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Comparison of Epiphytic Lichen Diversity on the Base and Trunk of *Quercus robur* Population in Görükle Campus Area of Bursa Uludag University (Bursa, Türkiye)

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Abstract: This study was carried out in a pedunculate oak grove located next to the Faculty of Agriculture in the Görükle campus area of Bursa Uludag University. Differences in epiphytic lichen diversity on the base and trunk of *Quercus robur* L. were analyzed. A significant difference in epiphytic lichen diversity between the base and trunk of the tree was found. The community structure of epiphytic lichens on *Q. robur* is characterized by the Physcietum adscendens association within the alliance of Xanthorion parietinae. The diversity of epiphytic lichens and the number of species are higher on the trunk rather than at the base of the trees.

Keywords: Physcietum, Species diversity, Species richness, Xanthorion

Bursa Uludağ Üniversitesi (Bursa, Türkiye) Görükle Kampüs Alanındaki *Quercus robur* Populasyonunun Taban ve Gövdesi Üzerindeki Epifitik Liken Çeşitliliğinin Karşılaştırılması

Öz: Bu çalışma, Bursa Uludağ Üniversitesi Görükle yerleşkesi alanında Ziraat Fakültesi yanında bulunan saplı meşe korusunda gerçekleştirilmiştir. *Quercus robur* L.'un taban ve gövdesindeki epifitik liken çeşitliliğindeki farklılıklar analiz edilmiştir. Ağacın tabanında ve gövdesinde epifitik liken çeşitliliğinde önemli bir fark bulunmuştur. *Q. robur* üzerindeki epifitik likenlerin topluluk yapısı, Xanthorion parietinae alyansı içindeki Physcietum adscendens birliği ile karakterize edilmektedir. Epifitik likenlerin çeşitliliği ve tür sayısı gövdede ağacın tabanında olduğundan daha fazladır.

Anahtar kelimeler: Physcietum, Tür çeşitliliği, Tür zenginliği, Xanthorion

Introduction

Lichens are poikilohydric organisms and highly sensible to an increase of light intensity. They are not very efficient at controlling their water content. Therefore, they are very sensitive to changes in the microclimate (Rheault et al., 2003). The main site factors controlling the diversity and distribution of epiphytic lichens are light intensity and moisture. Because of the lower trunks receive much less light than upper trunk of trees, epiphytic lichen diversity and biomass are generally higher in the sun-exposed upper canopy than in trunk bases. Epiphytic lichen cover increases with increasing humidity (Hauck, 2011). Small changes in the microclimate affect the distribution and species composition of epiphytic lichens (Öztürk et al., 2019).

The epiphytic lichen species richness, density and composition varies between different fractions of a tree (Caruso and Thor, 2007; Hauck and Meifiner, 2002). The species richness and community structure of epiphytic lichens are changing from the base up the trunk (Marmor et al., 2013; Muchnik and Blagoveschenskaya, 2022). According to Castillo-Campos et al. (2019), species richness increases from the lowest part to the highest part of a tree.

Additionally, the impact of anthropogenic and agricultural activities in and around the settlements greatly alters epiphytic lichen variety and community structure (Wolseley et al., 2006; Shukla and Upreti, 2011; Garrido-Benavent et al., 2015). The importance of host tree species, size, bark, and habitat characteristics for epiphytic species were also investigated (Mitchell et al., 2021; Fazan et al., 2022).

The lichen biota of Türkiye is very rich with a total of 2000 lichenicolous and lichenized fungi taxa (Güvenç et al., 2020). Recently, studies on epiphytic lichen vegetation have also been carried out in Türkiye (Çobanoğlu and Sevgi, 2009; Sevgi et al., 2010; Öztürk and Güvenç, 2010).

The aim of this study is to determine the differences in epiphytic lichen diversity on the base and trunk of *Quercus robur*, located next to Faculty of Agriculture in Bursa Uludağ University campus.

