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Vertical distribution of epiphytic lichens on *Quercus robur* L. in Görükle Campus Area of Bursa Uludag University (Bursa, Türkiye)

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Bursa Uludağ Üniversitesi (Bursa, Türkiye) Görükle Yerleşkesi alanında *Quercus robur* L. üzerindeki epifitik likenlerin dikey dağılımı

Abstract: In this study, the vertical change of epiphytic lichen species on *Quercus robur* was examined in Johansson zones based on frequency and cover values. A total of 20 epiphytic lichen species were determined from five trees. Total frequency and cover values of epiphytic lichen species show significant changes in Johansson regions. Beta diversity and Shannon diversity index values shows significant change with Johansson zone pairs. There is a significant difference in epiphytic lichen diversity between the Z1Z2 zone pair corresponding to the base and middle part of trunk on trees, and the Z4Z5 zone pair corresponding to the branches. *Athallia pyracea, Catillaria nigroclavata, Physcia adscendens* and *Rinodina pyrina* were positively correlated with Johansson zones, while *Phaeophyscia orbicularis* was negatively correlated with Johansson zones. *A. pyracea* is an indicator species especially for thin branches (Z5). *P. adscendens* is an indicator for Z4 and *Ph. orbicularis* is for the trunk part of the tree (Z1, Z2 and Z3).

Key words: Epiphytic lichen, vertical distribution, species diversity, species richness, *Quercus robur*

Özet: Bu çalışmada *Quercus robur* üzerindeki epifitik liken türlerinin Johansson zonlarındaki dikey değişimi frekans ve örtü değerlerine göre incelenmiştir. Beş ağaç üzerinden toplam 20 epifitik liken türü belirlendi. Epifitik liken türlerinin toplam frekans ve örtü değerleri Johansson bölgelerinde önemli değişiklikler göstermektedir. Beta çeşitliliği ve Shannon çeşitlilik indeksi değerleri Johansson bölge çiftleri ile anlamlı değişim göstermektedir. Ağaçlarda gövdenin taban ve orta kısmına karşılık gelen Z1Z2 bölge çifti ile dallara karşılık gelen Z4Z5 bölge çifti arasında epifitik liken çeşitliliği açısından önemli bir fark bulunmaktadır. *Athallia pyracea, Catillaria nigroclavata, Physcia adscendens* ve *Rinodina pyrina* Johansson zonları ile pozitif korelasyon gösterirken *Phaeophyscia orbicularis* Johansson zonları ile negatif korelasyon göstermektedir. *A. pyracea* özellikle ince dallar (Z5) için gösterge türdür. *P. adscendens* Z4 için gösterge ve *Ph. orbicularis* ağacın gövde kısmı (Z1, Z2 ve Z3) için gösterge türlerdir.

Anahtar Kelimeler: Epifitik liken, dikey dağılım, tür çeşitliliği, tür zenginliği, *Quercus robur*

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1. Introduction

The presence of corticolous lichens is associated with forest type, age, composition and structure, as well as light and moisture availability (Li et al., 2015; Güvenç and Öztürk Kula, 2021). Lichens are poikilohydric and highly sensitive to increases in light intensity. They are not very efficient at controlling water content. Therefore, they are very sensitive to changes in microclimate (Rheault et al., 2003). The main environmental factors controlling the diversity and distribution of epiphytic lichens are light intensity and humidity. Because the lower trunks of trees receive much less light than the upper trunk, epiphytic lichen diversity and biomass are generally higher in the sun-exposed upper canopy than at the trunk bases. As humidity increases, epiphytic lichen cover also increases (Cleavitt et al., 2009; Hauck, 2011). At the tree scale, the vertical distribution of epiphytic lichen diversity and community structure are affected due to their poikilohydric nature (Normann et al., 2010), leading to changes in the species structure and composition of epiphytic lichens from the base to tip of a tree (Castillo-Campos et al., 2019; Öztürk et al., 2023).

Other parameters affecting the lichen community are the pH and structure of the bark (Hauck et al., 2001; Wolseley et al., 2006) and the environment where trees of the same species grow, tree height and colonization time (tree age) (Çobanoğlu and Sevgi, 2009; Güvenç and Öztürk, 2017). For this reason, the distribution of lichens on trees is not homogeneous; some species prefer shady and moist areas, while others thrive in brighter, drier areas. Some species exhibit a wider range of microenvironmental tolerance (Öztürk et al., 2019).

The conversion of natural ecosystems to agricultural lands causes the loss, fragmentation or degradation of habitats for many species and is therefore one of the greatest threats to biodiversity worldwide. In addition to habitat loss, agricultural activities, especially fertilizer-intensive agriculture and intensive animal husbandry, also have a great impact on the atmosphere. These activities are the main anthropogenic sources of atmospheric nitrogen compounds, and their effects on terrestrial vegetation and lichens have been widely reported (Filippini et al., 2020).

