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DIFFERENCE IN EPIPHYTIC LICHEN COMMUNITIES ON *QUERCUS CERRIS* FROM URBAN AND RURAL AREAS IN BURSA (TURKEY)

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Abstract

Sixty epiphytic lichen species were identified in seven localities from urban and rural areas in Bursa province. *Amandinea punctata, Hyperphyscia adglutinata, Opegrapha herbarum,* and *Parmelia sulcata* commonly found in areas with intensive anthropogenic influence were determined to be indicators of urban areas. *Pleurosticta acetabulum* and *Pseudevernia furfuracea* were determined to be indicators of rural areas. The species diversity and composition of the epiphytic lichens on *Quercus cerris* varied depending on the effects of macroclimatic and microclimatic factors, anthropogenic and agricultural activities.

Key words: Bursa, *Quercus cerris*, Epiphytic lichen, Lichen diversity, Lichen composition.

Introduction

Epiphytic lichens are used as bioindicators for the determination and monitoring of air pollution. Lichens are extremely sensitive to environmental stress and especially atmospheric pollutants. Several studies have emphasized that the species diversity of epiphytic lichens has significantly decreased in urban areas and in roadside habitats. These studies have also noted that the species composition in these areas is also extensively altered.

Lichen diversity and species composition varies according to the structural diversity of the area, such as different tree species, age and viability of trees, and microclimate (Nascimbene & Marini, 2010; Öztürk & Güvenç, 2010; Hauck, 2011; Nascimbene *et al.*, 2014; Orhan *et al.*, 2016). The development of epiphytic lichens depends on the structural and chemical properties of the bark of trees (Spribille *et al.*, 2008; Moning *et al.*, 2009).

Epiphytic lichen vegetation is strongly affected by altered microclimate, resulting from changes in forest structure (Johansson, 2008; Aragon *et al.*, 2010a) and anthropogenic impacts on forest ecosystems (Aragon *et al.*, 2010b; Svoboda *et al.*, 2010; Matwiejuk, 2016). In open areas, eutrophication caused by dust particles is one of the main causes of the rise in bark pH of *Quercus* sp. affecting epiphytic lichens (Pinhno *et al.*, 2008; Spier *et al.*, 2010).

Lichens have been known to be sensitive to air pollution since 1865, and today lichens have become one of the most widely used bioindicators of air pollution (Nimis *et al.*, 2002). Since the 1970s, lichens have been used as an indicator of sulfur dioxide (SO_2) pollution (Hawksworth & Rose, 1970). The composition of epiphytic lichen communities have also been shown to significantly correlate with concentrations of NO_2 and NH_3 (Wolseley *et al.*, 2006; Larsen *et al.*, 2007; Gadsdon *et al.*, 2010).

The aim of this study was to determine the difference of species diversity and the composition of epiphytic lichens on *Quercus cerris* in rural and urban areas and the relationship between species diversity and different macroclimatic and microclimatic factors.

Materials and Methods

The study area: This study was conducted at seven localities in urban and rural areas in Bursa province. The city of Bursa is located between 39°30'-40°37'N and 28°06'-29°58'E in the southeast of the Marmara region of Turkey. Bursa is usually dominated by a Mediterranean climate and is a transitional region between Mediterranean climate and the Black Sea climate (Öztürk, 2010).

The mean annual temperature (1975-2005) in Bursa (Alt. 155 m) is 14.5°C, the mean annual rainfall is 681.3 mm, temperature (1987-2000; 2007-2012) at Mudanya (Alt. 13 m) is 16.7°C, rainfall is 614 mm, at Karacabey (Alt. 15 m) is 14.7°C, 585.1 mm, at Büyükorhan (Alt. 1000 m) 10.3°C, 758 mm, and at Orhaneli (Alt. 484 m) 12.5°C, and 655 mm respectively (Anonymous, 2012).

Collection of samples: The study was conducted on *Quercus cerris*. *Quercus cerris* is distributed up to 1900 m above sea level in Western Turkey (Öztürk, 2013).