Material and Metod

Study area

This study was carried out in the Görükle campus area of Bursa Uludag University. Görükle campus area is located 20 km from Bursa city center in the Marmara Region. The campus has a total area of 1600 hectares, of which 691.65 hectares are forest area, 374.8 hectares are agricultural land, and 168.87 hectares are landscaped garden-woodland. The area is located between 40º23'81"-40º21'76" north latitudes and 28º88'57"-28º85'83" 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 78 lichen species have been recorded in the studies conducted in the Görükle campus area so far (Güvenç and Aslan, 1994; Oran and Öztürk, 2011; Oran, 2019).

Collection of lichen samples

This study was conducted in the base and trunk of the trees in pedunculate oak grove (Alt. 120 m, 40°13′29″N-28°51′39″E), located next to the Faculty of Agriculture in the Görükle campus area of Bursa Uludağ University on 27 December 2022. Five pedunculate oak trees (*Quercus robur* L.) were randomly selected in this area. The collection of lichen samples was carried out on both the base and trunk of the same tree.

Lichen samples were collected using the methods suggested by Asta et al. (2002). The sampling grid templates, each having five 10x10 cm contiguous quadrats were placed on the north (N), east (E), south (S) and west (W) sides both 10-15 cm above the ground of the base, and 150 cm above the ground on the tree trunk. As result, lichen samples were collected for a total of 40 subunits from each oak tree. All lichen species found in each subunit of the sample grid were recorded. The frequency of each species was calculated as the number of subunits at either base or trunk where it was present. The cover value of each species was calculated as the surface area covered by the subunits at the base or trunk. The circumference of the tree was measured 30 cm above the ground at the base and 170-180 cm above the ground at the trunk, corresponding to the middle of the sampling grid templates.

Statistical Analyses

Frequency and cover are the most commonly used parameters as a measure of the importance of taxa in epiphytic communities and habitats (Lara and Mazimpaka, 1998). Importance values of lichens were used for statistical evaluation. The importance value is as the sum of the % relative cover and % relative frequency values of each species in the sampling plots (Pirintsos et al., 1993).The cover and frequency of lichen species were calculated according to the north, south, east, west side on the base and trunk for each trees. The statistical analyses were conducted using the IBM SPSS Statistics 23 sotware. The Mann-Whitney U test was used to analyze whether the diversity of epiphytic lichens on the base and trunk of a tree was different. If the p-value is $\geq$ 0.05, there is no statistical difference between the base and trunk of a tree, or if the p-value is $<$ 0.05, the epiphytic lichen diversity is suggested to be significant different between the base and trunk of a tree. The Kruskal-Wallis H test was used to analyze whether epiphytic lichen diversity differs in different directions (north, south, east, west) on the body of a tree. If the p-value is $\geq$ 0.05, there is no statistical difference between the diversity of epiphytic lichens in different directions on the body of a tree, or if the p-value is < 0.05, a significant difference is suggested. PCA ordination diagram of the species and trees according to the base and trunk parts of the tree body was obtained using the indirect linear model with Principal Component Analysis (PCA) in CANOCO 4.5 (Ter Braak and Smilauer, 2002).

Results

In this study, a total of 22 epiphytic lichen species were determined on *Quercus robur*. While five species (*Catillaria nigroclavata* (Nyl.) J. Steiner, *Physcia aipolia* (Ehrh. ex Humb.) Fürnr., *Physconia enteroxantha* (Nyl.) Poelt, *Ramalina pollinaria* (Westr.) Ach. and *Scoliciosporum chlorococcum* (Graewe ex Stenh.) Vězda) were found only on the base of the tree, three species (*Evernia prunastri* (L.) Ach., *Parmelina tiliacea* (Hoffm.) Hale and *Physconia perisidiosa* (Erichsen) Moberg) were found only on the trunk of the tree (Table 1). *Xanthoria parietina* (L.) Th. Fr. has a highest frequency and cover value on both the base and the trunk of the tree, followed by *Physcia adscendens* H. Olivier and *Phaeophyscia orbicularis* (Neck.) Moberg, respectively. Other common species found in all sampling frames at both the trunk and base of the tree were *Athallia cerinella* (Nyl.) Arup, Frödén & Søchting, *Caloplaca cerina* (Hedw.) Th. Fr, *Lecania cyrtella* (Ach.) Th. Fr., *Lecanora chlarotera* Nyl., *Lecidella elaeochroma* (Ach.) M. Choisy and *Rinodina pyrina* (Ach.) Arnold.

