TÜBİTAK

Turkish Journal of Botany

http://journals.tubitak.gov.tr/botany/

Research Article

Turk J Bot
(2019) 43: 551-569
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doi:10.3906/bot-1812-38

The epiphytic bryophyte vegetation of Kamilet Valley (Artvin, Turkey)

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Received: 19.12.2018 • **Accepted/Published Online:** 08.04.2019 • **Final Version:** 08.07.2019

Abstract: In this study, the vegetation of epiphytic bryophytes in the Kamilet Valley and its surroundings (Arhavi, Artvin) was investigated. The study area is located within the borders of the Eastern Black Sea Mountains and is one of the 122 important plant areas in Turkey. The investigation of epiphytic bryophyte communities was carried out in 2016 during different vegetation periods according to Braun-Blanquet's phytosociological methodology. Phytosociological data obtained from 65 relevés were ordinated using detrended correspondence analysis (DECORANA) and classified using two-way indicator species analysis (TWINSPAN). Consequently, six epiphytic bryophyte communities new to Turkey were determined with TWINSPAN and DECORANA: *Leucobryo-Tetraphidetum pellucidae*, *Anomodonto attenuati-Neckeretum crispae*, *Frullanio tamarisci-Exsertothecetum crispae*, *Ulotetum crispae*, *Anomodonto attenuati-Neckeretum crispae-leucodontetosum sciuroidis*, and *Ulotetum crispae-isothecietosum alopecuroidis*. All syntaxa are presented by analyzing them in terms of their ecological and floristic classifications.

Key words: Bryophyte, epiphytic vegetation, Kamilet Valley, Turkey

1. Introduction

Nutrient-rich tree roots, cracks on bark, irregular surfaces on branches, and collapsed branches are all suitable areas for the growth of epiphytic bryophytes. These microhabitats that are formed on the trunks of trees allow for the development and survival of different epiphytic bryophytes, according to tree age and species (Schofield, 2001). Ecological tendencies of epiphytic bryophytes allow them to come together and form similar colonies (Schofield, 2001).

Many bryofloristic studies have been carried out in Turkey. However, there are few ecological studies on bryophyte vegetation (Walther and Leblebici, 1969; Walther, 1975, 1979; Kürschner et al., 1998, 2006, 2012; Düzenli et al., 2009; Alataş et al., 2015, 2016, 2017; Ezer, 2017; Alataş and Uyar, 2017; Can Gözcü et al., 2018; Alataş, 2018). In accordance with the results of studies conducted on epiphytic bryophyte vegetation in Turkey to date, 41 syntaxa were determined. Among these syntaxa, 34 are at the level of association or subassociation and seven are at the level of community with an unknown syntaxonomical category (Alataş, 2018). Despite these completed studies and determined syntaxa, additional research is needed to fully reveal the bryosociological richness of Turkey. Future studies should first focus on the regions that were described by the WWF due to the presence of threatened plant species and the rare habitats that make these sites special.

The Kamilet Valley and its surroundings (Arhavi, Artvin) are located within the borders of the Eastern Black Sea Mountains and constitute one of the 122 important plant areas in Turkey (Özhatay et al., 2003). Although a few bryofloristic studies have been conducted in Artvin (Batan and Özdemir, 2008, 2013a, 2013b), no detailed study on the epiphytic bryophyte vegetation of the study area has yet been carried out.

The current bryosociological study performed in the study area has made a contribution to the epiphytic bryophyte vegetation of Turkey by determining four new epiphytic bryophyte associations and two subassociations for Turkey. With the contributions of this study, the number of epiphytic bryophyte syntaxa in the literature for Turkey has increased to 47 (Alataş, 2018).

2. Materials and methods

2.1. Study region

The Kamilet Valley is located in the Eastern Black Sea region of Turkey and is affiliated with the Arhavi district of Artvin province. It is surrounded by the Arhavi district

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center in the north, Murgul and Yusufeli in the south, Fındıklı (Rize) in the west, and Murgul Basin in the east (Figure 1). According to the Turkish grid system adopted by Henderson (1961) for bryophytes in Turkey, the study area is located in A4, as well as in the Colchic zone of the Euro-Siberian phytogeographic region (Anşin, 1983).