Sampling in urban areas was conducted at a total of 4 localities, including 2 localities in Mudanya district and 2 localities in Karacabey district in the Marmara sea coast of Bursa province. Sampling in rural areas was conducted at one locality at Büyükorhan and two localities at Orhaneli in Bursa (Table 1). Macroclimate (mean annual temperature, mean annual rainfall, altitude, exposition of the localities) and microclimate (mean tree diameter, exposition of the tree trunk) as environmental variable components that were noted in each of the localities.

Sampling was performed on 21 trees in total, including three trees at each of seven different localities. Epiphytic lichen samples on the trunk of *Quercus cerris* were collected using the methods specified by Asta *et al.* (2002).

Statistical analysis: The data matrix of 60 species × 84 samples and relative frequency values (%) of lichens were used for statistical evaluation. A one-way analysis of variance (ANOVA) with a Tukey test was used to test whether there is a difference in epiphytic lichen diversity on *Quercus cerris* between urban and rural areas. Standard statistical analyses were performed using SPSS for Windows (Version 22). In all tests, the level of significance was $p \leq 0.05$. The ordination graphs of species diversity and species composition at the urban and rural localities were obtained with a detrended correspondence analysis (DCA). The relationship between environmental variables and epiphytic lichens in the localities were obtained with a canonical correspondence analysis (CCA), using the CANOCO 4.5 package (Ter Braak, 1995). Indicator species analysis was conducted with TWINSPAN for Windows Version 2.3 (Hill & Šmilauer, 2005).

Table 1. Data on environmental variables at the localities where the lichen samples were collected.

	Localities						
	1	2	3	4	5	6	7
Districts	**Karacabey**	**Karacabey**	**Mudanya**	**Mudanya**	**Orhaneli**	**Orhaneli**	**Büyükorhan**
Village	Boğazköy	Bayramdere	Esence	Çepni	Kadıköy	Karaoğlan	Central
Latitude	40°21'45"N	40°23'35"N	40°20'22"N	40°20'15"N	39°48'18"N	39°50'43"N	39°47'27"N
Longitude	28°26'10"E	28°22'31"E	28°40'42"E	28°50'25"E	28°59'45"E	28°59'15"E	28°54'45"E
Sampling date	14.08.2014	14.08.2014	23.10.2014	07.11.2014	29.09.2014	29.09.2014	20.04.2015
Altitude(m)	21	40	140	290	882	744	717
Mean annual temperature (C°)	14.7	14.7	16.7	16.7	10.3	12.5	10.3
Mean annual rainfall (mm^3)	585.1	585.1	614	614	758	655	758
Distance from sea (km)	3.5	0.5	2.5	5.0	60	56	62
Direction of the localities	N	N	SE	N	SW	SW	N
Management status of localities	Area which is covered with oak, 100 meters from the road	Area which is covered with oak near to Picnic area	Open areas where intensive agricultural activities	Area which is covered with old oak in cemetery	Open areas where intensive agricultural activities, 10 meters from the road	Area which is covered with oak, 20 meters from the road	Area which is covered with oak in the roadside near the dam
Mean circumference of tree trunks (cm)	99.00 ± 5.59	130.00 ± 30.75	91.67 ± 7.74	123.67 ± 8.75	94.67 ± 8.96	113.33 ± 2.61	112.67 ± 18.71
Direction of the tree trunk	NSEW	NSEW	NSEW	NSEW	NSEW	NSEW	NSEW

A data matrix with an equal weight distribution of the species at the localities was used with various cut levels (0, 4, 7, 11, 16). The relationship between lichen species composition at the locality level and environmental variables was determined by a Monte Carlo permutation test (1000 permutations).

Results

Sixty epiphytic lichen species was recorded (Table 2). *Lecanora chlarotera* the most common was followed in both urban and rural areas by *Lecidella elaeochroma* and *Physcia adscendens* (19 trees), *Parmelia sulcata* (17), *Eopyrenula leucoplaca* (15), *Lecanora carpinea* (14), *Lepraria incana*, *Melanohalea elegantula* and *Rinodina exigua* (13), *Caloplaca holocarpa*, *Evernia prunastri* and *Pleurosticta acetabulum* (12), *Hyperphyscia adglutinata*, *Opegrapha herbarum* and *Physcia aipolia* (11), *Physconia enteroxantha* and *Ramalina fraxinea* (10).