When the means importance values of epiphytic lichens on the base and trunk parts of the tree are compared, there is a significant difference (Z: -2.402, p<0.05) between the base and trunk. The biggest difference between the base and trunk parts of the tree is in the south direction (Z: -2.611, p<0.01).

Table 1. Mean percent of relative frequency (RF%) and relative cover (RC%) values of epiphytic lichens on the base and trunk of *Quercus robur*

		BASE								TRUNK							
		North		South		East		West		North		South		East		West	
Species	**Abbrev.**	RF%	RC%	RF%	RC%	RF%	RC%	RF%	RC%	RF%	RC%	RF%	RC%	RF%	RC%	RF%	RC%
Athallia cerinella	Atha cer	3.33	0.15	3.23	1.07	4.44	0.44	2.22	0.40	1.18	0.13	14.51	0.56	4.00	0.71	4.89	0.41
Caloplaca cerina	Calo cer	0.67	0.06	10.67	2.09	4.67	0.82	5.33	0.50	3.53	0.26	11.76	1.00	2.35	0.19	4.71	0.45
Catillaria nigroclavata	Cati nig	-	-	-	-	-	-	1.33	0.47	-	-	-	-	-	-	-	-
Evernia prunastri	Ever pru	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.18	0.06
Lecania cyrtella	Leca cyr	3.33	0.35	4.67	0.35	0.67	0.12	6.00	1.15	1.18	0.03	3.53	0.10	-	-	8.24	0.84
Lecanora chlarotera	Leca chl	4.00	0.94	0.67	0.06	1.33	0.12	6.67	1.82	4.71	0.64	1.18	0.06	2.35	0.13	3.53	0.26
Lecidella elaeochroma	Leci ela	4.67	1.00	0.67	0.06	-	-	4.00	0.94	4.71	0.51	1.18	0.06	2.35	0.13	2.35	0.19
Melanelixia subaurifera	Mela sub	0.67	0.18	-	-	-	-	0.67	0.06	-	-	-	-	1.18	0.13	-	-
Parmelina tiliacea	Parm til	-	-	-	-	-	-	-	-	1.18	0.39	-	-	-	-	-	-
Phaeophyscia orbicularis	Phae orb	9.33	1.94	8.00	4.05	13.33	9.22	8.00	1.00	22.35	12.93	28.24	18.39	29.41	17.56	25.88	20.71
Physcia adscendens	Phys ads	13.33	6.81	12.00	4.46	9.33	7.58	12.67	6.11	18.82	8.23	21.18	3.15	15.29	3.67	24.71	3.02
Physcia aipolia	Phys aip	2.00	1.00	1.33	0.59	-	-	-	-	-	-	-	-	-	-	-	-
Physcia stellaris	Phys ste	2.67	0.59	8.00	2.06	4.00	1.23	5.33	2.35	14.12	3.99	14.12	2.57	15.29	3.15	16.47	2.89
Physconia enteroxantha	Psco ent	0.67	0.47	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Physconia perisidiosa	Psco per	-	-	-	-	-	-	-	-	-	-	2.35	0.39	-	-	-	-
Pleurosticta acetabulum	Pleua ce	0.67	0.06	-	-	0.67	0.18	-	-	-	-	1.18	0.58	-	-	-	-
Poeltonia grisea	Poel gri	-	-	0.67	0.23	1.33	0.35	-	-	-	-	-	-	1.18	0.13	-	-
Polyozosia hagenii	Polyh ag	0.67	0.06	0.67	0.03	-	-	2.00	0.15	-	-	2.35	0.10	1.18	0.03	2.35	0.06
Ramalina pollinaria	Rama pol	-	-	-	-	-	-	1.33	0.41	-	-	-	-	-	-	-	-
Rinodina pyrina	Rino pyr	2.67	0.18	8.67	1.06	4.67	0.47	6.00	0.79	4.71	0.29	7.06	0.35	2.35	0.06	7.06	0.45
Scoliciosporum chlorococcum	Scol chl	-	-	-	-	-	-	2.00	0.21	-	-	-	-	-	-	-	-
Xanthoria parietina	Xant par	16.67	83.52	16.67	45.52	16.67	51.51	16.67	76.65	29.41	87.07	28.24	61.35	28.24	62.06	29.41	89.39