The old trunk of *Quercus robur* is host a variety of lichen flora. Over time, oak bark becomes suitable for rare and threatened species with increasing age (Johansson et al., 2010; Jonsson et al., 2011).

The aim of this study is to determine whether there is a vertical difference in epiphytic lichen diversity from base to tip on the trunk of *Q. robur*.

2. Materials and Method

2.1. Study area

This study was carried out in the oak grove next to the Faculty of Agriculture in Bursa Uludağ University Görükle campus. This pure oak grove consists of *Quercus robur*. trees. The faculty of agriculture was moved to Bursa Uludağ University Görükle Campus in 1996. There are agricultural application areas, roads and a heating center around the faculty of agriculture. The trees in the pure stemmed oak grove selected as the study area were planted in 1996. Coal was burned in the heating center until 2005. Natural gas was switched to the Görükle campus in 2005.

Q. robur, also known as pedunculate or English oak, is a broad-leaved deciduous tree. Individuals are very long-lived and can reach 3-4 meters in diameter and 40 meters in height. The main trunk of *Q. robur* tends to disappear in the crown and irregular branches with sinuous branches develop. Their bark is thick, gray and cracked. *Q. robur* is common throughout much of Europe; it extends to southern Norway and Sweden in the north, and to the northern part of the Iberian Peninsula, Southern Italy, the Balkan Peninsula and Turkey in the south. *Q. robur* is chosen for ornamental purposes due to its size and shade, and is especially preferred as a park or roadside tree (Eaton et al., 2016).

Epiphytic lichen samples were collected from 5 trees in the oak grove on 07 November 2023. The study area is located between 40°13′26-28″ north latitudes and 28°51′38-41″ east longitudes. Görükle campus area is under the influence of Mediterranean climate (Akman, 1999). The mean annual temperature is 14.4°C, and the mean annual rainfall is 691.9 mm in the Görükle campus area. The campus area has a wide variety of different plants, natural and planted and a total of 252 species, 71 subspecies and 33 varieties were recorded from here. Most of these taxa are Mediterranean element, followed by Euro-Siberian and Irano-Turanian elements, respectively (Tarımcılar and Kaynak, 1994; 1995). A total of 79 lichen species have been recorded in the studies conducted in the Görükle campus area so far (Güvenç and Aslan, 1994; John and Güvenç, 2023; Oran and Öztürk, 2011; Oran, 2019).

2.2. Collection of lichen samples

Lichen sampling was carried out on 5 *Quercus robur* trees in the study area. Each tree was sampled by dividing it into five Johansson zones defined by Gradstein et al. (2003) (Table 1). Trees close together in the same environment were selected to minimize the impact of environmental conditions on epiphytic lichen diversity. In order to minimize the effect of environmental conditions on epiphytic lichen diversity, trees close to each other in the same environment were selected. The trees in the pure-peduncle oak grove selected as the study area were planted in 1996. Therefore, the development of all trees is not at the same level. Therefore, five trees suitable for sampling were selected.

A modified form of the method used by Castillo-Campos et al. (2019) was used to collect the samples. To obtained the frequency and cover value of epiphytic lichens in each Johansson region, 10×10 cm^2 sampling templates consisting of four squares, each divided into 5×5 cm^2 squares, were placed in the north and south directions at the base, middle and upper parts of the trunk.

Samples were taken by randomly selecting 8 thick branches and placing a square with a surface area of 5x5 cm^2 on each of them. 8 branch pieces, 15 cm long, were randomly cut from the thin branches at the ends. A sampling template consisting of 4 vertically placed squares with an area of 2.5 cm^2 was used on each branch. Thus, sampling was made from an area of 5x5 cm^2 on a thin branch. In order to calculate the area (cover value) occupied by lichen species on the trunk and branches, photographs were taken of each sampling performed on each tree. According to this method, when a species is found in all frames sampled in a Johansson region on a tree, the frequency value can be maximum 8, and if the entire sampled surface is covered, the cover value can be maximum 200 cm^2.

2.3. Statistical Analyses

Total frequency and total cover values were used to analyze the vertical variation of epiphytic lichen species from the base to the thin branches at the tip of the tree. To compare epiphytic lichen diversity in five different Johansonn zones on the tree, we calculated total beta diversity (β_{cc}) and the difference in species richness between pairs of zones (β_{rich}) according to Castillo-Campos et al. (2019).

Total beta diversity

$$\beta_{cc} = \frac{b+c}{a+b+c}$$

The difference in species richness between pairs of zones

$$\beta_{rich} = \frac{|b-c|}{a+b+c}$$

Here;
a: the number of species common to both regions,
b: the number of species specific to the first region,
c: the number of species specific to the second region.