The species restricted to urban areas are *Alyxoria varia*, *Amandinea punctata*, *Bactrospora corticola*, *Buellia griseovirens*, *Candelaria concolor*, *Lepraria lobificans*, *Pertusaria albescens*, *P. leioplaca*, *Phlyctis agelaea*, *P. argena*, *Physconia grisea* and *Scoliciosporum umbrinum*. The species collected only from rural areas are *Anaptychia ciliaris*, *Buellia disciformis*, *Caloplaca haematites*, *Candelariella vitellina*, *Cliostomum griffithii*, *Hypogymnia farinacea*, *H. tubulosa*, *Lecanora subcarpinea*, *Melanelia subaurifera*, *Melanelixia glabratula*, *Melanohalea exasperata*, *Parmelina carporrhizans*, *P. pastillifera*, *Pertusaria flavida*, *Physconia distorta*, *Platismatia glauca*, *Pseudevernia furfuracea*, *Ramalina canariensis*, *R. fastigiata*, *Rinodina sophodes*, *Strangospora moriformis*, *Usnea filipendula* and *U. hirta*.

Differences in the species diversity and composition of the epiphytic lichens on *Quercus cerris* in urban and rural areas were evaluated using the TWINSPAN program. The epiphytic lichens are divided into four groups according to the results of a two way indicator species analysis (Fig. 1). Group I and II consists of the localities in urban areas, while Group III and IV consists of the localities in rural areas.

Localities are divided into two groups in urban and rural areas at the first level. *Amandinea punctata* is the indicator species of urban localities, and *Pleurosticta acetabulum* and *Pseudevernia furfuracea* are indicator species of rural localities. At the second level, Group I is located near a picnic area with indicator species, such as *Opegrapha herbarum*, at Karacabey district. Group II, another group of urban areas, consists of localities in the area of agricultural land and roadside habitat in Karacabey and Mudanya districts. *Amandinea punctata*, *Hyperphyscia adglutinata* and *Parmelia sulcata* are indicator species of this group. Localities that were located close to the roadside and to agricultural land in the Orhaneli district in rural areas harbored species of Group III. The most common indicator species of this group was *Lecanora carpinea*. Group IV is located in roadside habitat near the Büyükorhan dam.

Table 2. Mean ± Standard deviation (SD) of the relative frequency of epiphytic lichen species from rural and urban areas.