Although there are different types of vegetation in this valley, including alpine, subalpine, and wetland, this area is usually covered with humid forest vegetation (Kurdoğlu and Akbulut, 2015). While the conifer *Picea orientalis* (L.) Link is the dominant species, the deciduous *Juglans regia* L. and *Fagus orientalis* Lipsky are codominant. Additionally, *Castanea sativa* Mill., *Pinus sylvestris* L., *Carpinus betulus* L., *Alnus glutinosa* L., *Corylus avellana* L., *Malus sylvestris* (L.) Mill., and *Pyrus communis* L. are widespread tree species in the study area.

The annual precipitation is 2053 mm, and the average annual temperature is 14.4 °C. The hottest month of the year is August and the coldest month is January.[1] Annual precipitation is in the form of fall, winter, spring, and summer (FWSS), and the study area falls under the influence of the Oceanic Precipitation Regime Type 1 of the Eastern Black Sea region (Akman, 2011).

2.2. Vegetation analysis

A survey of the epiphytic bryophyte communities in the Kamilet Valley (Artvin) was carried out during different vegetation seasons in 2016. A total of 65 relevés were taken from the lower (0–0.5 m) and middle (0.5–2 m) parts of tree trunks in various localities of the Kamilet Valley (Table 1). These relevés were selected according to the minimal area concept using the abundance–coverage scale of Frey and Kürschner (1991) (Table 2).

The relevés were evaluated in accordance with the classical method of Braun-Blanquet (1964), and the vegetation associations were arranged according to diagnostic species (Braun-Blanquet, 1964) and named according to Weber et al. (2000). The determination of associations was carried out via comparison with related associations of Marstaller (2006) and classified in line with other published studies, and the bryophyte specimens were identified in accordance with relevant studies (Nyholm, 1981; Paton, 1999; Hedenäs, 1992; Zander, 1993; Cortini