Abbrev.: Abbreviation of species names

When the means importance values of epiphytic lichens in the north, south, east and west directions of the trees were compared, no significant difference was found (H: 3.209, p>0.05) (Table 2).

In the comparison of the differences between the base and trunk of the epiphytic lichen species, *Phaeophyscia orbicularis* (Z: -2.309, p<0.05), *Physcia adscendens* (Z: -2.021, p<0.05) and *Physcia stellaris* (Z: -2.309, p<0.05) were significant for the tree trunk (Table 3).

A PCA ordination diagram is provided in Figure 1. The first axis was associated with the change in epiphytic lichen diversity on trees from base to trunk of trees. The first and second axes of the PCA explained 60.2 % and

32.5 %, respectively, of the total variance in the species data. The upper left side of the first axis represents the trunk of the trees, and the lower central side represents the base of the trees. On the upper and lower left side of the first axis, there are trees with high epiphytic lichen diversity on the trunk, and there are trees with low lichen diversity in the center. On the contrary, trees with high diversity at the base are located in the lower right, and those with low diversity are located in the central right. The diversity of epiphytic lichens on the base (1) and trunk (6) of a tree is similar. Lichen diversity differs only on the southern side of the tree. Therefore, numbers 1 and 6 are side by side in the ordination diagram of PCA. Similarly, the diversity of epiphytic lichens found at the base (5) and trunk (10) of tree is quite similar. The importance values of epiphytic lichen species on the trunk of the tree are higher than those at the base (Table 2). For this reason, samples 5 and 10 are distributed to each other in PCA ordination. The species with the highest importance are *Xanthoria parietina, Phaeophyscia orbicularis, Physcia adscendens* and *Physcia stellaris,* respectively. These are followed by *Caloplaca cerina, Rinodina pyrina, Athallia cerinella, Lecania cyrtella, Lecanora chlarotera* and *Lecidella elaeochroma*, respectively. *Phaeophyscia orbicularis, Physcia adscendens* and *Physcia stellaris* show significant differences between the base and trunk of the trees. These species have significant differences for the trunk of the tree. Species with high importance values are located in the upper and lower left parts of the second axis of the PCA orientation, and those with lower values are located in the right central parts of the second axis (Table 3, Figure 1).

In our study, the most common species collected from all sample squares on *Quercus robur* are *Athallia cerinella, Caloplaca cerina, Lecanora chlarotera, Phaeophyscia orbicularis, Physcia adscendens, Physcia stellaris, Rinodina pyrina* and *Xanthoria parietina*. Eight of the 22 epiphytic lichen species in this study belong to the Physciaceae family.

Due to intensive fertilization in the agricultural areas of the Faculty of Agriculture, nitrophilous species such as *Lecanora chlarotera, Parmelia sulcata, Parmelina tiliacea, Phaeophyscia orbicularis, Physcia adscendens, Physcia stellaris, Physcia tenella, Pleurosticta acetabulum*, *Polyozosia hagenii* and *Xanthoria parietina* were frequently encountered on trees (Oran, 2019).

Table 2. Comparison of means ± standart deviation (SD) of importance value of epiphytic lichen diversity according to the base and trunk parts of the trees and the direction (North, South, East and West) of the body of the tree.