Table 1. Characteristics and average number of species of Johansson zones

Johansson zones	Location of zones on the tree trunk	Average circumference of the sampled part of trees	Average number of Lichen species
Z1	Base of tree (at ground level)	102.6±13.0	5.6±1.82
Z2	Middle part (at breast level)	85.4±11.5	5.6±1.52
Z3	Upper part (starting level of thick branches)	87.6±11.5	4.8±2.68
Z4	Thick branches (1 m above the beginning of branching)	24.3±4.2	5.8±1.48
Z5	Thin branches (at the tip)	4.5±1.1	7.8±1.92

Additionally, the difference in species diversity in different Johansson regions was analyzed according to the Shannon-Wiener Diversity Index (H') values calculated using frequency values (Nolan and Callahan, 2006). One-way analysis of variance (ANOVA) was used to analyze the changes in total frequency and cover values in the Johnsson zones. Total frequency, total cover and species richness (Shannon-Wiener Diversity Index, beta diversity) data calculated for Johansson zones and characteristic species for zones were compared using nonparametric Kruskal-Wallis tests followed by the Wilcoxon test for pairwise comparisons. Statistical analyses were performed using the IBM SPSS Statistics version 28. The significance level in the tests was evaluated as $p<0.05$.

3. Results

In this study, a total of 20 epiphytic lichen species were determined on *Quercus robur*. *Phaeophyscia orbicularis, Physcia adscendens* and *Xanthoria parietina* are the most common species. In all Johnsson regions, the cover and frequency values of *Ph. orbicularis, P. adscendens* and *X. parietina* are highest, while *Glaucomaria carpinea* and *Physcia stellaris* are low. Species found only in one zone are: *Amandinea punctata* (Z1), *Lecanora chlarotera* (Z2), *Biatora globulosa* and *Polyozosia hagenii* (Z5). While *A. punctata, Lecania cyrtella, L. chlarotera, Lecidella elaeochroma, Physconia distorta* and *Physconia grisea* were found only on the trunk part of the tree (Z1, Z2, Z3), *B. globulosa* and *Po. hagenii* were found only on the thin branches of the tree (Z5). The families with the highest species content are Lecanoraceae and Physciaceae (6 species), followed by Teloschistaceae with 4 species and Caliciaceae, Candelariaceae, Catillariaceae and Ramalinaceae with 1 species each (Table 2).

Total frequency and cover values in Johansson areas vary significantly from the base to the tip of the tree (Table 3). While the total frequency value shows a positive correlation with Johansson zones and an increase in the branches (F: 3.461, $p<0.05$), the total cover value shows a negative correlation and decrease in the branches part of the tree (F: 7.166, $p<0.01$).

Beta diversity values shows significant change with Johansson zone pairs. There is a significant difference in epiphytic lichen diversity between the Z1Z2 zone pair corresponding to the base and middle part of trunk on trees, and the Z4Z5 zone pair corresponding to the branches (Z: -2.032, $p<0.05$) (Fig. 1A). Similarly, in the comparison between Shannon diversity index values and Johansson zones, a significant difference (Z: -2.023, $p<0.05$) was found between the base (
1B).

When Johansson zone pairs are compared based on the difference in species richness, the lowest mean value is in the Z1Z2 zone pair corresponding to the base and middle part of the trunk of the tree, and the highest mean value is in the Z3Z4 zone pair, corresponding to the upper part of

Table 2. Total cover (cm^2) and frequency of epiphytic lichen species in Johansson areas on *Quercus robur*