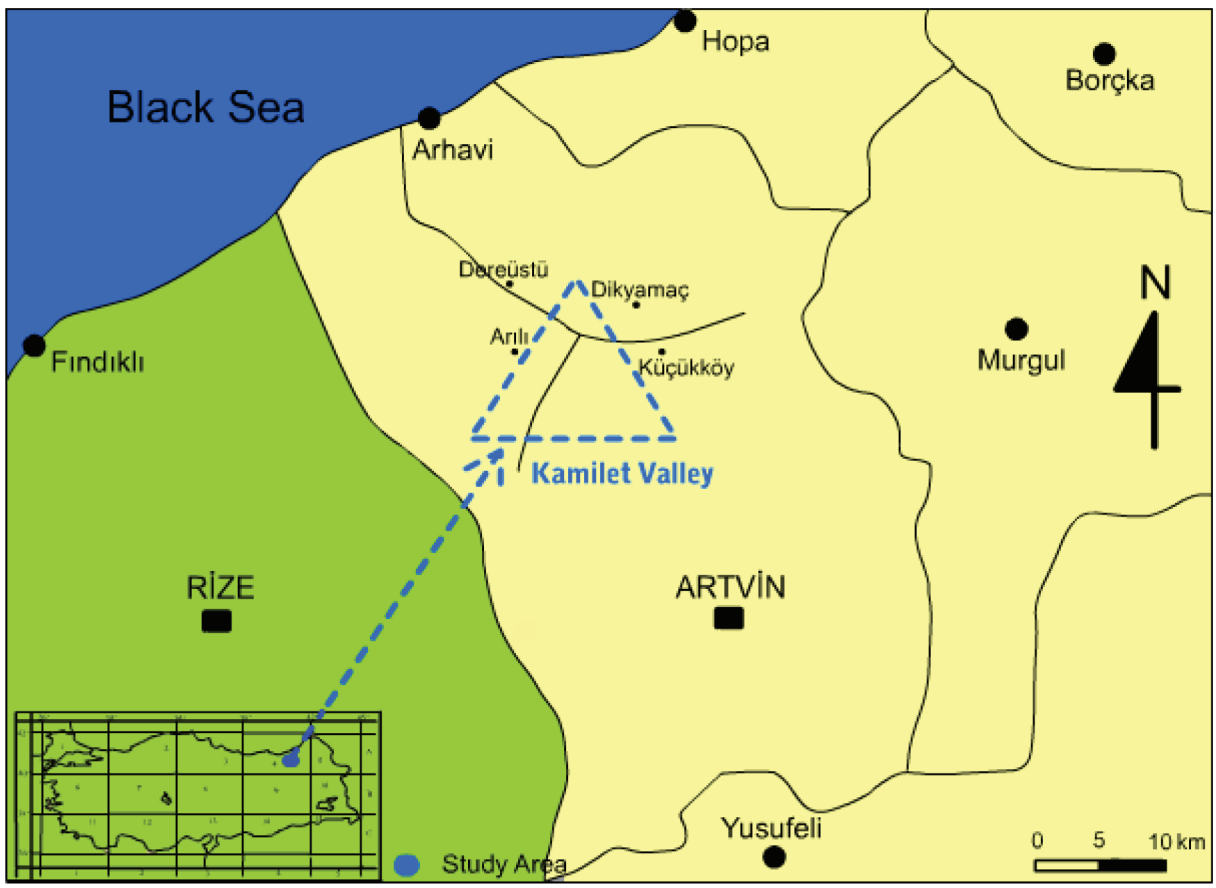

Figure 1. Grid system of Turkey adopted by Henderson (1961) and the study area.

[1] https://tr.climate-data.org/location/8541

Table 1. List of localities.

Number of relevés	Localities	Altitude (m)	Phorophyte	Date	GPS coordinates
1–10	1	513	*A.g., J.r.*	07.09.2015	41°15′ 09.60″N, 41°21′17.41″E
11–14	2	430	*J.r.*	08.09.2015	41°16′17.82″N, 41°22′32.27″E
15–22	3	565	*A.g., J.r.*	09.09.2015	41°16′32.61″N, 41°22′03.51″E
23–28	4	285	*M.s., C.o., C.s.*	23.04.2016	41°16′32.88″N, 41°22′33.01″E
29–34	5	460	*C.s.*	24.04.2016	41°16′48.54″N, 41°22′54.27″E
35–40	6	672	*A.g.*	25.04.2016	41°17′10.18″N, 41°23′15.74″E
41–44	7	592	*J.r., C.s., P.c.*	27.05.2016	41°14′40.74″N, 41°21′14.65″E
45–47	8	656	*A.g., C.s.*	28.05.2016	41°14′16.63″N, 41°20′57.33″E
48–49	9	1157	*A.g.*	29.05.2016	40°57′33.86″N, 41°05′25.52″E
50–52	10	1009	*F.o.*	06.08.2016	40°58′12.86″N, 41°04′38.87″E
53–56	11	835	*F.o.*	07.08.2016	40°59′41.26″N, 41°03′44.92″E
57–59	12	570	*J.r., F.o.*	08.08.2016	41°01′30.19″N, 41°02′54.08″E
60–65	13	420	*J.r.*	09.08.2016	41°02′31.65″N, 41°02′05.08″E

C.s.: *Castanea sativa*, *F.o.*: *Fagus orientalis*, *C.o.*: *Carpinus orientalis*, *J.r.*: *Juglans regia*, *A.g.*: *Alnus glutinosa*, *M.s.*: *Malus sylvestris*, *P.c.*: *Pyrus communis*.

Table 2. Abundance–coverage scale used for bryophytes.