Species	Abbrev.	*F*	Localities							ANOVA
			1	2	3	4	5	6	7	Sig.
Group-I										
Alyxoria varia	Alyx var	1		5.78 ± 13.65						**0.050**
Bactrospora corticola	Bact cor	3		1.88 ± 3.53	0.79 ± 2.74	0.73 ± 2.54				**0.015**
Lepraria lobificans	Lepr lob	3	0.38 ± 1.30	13.49 ± 13.51						**0.000**
Opegrapha herbarum	Opeg her	11	2.84 ± 3.29	19.10 ± 13.84	1.04 ± 2.08	1.56 ± 3.00			1.18 ± 2.78	**0.000**
Phlyctis argena	Phly arg	5		3.29 ± 6.40		1.98 ± 3.15				**0.012**
Group-II										
Amandinea punctata	Aman pun	9	10.63 ± 7.11		6.71 ± 4.06	7.09 ± 6.72				**0.000**
Lepraria incana	Lepr inc	13	7.05 ± 6.28	4.27 ± 8.20	6.85 ± 5.84	4.93 ± 7.03	0.15 ± 0.52	0.27 ± 0.92		**0.001**
Parmelia sulcata	Parm sul	17	1.83 ± 3.40		10.03 ± 5.25	6.36 ± 8.36	7.60 ± 3.67	6.50 ± 5.60	11.00 ± 4.27	**0.000**
Pertusaria leioplaca	Pert lei	3	1.63 ± 2.81							**0.002**
Scoliciosporum umbrinum	Scol umb	10	4.68 ± 3.77	0.56 ± 1.93	15.42 ± 6.22	1.38±2.74				**0.000**
Group-III										
Caloplaca holocarpa	Calo hol	12	0.38 ± 0.88		0.40 ± 1.39		6.43 ± 3.63	1.92 ± 2.61	1.15 ± 1.54	**0.000**
Hypogymnia farinacea	Hypo far	7					6.68 ± 4.13	4.71 ± 5.46	1.42 ± 3.72	**0.000**
Melanohalea exasperatula	Mela ula	4				3.13±4.45			0.57 ± 1.40	**0.000**
Parmelina carporrhizans	Parm car	4					5.28±5.74	0.24 ± 0.84		**0.000**
Physcia aipolia	Phys aip	11	0.83 ± 1.55		0.53 ± 1.82	0.63±1.48	4.72±4.31	1.08 ± 1.69		**0.000**
Physconia enteroxantha	Phyc ent	10				7.68±8.30	0.17±0.58	4.56 ± 6.05	2.39 ± 3.37	**0.000**
Pleurosticta acetabulum	Pleu ace	12	0.38 ± 1.30			0.60±1.40	8.95±2.79	12.20 ± 2.85	4.47 ± 3.82	**0.000**
Ramalina fastigiata	Rama fas	2						1.54 ± 2.55		**0.001**
Ramalina fraxinea	Rama fra	10			2.28 ± 3.80		3.02±2.98	3.43 ± 2.91	1.56 ± 3.12	**0.001**
Rinodina sophodes	Rino sop	5					9.45±4.05	1.42 ± 2.19		**0.000**
Xanthoria parietina	Xant par	9	0.57 ± 1.03		0.18 ± 0.64	1.05±1.92	2.37±2.70	3.60 ± 5.00	0.19 ± 0.66	**0.001**
Group-IV										
Buellia disciformis	Buel dis	5						0.43 ± 1.01	4.38 ± 3.51	**0.000**
Cliostomum griffithii	Clio gri	3							6.00 ± 4.72	**0.000**
Hypogymnia physodes	Hypo phy	7			0.61 ± 1.43	0.18±0.61	0.20±0.69	0.24 ± 0.84	3.37 ± 4.75	**0.000**
Hypogymnia tubulosa	Hypo tub	2							2.08 ± 3.12	**0.000**
Lecanora subcarpinea	Leca sub	3							6.68 ± 6.03	**0.000**
Melanelixia glabratula	Mela gla	6					0.34±1.18	0.47 ± 1.10	5.03 ± 3.89	**0.000**
Melanohalea exasperata	Mela ata	5						1.10 ± 2.40	0.74 ± 1.38	**0.040**
Parmelina pastillifera	Parm pas	2						2.63 ± 5.53		**0.019**
Parmelina tiliacea	Parm til	9				0.57±1.33		0.23 ± 0.78	1.19 ± 2.39	**0.050**

Table 2. (Cont'd.).