		Z1		**Z2**		**Z3**		**Z4**		**Z5**		**Total**	
	Average circumference of the sampled part of the tree	**102.6±13.0**		**85.4±11.5**		**87.6±11.5**		**24.3±4.2**		**4.5±1.1**			
	Average number of lichen species	**5.6±1.82**		**5.6±1.52**		**4.8±2.68**		**5.8±1.48**		**7.8±1.92**			
	The Shannon-Weiner Species Diversity Index	**1.44±0.34**		**1.44±0.28**		**1.27±0.46**		**1.53±0.17**		**1.83±0.29**			
Families	**Species**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**
Teloschistaceae	*Athallia cerinella* (Nyl.) Arup. Frödén & Søchting	4	4	1	0.5	0	0	2	0.7	12	6.8	19	12
Teloschistaceae	*Athallia pyracea* (Ach.) Arup. Frödén & Søchting	2	0.5	0	0	1	0.3	9	3	35	27	47	30.8
Ramalinaceae	*Biatora globulosa* (Flörke) Rabenh.	0	0	0	0	0	0	0	0	3	0.8	3	0.8
Teloschistaceae	*Caloplaca cerina* (Hedw.) Th. Fr.	0	0	1	0.5	0	0	0	0	4	1	5	1.5
Candelariaceae	*Candelaria concolor* (Dicks.) Arnold	0	0	0	0	1	0.3	1	0.8	0	0	2	1
Catillariaceae	*Catillaria nigroclavata* (Nyl.) J. Steiner	0	0	0	0	1	0.3	14	13.8	7	4	22	18
Lecanoraceae	*Glaucomaria carpinea* (L.) S.Y. Kondr., Lőkös & Farkas	4	1.5	3	0.8	2	0.5	3	1.3	2	0.5	14	4.5
Lecanoraceae	*Lecania cyrtella* (Ach.) Th. Fr.	0	0	1	0.3	1	0.5	0	0	0	0	2	0.8
Lecanoraceae	*Lecanora chlarotera* Nyl.	0	0	2	0.5	0	0	0	0	0	0	2	0.5
Lecanoraceae	*Lecidella elaeochroma* (Ach.) M. Choisy	2	0.8	0	0	2	2	0	0	0	0	4	2.8
Physciaceae	*Phaeophyscia orbicularis* (Neck.) Moberg	32	69.8	32	62.8	34	160.3	17	19.8	5	3	120	315.5
Physciaceae	*Physcia adscendens* H. Olivier	16	31.8	18	47.8	13	22.8	38	99	32	31.5	117	232.8
Physciaceae	*Physcia stellaris* (L.) Nyl.	2	1.8	5	5.3	6	12	1	1.3	1	0.3	15	20.5
Physciaceae	*Physconia distorta* (With.) J.R. Laundon	1	1	1	1	0	0	0	0	0	0	2	2
Physciaceae	*Physconia* grisea (Lam.) Poelt	5	20.8	2	12	0	0	0	0	0	0	7	32.8
Lecanoraceae	*Polyozosia hagenii* (Ach.) S.Y. Kondr., Lőkös & Farkas	0	0	0	0	0	0	0	0	5	1.3	5	1.3
Lecanoraceae	*Polyozosia persimilis* (Th. Fr.) S.Y. Kondr., Lőkös & Farkas	0	0	3	1	2	0.8	3	0.8	16	5	24	7.5
Physciaceae	*Rinodina pyrina* (Ach.) Arnold	3	3.5	1	0.5	1	0.5	0	0	15	5.8	20	10.3
Teloschistaceae	*Xanthoria parietina* (L.) Th. Fr.	37	343.3	40	406.3	39	347.3	40	468.8	40	245.5	196	1811
	Total	**109**	**479**	**110**	**539**	**103**	**547.3**	**128**	**609**	**177**	**332.3**	**627**	**2506.5**

Table 3. Comparison of mean ± standard deviation of total cover and frequency in Johansson areas (One-Way Anova)

Johansson zones	Total frequency	Total cover
Z1	21.8±8.2	96.2±16.3
Z2	22.0±5.2	107.8±10.1
Z3	20.6±6.1	109.6±24.1
Z4	25.6±2.9	122.2±14.0
Z5	35.4±11.2	66.4±20.4
df	4	4
F	3.461	7.166
Sig.	0.026*	0.001**

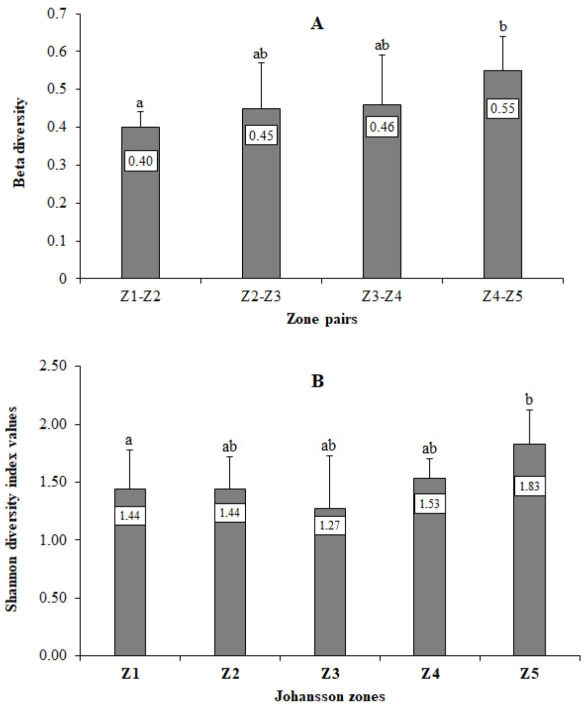

Figure 1. Comparison of Johansson zone pairs based on beta diversity (A) and Johansson zones based on Shannon diversity index values (B).

the trunk and thick branches. Z1Z2 zone pair is significantly different from both Z3Z4 (Z: -2.023, p<0.05) and Z4Z5 zone pairs (Z: -2.032, p<0.05). There is no significant difference between Z3Z4 and Z4Z5 zone pairs (Fig. 2).