Scale	Abundance–coverage	Scale	Abundance–coverage
+	<1%	3	12.1%–25.0%
1	1.1%–6.0%	4	25.1%–50.0%
2	6.1%–12.0%	5	50.1%–100%

Pedrotti, 2001, 2006; Heyn and Herrnstadt, 2004; Smith, 2004; Frey et al., 2006; Guerra and Cros, 2007; Casas et al., 2009; Kürschner and Frey, 2011; Plášek et al., 2015; Lara et al., 2016). The ecological characteristics of the species were drawn from Dierßen (2001), while the habitat affinities of the taxa were determined according to Draper et al. (2003). Vouchers are deposited in the Bioengineering Department of the Faculty of Engineering, Munzur University, Turkey.

2.3. Data analysis

In order to explore relationships between species composition of epiphytic bryophyte communities and the habitat factors of the study area, multivariate ordination techniques were used. The classification and ordination of the epiphytic bryophyte communities were carried out using two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) with the Community Analysis Package (CAP) computer program, version 3.2 (Seaby et al., 2004). The computations of the multivariate analysis system were based on a floristic data matrix consisting of presence/absence, abundance, and coverage data.

3. Results and discussion

3.1. Epiphytic vegetation

As a result of the evaluation of 65 relevés taken from tree trunks in the study region using the Braun-Blanquet method, *Leucobryo-Tetraphidetum pellucidae*, *Anomodonto attenuati-Neckeretum crispae*, *Frullanio tamarisci-Exsertothecetum crispae*, and *Ulotetum crispae* associations and *Anomodonto attenuati-Neckeretum crispae-leucodontethosum sciuroidis* and *Ulotetum crispae-isothecietosum alopecuroidis* subassociations were determined and classified. All of these syntaxa were recorded for the first time in Turkey (Alataş, 2018). The floristic and ecological characteristics of these syntaxa are given below in accordance with Marstaller's sequence (2006).

Class: Cladonio digitatae - Lepidozietea reptantis Jez. & Vondr. 1962

Order: Cladonio digitatae - Lepidozietalia reptantis Jez. & Vondr. 1962

Alliance: Tetraphidion pellucidae von Krusenstjerna 1945

Association: *Leucobryo-Tetraphidetum pellucidae* Barkm. 1958

Class: Neckeretea complanatae Marst. 1986

Order: Neckeretalia complanatae Jez & Vondr. 1962

Alliance: Neckerion compalantae Sm. & Had. ex Kl. 1948

Association: *Anomodonto attenuati - Neckeretum crispae* Plăm. 1982

Subassociation: *-leucodontetosum sciuroidis* Grgić 1972

Association: *Frullanio tamarisci - Exsertothecetum crispae* Pilous 1961 em. Gillet 1986

Class: Frullanio dilatatae-Leucodontetea sciuroidis Mohan 1978

Order: Orthotrichetalia Had. in Kl. & Had. 1944

Alliance: Ulotion crispae Barkm. 1958

Association: *Ulotetum crispae* Ochsn. 1928

Subassociation: *-isothecietosum alopecuroidis* Marst. 1985

3.1.1. *Leucobryo-Tetraphidetum pellucidae* Barkm. 1958 (Table 3)

Leucobryo-Tetraphidetum pellucidae was first identified by Barkman (1958); with this study, the same association is newly reported for Turkey. It was determined with 10

Table 3. *Leucobryo-Tetraphidetum pellucidae* Barkm. 1958.