Species	Abbrev.	*F*	Localities							ANOVA
			1	2	3	4	5	6	7	Sig.
Pseudevernia furfuracea	Pseu fur	5					7.02 ± 4.28	4.95 ± 4.89	4.97 ± 5.00	**0.000**
Ramalina farinacea	Rama far	8				1.15 ± 2.01	0.35 ± 0.82	0.22 ± 0.75	4.53 ± 3.83	**0.000**
Usnea hirta	Usne hir	2							0.78 ± 1.55	**0.011**
Common species										
Eopyrenula leucoplaca	Eopy leu	15	11.23 ± 4.64	21.54 ± 11.20		8.23 ± 5.30		5.49 ± 5.24	5.63 ± 4.74	**0.000**
Evernia prunastri	Ever pru	12	1.43 ± 2.42		8.53 ± 5.40		6.68 ± 5.15	2.89 ± 3.45	11.9 3 ±3.75	**0.000**
Hyperphyscia adglutinata	Hype adg	11	10.64 ± 4.77		3.24 ± 8.96	7.19 ± 6.66	0.67 ± 2.31	3.43 ± 5.64		**0.000**
Lecanora carpinea	Leca car	14	3.84 ± 6.49	0.49 ± 1.70	0.68 ± 1.61	10.99 ± 4.97	10.69 ± 2.09	7.66 ± 3.63		**0.000**
Lecanora chlarotera	Laca chl	21	9.88 ± 4.60	9.63 ± 9.33	2.03 ± 1.86	4.13 ± 3.13	7.50 ± 3.85	10.78 ± 4.50	4.41 ± 3.44	**0.000**
Lecidella elaeochroma	Leci ela	19	9.48 ± 4.94	10.52 ± 9.22	10.47 ± 4.44	15.16 ± 4.05	0.83 ± 1.34	12.32 ± 2.31	5.75 ± 3.93	**0.000**
Melanohalea elegantula	Mela ele	13	1.82 ± 2.56	0.56 ± 1.93	13.52 ± 6.54	1.28 ± 2.63	2.84 ± 2.97	1.13 ± 1.88	0.82 ± 2.83	**0.000**
Physcia adscendens	Phys ads	19	11.23 ± 4.77	4.47 ± 4.63	13.35 ± 6.15	9.53 ± 6.98	6.61 ± 7.53	1.63 ± 2.61	0.85 ± 2.32	**0.000**
Rinodina exigua	Rino exe	13	7.33 ± 4.22	0.98 ± 2.31	2.64 ± 2.88	0.46 ± 1.09			2.33 ± 3.86	**0.000**
Rare species										
Anaptychia ciliaris	Anap cil	1						0.24 ± 0.32		0.432
Buellia griseovirens	Buel gri	4		1.44 ± 3.97		0.77 ± 2.08		0.19 ± 0.66	0.38 ± 1.30	0.372
Caloplaca haematites	Calo hae	2						1.08 ± 2.54		0.054
Candelaria concolor	Cand con	2				1.51 ± 4.02				0.135
Candelariella vitellina	Cand vit	2						0.44 ± 1.53	1.07 ± 2.09	0.062
Lecanora circumborealis	Leca cir	2	0.58 ± 1.47					0.23 ± 0.78		0.188
Lecanora symmicta	Leca sym	5	0.70 ± 1.29			1.03 ± 2.40			0.19 ± 0.66	0.095
Melanelia subaurifera	Mela sub	1							0.75 ± 2.01	0.138
Parmelina quercina	Parm que	2	0.38 ± 0.90	0.90	0.67 ± 2.31		0.55 ± 1.37			0.483
Pertusaria albescens	Pert alb	2				0.68 ± 1.64				0.065
Pertusaria flavida	Pert fla	1							0.18 ± 0.61	0.432
Phlyctis agelaea	Phly age	1		2.06 ± 4.84						0.055
Physconia distorta	Phyc dis	1						0.49 ± 1.70		0.432
Physconia grisea	Phyc gri	1	0.22 ± 0.75							0.432
Platismatia glauca	Plat gla	3					0.18 ± 0.64		0.69 ± 1.63	0.103
Ramalina canariensis	Rama can	3					0.55 ± 1.37	0.24 ± 0.84	0.19 ± 0.66	0.312
Strangospora moriformis	Stra mor	1							1.21 ± 3.02	0.089
Usnea filipendula	Usne fil	1					0.17 ± 0.58			0.432

The results were obtained by one-way ANOVA (n=12, df=6), and groups resulted from TWINSPAN.