Of the total 20 epiphytic lichen species detected on *Q. robur*, 6 species show significant differences when compared between the five Johansson zones. *A. pyracea, C. nigroclavata* and *Ph. orbicularis* show significant differences between Johansson zones in both frequency and cover values at the p<0.01 level. *P. adscendens* and *R. pyrina* have a significant difference between Johansson zones only in frequency values at the p<0.05 level. *X. parietina* has a significant difference only in cover values at the p<0.05 level. Depending on the change in frequency values, *A. pyracea, C. nigroclavata, P. adscendens* and *R. pyrina* were positively correlated with Johansson zones, while *Ph. orbicularis* was negatively correlated with Johansson zones (Table 4).

The frequency and cover values of *A. pyracea* increase significantly from the base to the thin branches of the tree. It is a characteristic species especially for thin branches

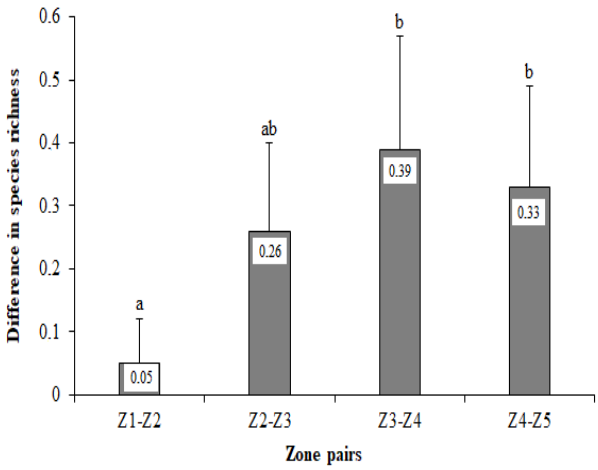

Figure 2. Comparison of Johansson zone pairs based on differences in species richness.

Table 4. Species showing significant differences in vertical change from the base to the tip of the tree (n:5)

		Mean Rank					Kruskal-Wallis H	df	Asymp. Sig.
		Z1	Z2	Z3	Z4	Z5			
A. pyracea	F	9.90	8.00	9.60	14.50	23.00	17.487	4	**0.002****
	C	9.80	8.00	9.60	14.60	23.00	17.606	4	**0.001****
C. nigroclavata	F	8.50	8.50	10.50	19.40	18.10	14.304	4	**0.006****
	C	8.50	8.50	10.20	19.70	18.10	14.913	4	**0.005****
Ph. orbicularis	F	17.40	16.90	18.80	7.80	4.10	16.517	4	**0.002****
	C	16.60	15.40	20.00	9.40	3.60	15.664	4	**0.004****
P. adscendens	F	8.80	9.90	7.70	20.70	17.90	13.105	4	**0.011***
	C	10.10	13.70	8.80	20.40	12.00	7.606	4	0.107
R. pyrina	F	12.00	11.50	11.50	9.50	20.50	10.923	4	**0.027***
	C	12.60	11.50	11.50	9.50	19.90	9.500	4	0.050
X. parietina	F	9.40	14.50	12.10	14.50	14.50	5.948	4	0.203
	C	11.40	16.10	11.80	19.90	5.80	10.444	4	**0.034***

*P<0.05 **P<0.01

(Z5). Similarly, the vertical change in the frequency and cover values of *P. adscendens* is characteristic for Z4. On the contrary, the frequency and cover values of *Ph. orbicularis* are high in the trunk part of the tree and low in the branches. It is a characteristic species for the trunk part of the tree (Z1, Z2 and Z3). While the change in frequency values of *X. parietina* in Johansson zones is not significant, the vertical change in cover values is significant for Z1, Z2 and Z4 (Table 5).

4. Discussions

The availability of light and moisture are important factors controlling the within-stand variation of epiphytic lichens. Generally, epiphytic lichen cover increases with increasing humidity. Increasing or decreasing the amount of light has an effect on the community structure of epiphytic lichens. Habitat diversity has a substantial influence on the diversity of epiphytic lichens (Hauck, 2011). Light conditions on the tree trunk are affected by the tree structure, and low light availability on the trunk can have a negative effect on lichens living on the base of the trunk (Bäcklund et al., 2016).

Bark pH, light and nutrient availability relative to water content of bark are determinants of a species' ability to colonize the bark surface (Ellis et al., 2021). The diversity of epiphytic lichens along the trunk of a tree is also significantly affected by the age of the tree and changes in microclimate (Fritz, 2009; Öztürk et al., 2019).Various studies have been conducted examining the vertical distribution of epiphytic lichen diversity on the tree trunk (Córdova-Chávez et al., 2016; Fanning et al., 2007; Li et al., 2015).