Number of relevés	39	56	57	27	31	1	28	40	22	35
Altitude (m)	672	835	570	285	460	513	285	672	565	672
Size of relevés (dm^2)	12	16	15	20	12	18	24	12	20	12
Phorophyte	*A.g.*	*F.o.*	*F.o.*	*C.s.*	*C.s.*	*A.g.*	*C.s.*	*A.g.*	*A.g.*	*A.g.*
Trunk (m)	1.6	3.2	3.6	2.8	1.8	2.4	3.2	1.8	2.8	1.9
Exposition	N	N	N	N	N	N	N	N	N	N
Position of relevés	N	N	N	N	N	N	N	N	N	NE
Covering (%)	93	97	95	88	95	98	95	96	75	89
Closure (%)	90	90	90	90	100	80	90	90	100	90
Base (B)/trunk (T)	T	T	T	T	T	T	T	T	T	T
Number of species	7	10	9	9	6	9	8	9	5	6
ChAss.										
Tetraphis pellucida Hedw.	1	1	1	2		1	1	1		1
ChAll. Tetraphidion pellucidae										
Leucobryum juniperoideum (Brid.) Müll.Hal.	2	2	2	1	2	2	2	2	3	
Dicranodontium denudatum (Brid.) E.Britton		1	1	1			1			1
Ch.Cl Cladonio digitatae-Lepidozietea reptantis and ChO. Cladonio digitatae-Lepidozietalia order										
Cladonia sp.		1	1	2	1		1	1		
Lophocolea heterophylla (Schrad.) Dumort.			1					1		
Others										
Plagiochila porelloides (Torrey ex Nees) Lindenb.	2					2		1	2	2
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt	4	4	3	3	5		4			
Hypnum cupressiforme var. *cupressiforme* Hedw.		3	4	3		2	3	4	4	4
Isothecium myosuroides Brid.	3			2	3	2	2	3		
Frullania tamarisci (L.) Dumort.	2									3
Plagiomnium ellipticum (Brid.) T.J.Kop.								1		
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt				2			3			
Radula complanata (L.) Dumort.						2				
Anomodon attenuatus (Hedw.) Huebener		2	2			3				
Isothecium alopecuroides (Lam. ex Dubois) Isov.					1	1			2	
Metzgeria furcata (L.) Dumort.		2		1						
Frullania dilatata (L.) Dumort.		1								
Tortella tortuosa (Hedw.) Limpr.	1					1				
Eurhynchium striatum (Hedw.) Schimp.		2	2							
Thuidium delicatulum (Hedw.) Schimp.					2			2	2	
Dicranum scoparium Hedw.										2

relevés located between 285 and 835 m in the study region. These relevés are usually found in the middle parts of the trunks of *Fagus orientalis*, *Castanea sativa*, and *Alnus glutinosa*, which were spread over the northern parts of the study region. The most preferred phorophyte in the association was *Alnus glutinosa* (Figure 2). When *Alnus glutinosa* is young, its dark green trunk bark is thin and uncracked, while at advanced ages, its trunk is dark gray in color and cracked (Mamıkoğlu, 2007). The cracked and rough structure of its bark generates microhabitats with differing features. These microhabitats, which are caused on the tree trunk by height and humidity, enable the growth of various species of epiphytic bryophytes.

While the general coverage of the association ranged from 75% to 98%, the canopy coverage was estimated between 80% and 100%. The association included 20 bryophyte taxa: six liverworts and 14 mosses. Among the mosses, eight taxa were pleurocarpous and six taxa were acrocarpous. Both the rate of coverage and the number of acrocarpous and pleurocarpous mosses indicate that the study area consists of both humid and semiarid habitats.

The hygrophilic *Tetraphis pellucida*, which is a characteristic species of the association, was the second taxon with a high rate of occurrence, and its permanency was at 80% among the relevés. *Tetraphis pellucida* spreads on tree trunks as an epiphytic and on rock surfaces as an epilithic, and it prefers acidic, humid, and shaded habitats. The average number of taxa in the association was 7.

An evaluation of the habitat tendencies of the taxa in the association revealed that the cortico-saxicolous taxa occurred at a rate of 40%, while the epiphytes occurred at 25% and the rate of taxa preferring all habitats was 35% (Figure 3). Therefore, the association is cortico-saxicolous.

Its characteristic species, including *Tetraphis pellucida*, *Leucobryum juniperoideum*, *Dicranodontium denudatum*, *Cladonia* sp., and *Lophocolea heterophylla*, generally grow on tree trunks as epiphytes and choose semineutral environments and humid and shady habitats; therefore, the association must be classified to the alliance *Tetraphidion pellucidae* of the order *Cladonio digitatae-Lepidozietalia reptantis*, class *Cladonio digitatae-Lepidozietea reptantis* (Table 3).