Trees		Circumference of tree (cm)	Richness Number	Richness Means	North	South	East	West	Means	Kruskal-Wallis H	df	p-value
BASE	1	100	15	9.75	9.09±20.04	6.45±10.49	6.21±14.75	10.21±13.36	7.99±1.98	3.503	3	0.320
	2	108	9	5.25	6.73±21.74	6.43±13.90	3.94±10.80	7.19±28.99	6.07±1.46			
	3	132	9	4.75	5.76±19.19	3.88±7.98	4.02±10.07	6.58±19.40	5.06±1.32			
	4	98	10	6.25	7.41±23.65	6.95±21.16	7.61±20.65	7.00±22.81	7.25±0.32			
	5	93	12	8.25	7.97±23.84	7.54±19.32	8.48±28.65	8.38±17.39	8.09±0.43			
	Means±SD	N=5	**11±2.55**	**6.85±2.10**	**7.39±1.26**	**6.25±1.40**	**6.05±2.06**	**7.87±1.47**	**6.89±1.64**			
TRUNK	6	84	12	8.50	9.09±22.86	14.33±20.16	8.98±17.50	11.57±22.95	10.99±0.88	3.206	3	0.361
	7	92	8	4.75	7.70±24.53	9.41±19.11	8.49±19.34	11.91±35.53	9.38±0.35			
	8	118	7	4.75	10.46±27.54	7.87±18.47	4.70±13.80	9.33±22.48	8.09±2.53			
	9	88	5	4.25	10.22±30.61	9.39±25.85	10.35±32.18	10.35±26.35	10.08±1.83			
	10	80	12	7.75	12.61±28.56	10.26±30.50	11.37±31.52	13.55±31.28	11.95±2.50			
	Means±SD	N=5	**8.8±3.11**	**6±1.97**	**10.02±1.82**	**10.25±2.44**	**8.78±2.55**	**11.34±1.60**	**10.10±2.18**			
Means±SD		N=10	**9.9±2.92**	**6.43±1.97**	**8.70±2.02**	**8.25±2.82**	**7.42±2.61**	**9.61±2.33**	**8.49±2.50**	3.209	3	0.360
Mann-Whitney U					2.500	.000	3.000	1.000	1.000			
Z					-2.095	-2.611	-1.984	-2.402	-2.402			
p-value					**0.036**	**0.009**	**0.047**	**0.016**	**0.016**			

Table 3. Comparison of means ± standard deviation of importance value of epiphytic lichen species according to the base and trunk parts of the trees (Mann-Whitney U test) and the direction (North, South, East and West) of the body of the tree (Kruskal-Wallis H test).

Species	BASE				TRUNK				Mann-Whitney U	Z	p-value	Kruskal-Wallis H	df	p-value
	North	South	East	West	North	South	East	West						
Athallia cerinella	3.48	4.30	4.88	2.63	1.31	15.07	4.71	5.30	5.000	-0.866	0.386	3.167	3	0.367
Caloplaca cerina	0.73	12.75	5.49	5.83	3.79	12.76	2.55	5.16	7.000	-0.289	0.773	5.500	3	0.139
Catillaria nigroclavata	-	-	-	1.80	-	-	-	-	6.000	-1.000	0.317	3.000	3	0.392
Evernia prunastri	-	-	-	-	-	-	-	1.24	6.000	-1.000	0.317	3.000	3	0.392
Lecania cyrtella	3.69	5.02	0.78	7.15	1.21	3.63	-	9.07	6.000	-0.577	0.564	6.167	3	0.104
Lecanora chlarotera	4.94	0.73	1.45	8.49	5.35	1.24	2.48	3.79	8.000	0.000	1.000	6.000	3	0.112
Lecidella elaeochroma	5.67	0.73	-	4.94	5.22	1.24	2.48	2.55	7.000	-0.289	0.773	6.000	3	0.112
Melanelixia subaurifera	0.84	-	-	0.73	-	-	1.31	-	7.000	-0.331	0.741	1.531	3	0.675
Parmelina tiliacea	-	-	-	-	1.56	-	-	-	6.000	-1.000	0.317	3.000	3	0.392
Phaeophyscia orbicularis	11.27	12.05	22.56	9.00	35.28	46.63	46.97	46.59	**0.000**	**-2.309**	**0.021**	1.500	3	0.682
Physcia adscendens	20.15	16.46	16.91	18.78	27.06	24.33	18.96	27.73	**1.000**	**-2.021**	**0.043**	2.167	3	0.539
Physcia aipolia	3.00	1.92	-	-	-	-	-	-	4.000	-1.512	0.131	2.357	3	0.502
Physcia stellaris	3.25	10.06	5.23	7.68	18.10	16.69	18.45	19.36	**0.000**	**-2.309**	**0.021**	3.000	3	0.392
Physconia enteroxantha	1.14	-	-	-	-	-	-	-	6.000	-1.000	0.317	0.667	3	0.881
Physconia perisidiosa	-	-	-	-	-	2.74	-	-	6.000	-1.000	0.317	3.000	3	0.392
Pleurosticta acetabulum	0.73	-	0.84	-	-	1.76	-	-	7.000	-0.331	0.741	1.531	3	0.675
Poeltonia grisea	-	0.90	1.69	-	-	-	1.31	-	6.000	-0.661	0.508	5.906	3	0.116
Polyozosia hagenii	0.73	0.70	-	2.15	-	2.45	1.21	2.42	4.500	-1.016	0.309	3.247	3	0.355
Ramalina pollinaria	-	-	-	1.74	-	-	-	-	6.000	-1.000	0.317	3.000	3	0.392
Rinodina pyrina	2.84	9.72	5.14	6.79	5.00	7.41	2.42	7.51	7.000	-0.289	0.773	5.500	3	0.139
Scoliciosporum chlorococcum	-	-	-	2.21	-	-	-	-	6.000	-1.000	0.317	3.000	3	0.392
Xanthoria parietina	100.19	62.19	68.18	93.32	116.49	89.59	90.29	118.80	4.000	-1.155	0.248	5.500	3	0.139