Abbrev.: The abbreviations of the species name. ***F***: Frequency

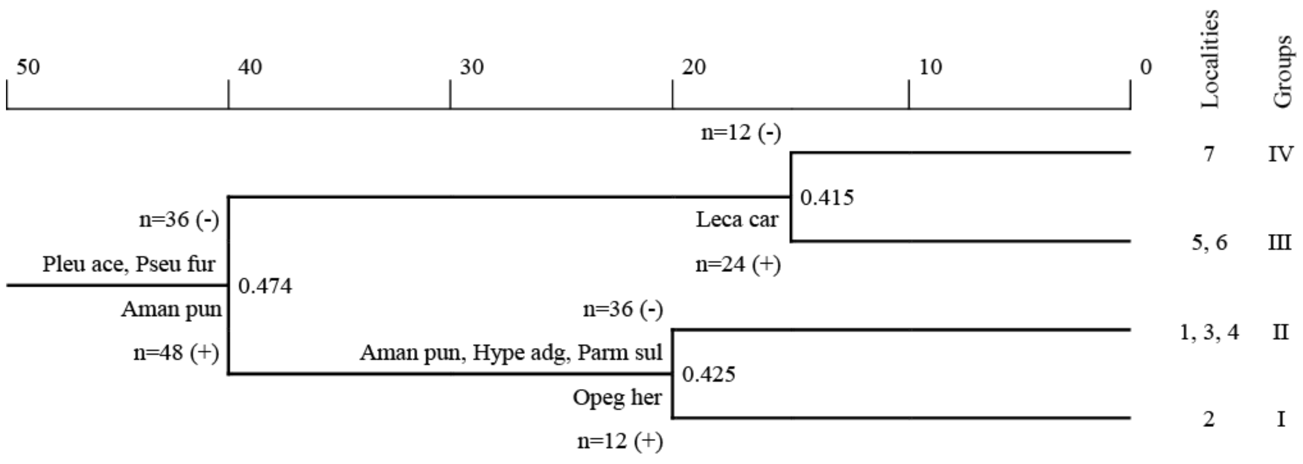

Fig. 1. Dendogram of Twinspan analysis of 84 quadrat segments placed on the north, south, east and west side on the trunk of *Q. cerris*.

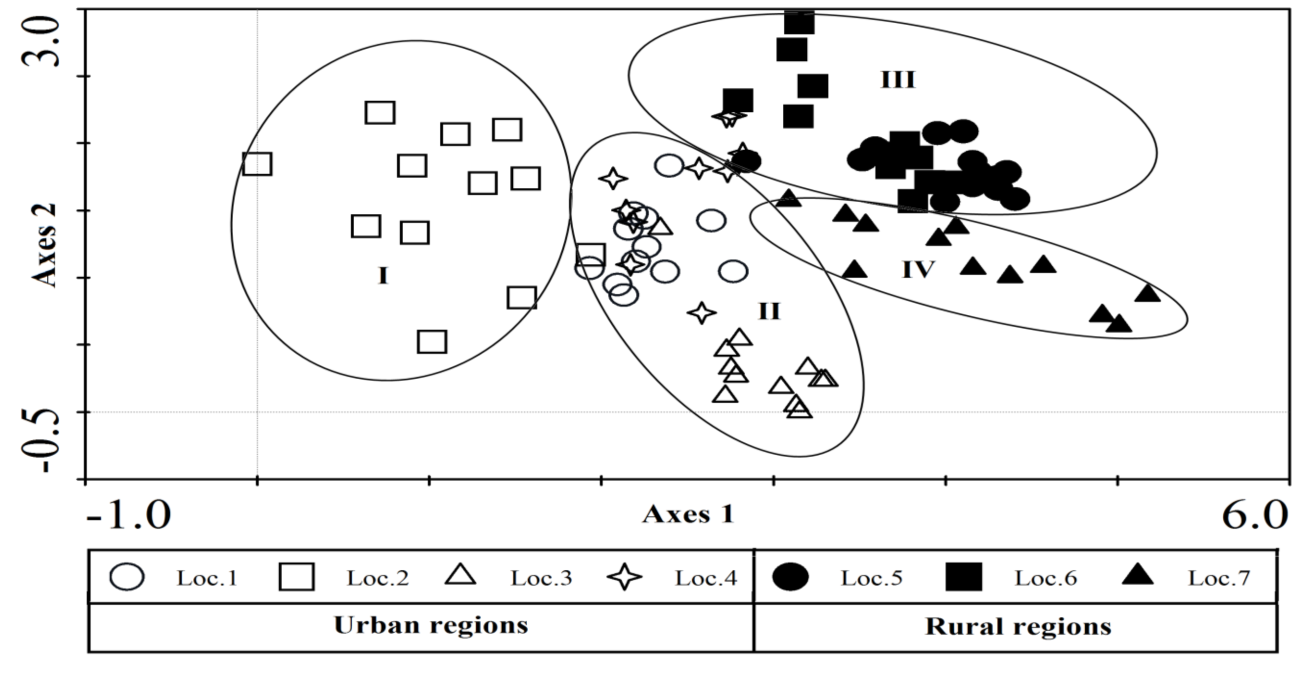

Fig. 2. DCA ordination of 84 quadrat segments placed on the north, east, south and west sides on the trunk of *Q. cerris* from rural and urban regions. Total inertia in species data: 4.59. Eigenvalues: 0.59 (axis 1), 0.29 (axis 2). Length of gradient: 5.17 (axis 1), 2.90 (axis 2). Cumulative percentage variance of species data: 12.9 (axis 1), 19.3 (axis 2).