In this study, we determined that there is a significant difference in species richness between different Johansson regions. Species richness increases from the lowest parts of the tree to the highest parts. Similarly, lower regions (Z1-Z2) have lower richness than higher regions (Z4-Z5). This result is consistent with the results obtained in the study carried out by Castillo-Campos et al. (2019), in which the vertical variation of epiphytic lichen species in five Johansson zones on *Quercus laurina* was analyzed. Recently, in a study carried out in the stemmed oak grove located next to the Faculty of Agriculture in Bursa Uludağ University Görükle campus, a significant difference in epiphytic lichen diversity was found between the base and trunk of *Q. robur* (Öztürk et al., 2023). On the contrary, in their study on *Quercus laurina* in the Great Smoky Mountains National Park, Córdova-Chávez et al. (2016) found that there was no difference in species richness between different Johansson regions.

When the results of this study were compared with the results of a previous study on *Q. robur* by Öztürk et al. (2023) in the same area, nine species identified in the previous study were not found in this study. These species consist of crustose (*Scoliciosporum chlorococcum* (Graewe ex Stenh.) Vězda), foliose (*Melanelixia subaurifera* (Nyl.) O. Blanco et al., *Parmelina tiliacea* (Hoffm.) Hale, *Physcia aipolia* (Ehrh. ex Humb.) Fürnr., *Physconia enteroxantha* (Nyl.) Poelt, *P. perisidiosa* (Erichsen) Moberg, *Pleurosticta acetabulum* (Neck.) Elix & Lumbsch) and fruticose (*Evernia prunastri* (L.) Ach. and *Ramalina pollinaria* (Westr.) Ach.). Unlike the previous study, seven species (*Amandinea punctata* (Hoffm.) Coppins & Scheid., *Athallia pyracea* (Ach.) Arup, Frödén & Søchting, *Biatora globulosa* (Flörke) Rabenh., *Candelaria concolor* (Dicks.) Arnold, *Glaucomaria carpinea* (L.) S.Y. Kondr., Lőkös & Farkas, *Physconia distorta* (With.) J.R. Laundon and *Polyozosia persimilis* (Th. Fr.) S.Y. Kondr., Lőkös & Farkas) were found in this study. This difference in species

Table 5. Indicator species and their Z values for Zohansson zones.

Wilcoxon Signed Ranks Test			Test Pairs									
			Z2 - Z1	Z3 - Z1	Z4 - Z1	Z5 - Z1	Z3 - Z2	Z4 - Z2	Z5 - Z2	Z4 - Z3	Z5 - Z3	Z5 - Z4
A. pyracea	F	Z	-1.000[c]	-.447[c]	-1.633[b]	**-2.041[b]**	-1.000[b]	-1.604[b]	**-2.041[b]**	-1.633[b]	**-2.060[b]**	**-2.032[b]**
		Sig.	0.317	0.655	0.102	**0.041**	0.317	0.109	**0.041**	0.102	**0.039**	**0.042**
	C	Z	-1.000[c]	-.447[c]	-1.633[b]	**-2.032[b]**	-1.000[b]	-1.732[b]	**-2.023[b]**	-1.633[b]	**-2.023[b]**	**-2.023[b]**
		Sig.	0.317	0.655	0.102	**0.042**	0.317	0.083	**0.043**	0.102	**0.043**	**0.043**
Ph. orbicularis	F	Z	.000[a]	**-.707[b]**	**-2.032[c]**	**-2.023[c]**	-.577[b]	-1.890[c]	**-2.032[c]**	**-2.023[c]**	**-2.032[c]**	-1.841[c]
		Sig.	1.000	**0.480**	**0.042**	**0.043**	0.564	0.059	**0.042**	**0.043**	**0.042**	0.066
	C	Z	-.135[c]	-1.483[b]	-1.753[c]	**-2.023[c]**	**-2.023[c]**	**-2.023[c]**	**-2.023[c]**	**-2.023[c]**	**-2.023[c]**	**-2.023[c]**
		Sig.	0.893	0.138	0.080	**0.043**	**0.043**	**0.043**	**0.043**	**0.043**	**0.043**	**0.043**
P. adscendens	F	Z	-.447[b]	-.736[c]	**-2.070[b]**	**-2.041[b]**	-1.089[c]	**-2.041[b]**	-1.841[b]	**-2.032[b]**	**-2.023[b]**	-1.414[c]
		Sig.	0.655	0.461	**0.038**	**0.041**	0.276	**0.041**	0.066	**0.042**	**0.043**	0.157
	C	Z	-1.461[b]	-.135[c]	**-2.023[b]**	-.135[c]	-1.75[c]	-1.753[c]	-.674[b]	**-2.023[b]**	-.674[b]	**-2.023[c]**
		Sig.	0.144	0.893	**0.043**	0.893	0.080	0.080	0.500	**0.043**	0.500	**0.043**
X. parietina	F	Z	-1.342[b]	-1.414[b]	-1.342[b]	-1.342[b]	-1.000[c]	.000[a]	.000[a]	-1.000[b]	-1.000[b]	.000[a]
		Sig.	0.180	0.157	0.180	0.180	0.317	1.000	1.000	0.317	0.317	1.000
	C	Z	-1.483[b]	-.135[c]	-1.753[b]	**-2.023[c]**	-1.753[c]	-1.761[b]	**-2.023[c]**	-1.753[b]	-1.483[c]	**-2.023[c]**
		Sig.	0.138	0.893	0.080	**0.043**	0.080	0.078	**0.043**	0.080	0.138	**0.043**