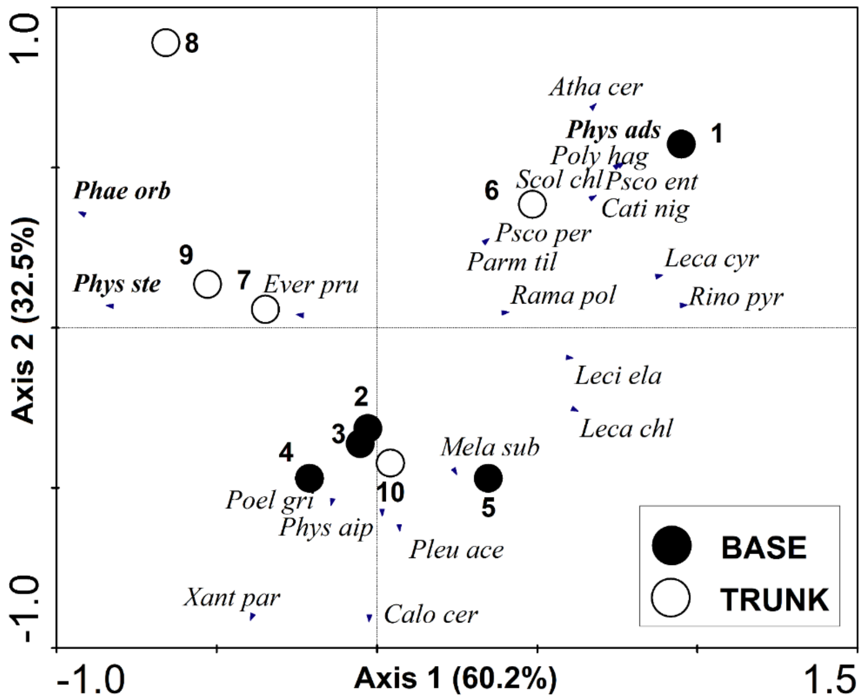

Figure 1. PCA Ordination diagram of the species and trees according to the base and trunk parts of the tree body.

Discussions

The area chosen as the study area in this study is under the influence of anthropogenic and agricultural activities in and around the settlement. We found that the richness (number of species) (R^2=0.7835) were significantly increased from the base to trunk of *Quercus robur* (Figure 2). The circumference of the tree was measured 30 cm above the ground at the base and 150 cm above the ground at the trunk, corresponding to the middle of the sampling grid templates.