The DCA analysis results of changes in urban and rural localities of species diversity and composition are shown in Fig. 2. Cumulative percentage variance of species data is 12.9 for axis 1 and 19.3 for axis 2. Together, both axes are 32.2. According to the results of the DCA analysis, the localities are divided into four groups, as was done in the TWINSPAN analysis. The four groups resulting from the ordination of the DCA analysis of the species are identical to the groups resulting from the TWINSPAN analysis and are shown in Table 2.

There is a significant correlation in the relationship between lichen species composition and environmental variables. According to the results of Monte Carlo permutation tests, all of the selected macroclimate and microclimate factors, except for rainfall, are significant at the 0.05 level (Table 3). Altitude was the most important variable, followed by temperature, circumference of the tree trunk and management status of localities.

In the CCA ordination (Fig. 3), the two axes represented 81.7 % of the total variation in the species-environmental relationship (30.3 % axis 1 and 51.4 % axis 2). Species in urban areas are located on the right part of the first axis, while species in rural areas are located on the left part of the first axis of the CCA ordination plot. From the groups listed in Table 1, the first group is located in the upper right, and the second group is located in the lower right of the CCA ordination. The third and fourth groups are located in the lower and upper regions of the left side of the CCA ordination, respectively. The species in the first group show a positive correlation with the circumference of the tree trunk, while the second group shows a positive correlation with temperature and management status at these localities. Species of Group III and IV have a positive correlation with altitude, rainfall and direction of the tree trunk (Fig. 3).

Table 3. Results of Monte Carlo permutation tests of the environmental variables.

Environmental variables	Axes1	Axes2	Eigenvalue	F	Sig.
Altitude	-0,8659	0,3076	0,48	9,61	0,001
Temperature	0,6785	-0,5778	0,41	5,75	0,001
Mean circumference of tree trunks	0,4593	0,3935	0,26	5,69	0,001
Management status of localities	0,0972	-0,4301	0,16	5,25	0,001
Localities	-0,7967	0,4356	0,43	5,24	0,001
Direction of the tree trunk	-0,4810	0,1722	0,27	3,58	0,001
Direction of the localities	-0,3146	-0,5160	0,25	3,42	0,001
Rainfall	-0,8476	0,3997	0,46	1,34	0,083
R(SPEC,ENV)	0,9629	0,9418	4,59	1.77	0.001

