.303(*)	0.969(**)	0.037					
DIV	-0.340(*)	-0.565(**)	-0.394(**)	0.158	-0.361(*)				
RIC	-0.283(*)	-0.614(**)	-0.326(*)	0.124	-0.293(*)	0.969(**)			
CRU	0.174	-0.679(**)	0.170	-0.116	0.109	0.467(**)	0.585(**)		
FOL	-0.258	-0.348(*)	-0.264	0.005	-0.260	0.478(**)	0.573(**)	0.378(**)	
FRU	-0.503(**)	-0.118	-0.530(**)	0.247	-0.428(**)	0.628(**)	0.621(**)	-0.096	0.270

\*\* Correlation is significant at the 0.01 level (2-tailed); \* Correlation is significant at the 0.05 level (2-tailed).

ALT=altitude; CIR= circumferences of the trunks of the sampled trees; GR= the groups result from twinspan analysis; DIV= Shannon's diversity based on species density on each of the sampled trees; RIC=number of species of lichens on each of the sampled trees; CRU; number of crustose lichen species; FOL; number of foliose lichen species; FRU; number of fruticose lichen species.

different from the other groups as seen in the results of DCA and TWINSpan analyses (Figs 1 and 2). The second group with this peculiarity formed a transitional zone from low altitudes to high altitudes in the Abietum zone on Mt. Uludag (Table 1).

The richness and diversity of species showed a negative correlation related to the increase of altitude (Table 2). Similarly, Mucina et al. (2000) determined that species richness of lichens was negatively correlated with the increase of altitude on trunks of the *Abies cephalonica* on Mount Aenos, Kefallinia, Ionian Island (Greece).

Pinokiyo et al. (2008) reported a greater number of foliose species at the intermediate altitudes and an absence of fruticose lichens at the lower altitudes in the research area in India. It was shown that among the lichen growth forms, crustose lichens were dominant (for 56% of all lichen species), followed by foliose (34%) and fruticose lichens (8%). Similarly, we found that among the lichen growth forms, crustose lichens (43.48% of all lichen species) were dominant followed by fruticose (41.30%) and foliose (15.22%). Epiphytic macrolichens are known for their drought tolerance and high light requirement (Pentecost 1998). In addition, Leppik and Jürriado (2008) indicated that foliose and fruticose lichens were better grown in open habitats rather than the overgrown stands. The Abietum zone on Mt Uludag is a heavily forested area. We think that the irradiance in this zone is not suitable for growing of foliose lichens. Consequently, the number of foliose lichens decreased with an increase in altitude.

In our study, most of the determined lichens are of the acidophytic species. In addition to acidophytic lichens, some nitrophytic or subneutral species such as *Caloplaca herbidella*, *Candelariella xanthostigma*, *Lecanora argentata*, *Melanelixia subaurifera*, *Phaeophyscia orbicularis* were found on the Uludag fir by us. Larsen et al (2007) reported that the bark pH is influenced by many factors. Similarly, Otnyukova and Sekretenko (2008 a) determined that the acid bark of the *Abies sibirica* is the most important natural factor influencing lichen communities and the occurrence of nitrophytes on acidic bark indicates that air quality might be changing the bark pH for conifer trees. So, we think that it is necessary to study the various parameters of pollution such as NO, NO<sub>2</sub>, NH<sub>3</sub> in this area in the future. Because, in the atmosphere, ammonia is the dominant alkaline component that neutralizes a major part of the acid components such as sulfur dioxide and nitrogen oxides (Otnyukova and Sekretenko 2008 b).

We think that another reason for the differences in diversity and species composition of epiphytic lichens on the *Abies nordmanniana* subsp. *bornmuelleriana* is the microclimatic properties between the localities. Because, the features of the Mediterranean climate along the altitudinal gradient on Uludag Mountain change due to the slightly lower temperatures and more abundant precipitation than those of the actual Mediterranean climate. The research areas are located between 1500 and 1900 m. So, the epiphytic lichen vegetation of at low altitude was clearly different

than that of the high altitude.

Consequently we have determined that the distribution and species composition of epiphytic lichens on the *Abies nordmanniana* subsp. *bornmuelleriana* changed significantly related to altitude. In addition, it was found that the species richness and diversity showed a negative correlation with altitude. Altitude was one of the main factors controlling the diversity and distribution of epiphytic lichens on the Uludag fir on Mt. Uludag. Also, the diversity and distribution of epiphytic

lichens were affected by the other microclimatic factors such as humidity, light, temperature, and the bark pH of the trees.

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