The average number of species was found to be less in the lower part of the tree than in the upper parts (Muchnik and Blagoveschenskaya, 2022). It was determined that species richness increased from the lowest parts to the highest parts of the tree (Castillo-Campos et al. 2019). These results are similar to our results.

Epiphytic lichen diversity varies depending on the tree species (Öztürk and Güvenç, 2010; Sevgi et al., 2010), age (Fazan et al., 2022), bark and site characteristics (Mitchell et al., 2021). It has been determined that the community structure of epiphytic lichen vegetation varies according to the characteristics of the sampling areas (elevation, aspect, slope, tree diameter classes and stand type) (Çobanoğlu and Sevgi, 2009).

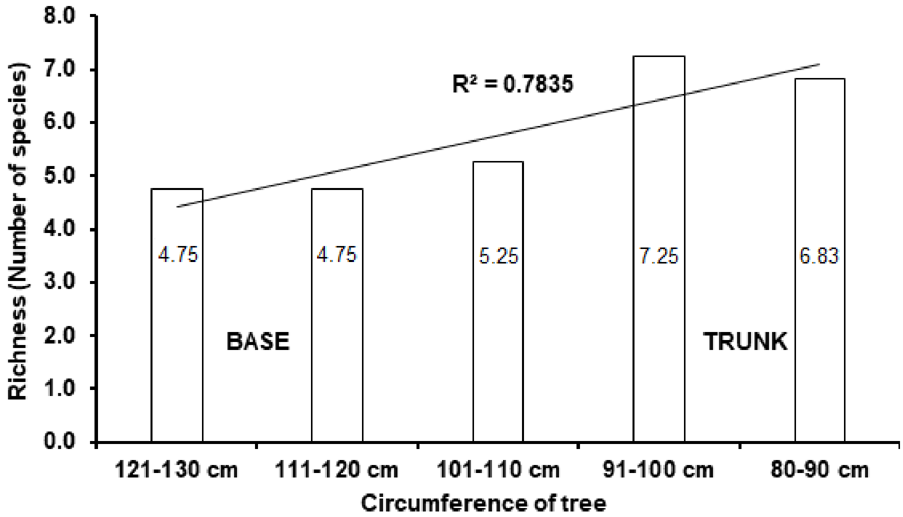

Figure 2. The relationship between species richness and trunk circumference thickness from the base to the trunk of the tree.

Epiphytic lichen diversity in host *Quercus* trees in London city parks has been shown to decrease significantly with increasing tree size. The community structure of epiphytic lichens on these oak trees was characterized by the *Physcietum adscendens* association within the alliance of *Xanthorion parietinae*. *Physcietum adscendens* consists of species adapted to nutrient-enriched substrates and high light intensities (Llewellyn et al., 2020). *Lecidella elaeochroma, Physcia adscendens* and *Xanthoria parietina* were the most abundant on oak trees in the vicinity of agricultural areas and settlements (Garrido-Benavent et al., 2015; Wolseley et al., 2006). According to Filippini et al. (2020), the frequency of the species belonging to the Physciaceae family on the trees increase with the increase in cultivated areas. *Phaeophyscia orbicularis, Physcia adscendens, P. aipolia, P. stellaris, Physconia enteroxantha, P. perisidiosa, Poeltonia grisea* and *Rinodina pyrina* species belonging to the Physciacea family were detected on *Quercus robur*. Of those, *Phaeophyscia orbicularis, P. adscendens, P. stellaris* and *Rinodina pyrina* were found in high frequency at the base and trunk of all sampling trees. This result is consistent with the results of Filippini et al. (2020). As result, our findings shows to be compatible with many source information in terms of characteristic species and association characteristic for *Querus*.

Author Contributions

All authors have equal contribution.

Conflict of Interest

The authors declare no conflict of interest.

Ethical Statement: It is declared that scientific and ethical principles have been followed while carrying out and writing this study and that all the sources used have been properly cited (Şule ÖZTÜRK, Şaban GÜVENÇ, Seyhan ORAN, Abdoulaye YENDE).

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