Z values in bold are significant at p<0.05 level.
a: The sum of negative ranks equals the sum of positive ranks.
b: Based on negative ranks.
c: Based on positive ranks

diversity is due to the fact that the sampled trees are in different pa rts of the study area. The sampled trees in the previous study were located close to agricultural areas, away from the road passing in front of the Faculty of Agriculture and the heat center. The sampled trees in this study are located in the immediate vicinity of the road and the heat center.

As a result of these two studies, a total of 29 species were found on *Q. robur* trees. There are 85 species in the records given so far from the campus area (Güvenç and Aslan, 1994; John and Güvenç, 2023; Oran and Öztürk, 2011; Oran, 2019). In this study, five additional species (*Athallia pyracea*, *Biatora globulosa*, *Candelaria concolor*, *Physconia distorta* and *Polyozosia persimilis*) were recorded for the campus. As a result, the total number of species in the Görükle campus area is 90.

In our study, *Ph. orbicularis, P. adscendens* and *X. parietina* are the most common species on *Q. robur*. These common species are also abundant on common oak species (*Quercus robur, Q. cerris, Q. rubra* and *Q. palustris*) in three parks in London (Llewellyn et al., 2020).

In this study, we determined that there is a significant difference in species richness between different Johansson regions. Species richness increases from the lowest parts of the tree to the highest parts. There is a negative relationship between trunk diameter and species diversity in the vertical change of epiphytic lichen diversity from the base of the tree to the thin branches. Species diversity is low at the base of the tree and highest in the thin branches (Fig. 1A, Table 1). A similar relationship between tree age and species diversity was reported by Öztürk et al. (2019) on *Q. petraea*. Of the total number of lichen species, 14 (70%) were crustose and 6 (30%) foliose lichens. The number of crustose and foliose species are equal in Z1 and Z2. Crustose species are more common than foliose species in the Z3, Z4 and Z5 zones (Fig. 3).

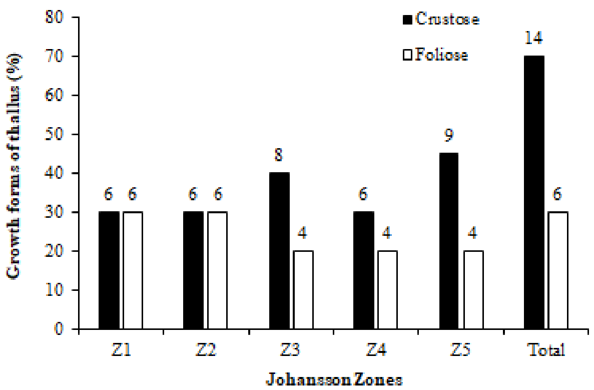

Figure 3. The number of growth forms of epiphytic lichens in Johansson regions.

The diversity of epiphytic lichens varies depending on trunk height. The greatest species diversity was found in the crown of the tree. In other parts, the diversity was quite variable (Muchnika and Blagoveschenskayab, 2022). Foliose lichens are more competitive than both crustose and fruticose species. Lichens with crustose growth forms are expected to resist drought events better due to their lower surface-to-volume ratio and consequently have a higher tolerance to desiccation. In addition, the competitive abilities of crustose species are weaker than foliose and fruticose species. Therefore, they are pioneers in colonizing young trees and thin branches of the tree (Armstrong and Bradwell, 2010; Kantelinen et al., 2022).

A. pyracea and *P. adscendens* are characteristic for the upper Johansson zones (Z4-Z5), while *Ph. orbicularis* and *X. parietina* are characteristic for the lower Johansson zones (Z1, Z2 and Z3). As a result of urbanization, epiphytic lichen richness and cover on *Q. robur* were found to be lower in urban trees than in rural trees. In addition, as the duration of urban trees being surrounded by houses increases, their richness and cover gradually decrease (Lättman et al., 2014). Epiphytic lichen diversity is affected by intensive agricultural activities. The frequency of Physciaceae tends to increase as the cultivation area increases. The increased frequency of *Physcia* species indicates a eutrophication process in that region (Filippini et al., 2020). In our study, the families with the highest species content are Lecanoraceae and Physciaceae (6 species), followed by Teloschistaceae with 4 species.