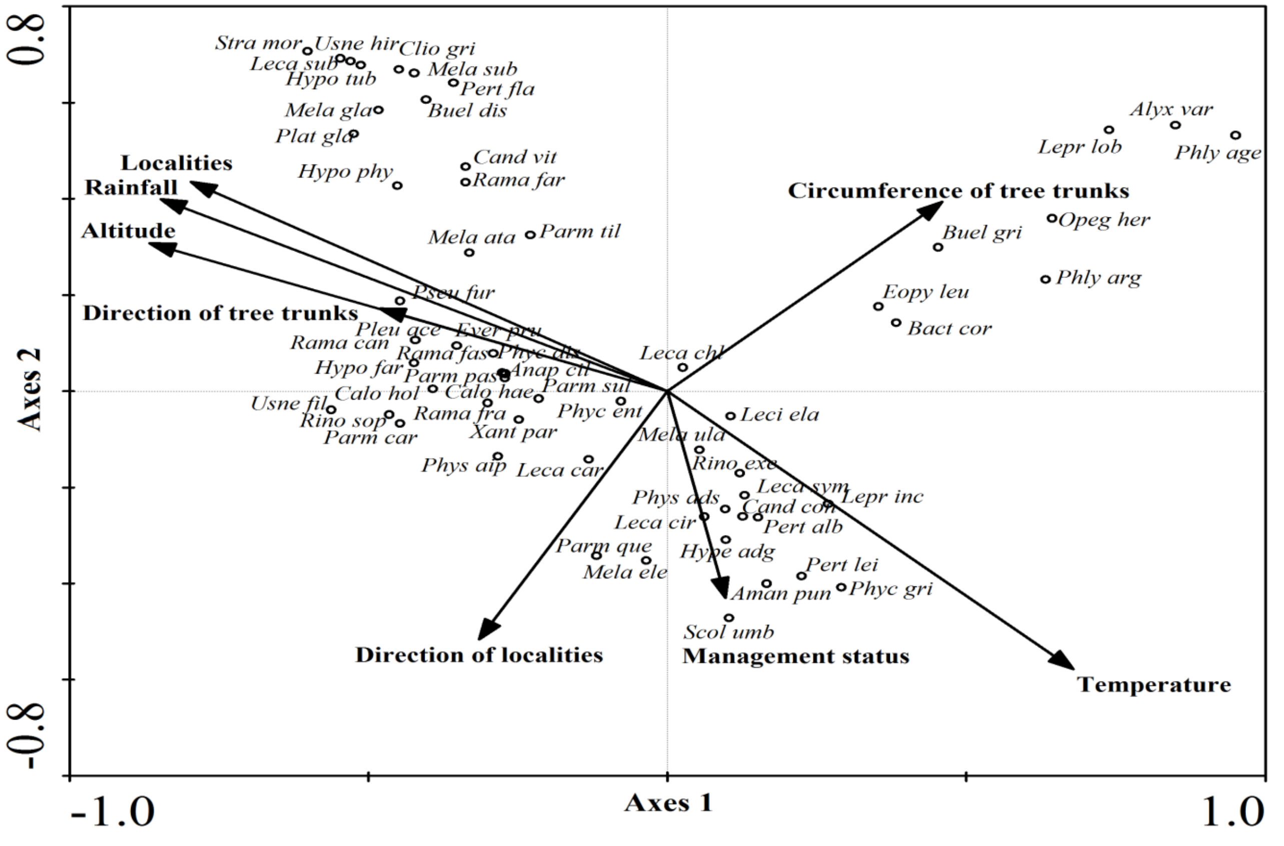

Fig. 3. Canonical correspondence analysis (CCA) of lichen species and environment variables biplot. Species abbreviations are provided in Table 2.

Discussion

The abundances of 18 species were influenced by the circumference of the tree trunk. *Alyxoria varia, Buellia griseovirens, Eopyrenula leucoplaca, Opegrapha herbarum* and *Phlyctis argena* in the upper right part of the ordination axes (Fig. 3) are common on large-diameter trees. *Caloplaca holocarpa, Melanohalea elegantula* and *Parmelina quercina* in the lower left part of the ordination axes are common on small-diameter trees. Similar results were obtained in a study conducted by Aragon *et al.* (2010a).

Similar to the results of Hauck & Javkhlan (2009), *Melanohalea exasperatula* was common in localities with intensive nitrogen pollution in urban areas and is located near the center right part of the second axis of the CCA ordination plot. Schmull *et al.* (2002) indicated that *Hypogymnia physodes* decreases in abundance as nitrogen pollution increases. We have found this species to be more abundant in rural areas rather than in urban areas. This species is located in the upper left of the second axis of the CCA ordination plot.

Phlyctis argena prefers low light conditions and is often found in the shade on the trunk of *Quercus* sp. In contrast, the foliose *Parmelia sulcata* and the fruticose *Evernia prunastri* and *Ramalina farinacea*, and the crustose lichen *Amandinea punctata* are abundant on the light trunks of *Quercus* sp. (Leppik *et al.*, 2011). Corresponding on *Quercus cerris Amandinea punctata, Evernia prunastri, Parmelia sulcata* and *Ramalina farinacea* have been identified as the most abundant species in the study area and are located on the middle left part of the second axis of the CCA ordination plot.

As shown in Table 2 and Fig. 3, species of *Xanthorion* communities in Group II were observed at their highest levels of abundance at localities (1, 2 and 4) that are located near residential and agricultural areas.

In this study, *Hypogymnia physodes* was found to be most abundant at the seventh locality in the rural area, which is located far away from agricultural areas and areas without nitrogen pollution (Table 2).

Conclusion

The species diversity and composition of the epiphytic lichens on *Quercus cerris* varied depending on the effects of macroclimatic and microclimatic factors, anthropogenic and agricultural activities. Differences in the species diversity and composition of the epiphytic lichens on *Quercus cerris* in urban and rural areas were statistically significant.

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