Görükle campus and its surroundings were evaluated as a semi-natural zone (low naturality) in terms of environmental quality based on lichen diversity. In the semi-natural zone, Xanthorion vegetation is dominated by nitrophytic species with high frequency. These species with high frequency were reported to be *C. vitellina, H. adglutinata, P. orbicularis, P. adscendens, P. stellaris, Ph. grisea* and *X. parietina*. In addition, Lecanorion species (*G. carpinea, L. chlarotera, L. elaeochroma* and *P. hagenii*) were shown as important species for this group. *H. adglutinata, L. elaeochroma, P. adscendens* and *X. parietina* were found abundantly in oak trees near agricultural areas and around settlements (Güvenç, 2017).

All of the annual and seasonal average $PM_{2.5}$ values measured in Bursa Uludağ University Görükle campus in 2015 are above the European Union limit value of 25 µg/m^3. In 2023, this value is slightly above the limit value only in the winter season. SO_2 and NO_2 values measured at Bursa Uludağ University Görükle campus in 2015 are below the European Union limit values of 20 and 40 µg/m^3, respectively. In 2023, these values dropped even lower. NO_x values measured at Bursa Uludağ University Görükle campus in both 2015 and 2023 are above the European Union limit value of 30 µg/m^3 (Table 6). According to the EPA Air Quality Index Classification, the air quality index at Bursa Uludağ University Görükle campus is at a "good" level for both 2015 and 2023 (UHKIA, 2015; 2023).

Nitrogen oxides (NO_x) values measured in the air of the Görükle campus are above the limit values in the autumn and winter seasons. These high nitrogen oxide values can be explained by the presence of the Istanbul-Izmir highway Görükle connection road, 500 meters away from the study area, and the road connecting the inner-city transportation to the Görükle center and the highway connection road right next to it, as well as the surrounding agricultural areas.

Because, primary sources of reactive nitrogen in the atmosphere are nitrogen oxides (NO_x) and ammonia (NH_3). While road traffic contributes the majority of atmospheric NO_x, NH_3 is largely a product of intensive agricultural activities (Wolseley et al., 2006). NO_2 concentration was found to be positively correlated with traffic density and negatively correlated with distance from the nearest highway (Frati et al., 2008).

Table 6. Annual and seasonal changes of the average values of pollutant (daily) concentrations in µg/m3 for the years 2015 and 2023 at Bursa - Uludağ University Meteorology Station (38) (UHKIA, 2015; 2023).

Years	Seasons	Pollutants						Air Quality Index Value
		$PM_{2.5}$	SO_2	NO_2	NO_x	NO	O_3	
2015	Spring	27.16	5.12	25.74	36.79	7.27	54.30	26.06
	Summer	26.35	3.62	17.64	22.14	3.02	74.23	24.50
	Autumn	31.09	4.31	23.54	51.72	19.26	40.33	28.38
	Winter	34.40	7.31	32.53	80.40	30.72	29.51	35.81
	Annual mean	**29.75**	**5.09**	**24.86**	**47.76**	**15.07**	**49.59**	**28.69**
2023	Spring	21.52	2.54	13.94	24.81	4.48	49.53	19.47
	Summer	19.30	2.27	17.42	36.44	4.11	78.38	26.32
	Autumn	18.96	3.31	19.27	48.37	13.44	55.03	26.40
	Winter	26.59	3.18	24.55	60.85	20.77	30.10	27.67
	Annual mean	**21.59**	**2.83**	**18.80**	**42.62**	**10.70**	**53.26**	**24.97**

AQI Value	AQI Category	AQI Color
0 - 50	Good	Green
51 - 100	Moderate	Yellow
101 - 150	Unhealthy for Sensitive Groups	Orange
151 - 200	Unhealthy	Red
201 - 300	Very Unhealthy	Purple

Loppi et al. (2002) reported that "semi-natural" areas were characterized by *C. concolor, H. adglutinata, P. adscendens, Ph. grisea* and Xanthorion elements, while "natural" areas were characterized by a high frequency of *Parmelia* species (*Flavoparmelia caperata* (L.) Hale, *M. subaurifera, Parmelia sulcata* Taylor and *Punctelia subrudecta* (Nyl.) Krog). The transition from Parmelion-dominated to Xanthorion-dominated lichen vegetation was generally interpreted as occurring due to increased human activities and air pollution. This suggests that under human disturbance conditions, more competitive opportunistic Xanthorion species tend to invade Parmelion communities and increase total species diversity. Therefore, synergistic effects may explain the absence or scarcity of certain sensitive lichen species, especially *Parmelia* species, from the "semi-altered" area, despite low SO_2 and NO_x levels.

Conflict of Interest

Authors have declared no conflict of interest.

Authors' Contributions

The authors contributed equally.

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