Moreover, evaluation of the acidity of the taxa within the association revealed the occurrence of acidophytes (pH < 5.7) at 50%, subneutrophytes (pH = 5.7–7) at 45%, and basiphytes (pH > 7) at 5%. Additionally, with respect to their moisture requirements, the occurrence of mesophilic taxa was 50%, hygrophilic taxa 45%, and xerophytic taxa 5% (Figure 5). The majority of taxa (95%) have sciophytic characteristics in terms of light and preference for shaded habitats (Figure 6). These results indicate that, with regard to ecological characteristics, the association has mesohygrophilic characteristics, is acidic, and spreads over semineutral shaded areas.

According to ecological and floristic composition, the association has characteristics similar to the association determined by Goia and Schumacker (2003) in Romania and by Marstaller (2006, 2007) and Hübschmann (1986) in Germany, and it has the same characteristics as species such as *Dicranodontium denudatum*, *Hypnum cupressiforme*, *Cladonia* sp., and *Plagiochila porelloides*.

3.1.2. *Anomodonto attenuati-Neckeretum crispae* Plăm. 1982 (Table 4)

Anomodonto attenuati-Neckeretum crispae is represented by 13 relevés that were taken from tree trunks. It was found from 285 to 672 m in the study area, especially in

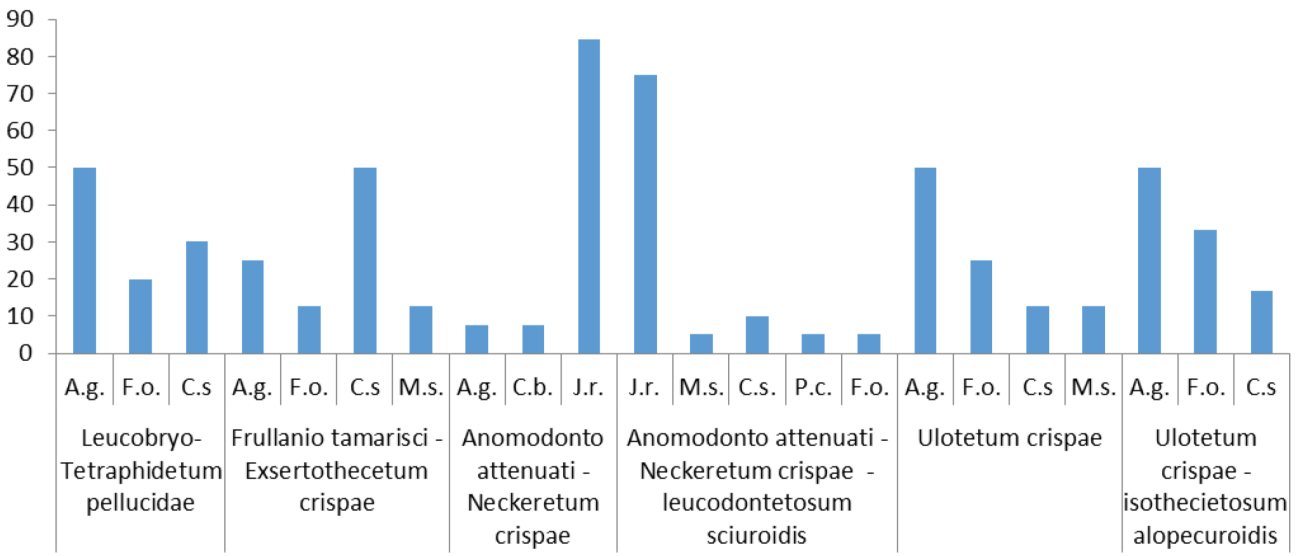

Figure 2. Tree preferences of the syntaxa. See Table 2 for abbreviations.

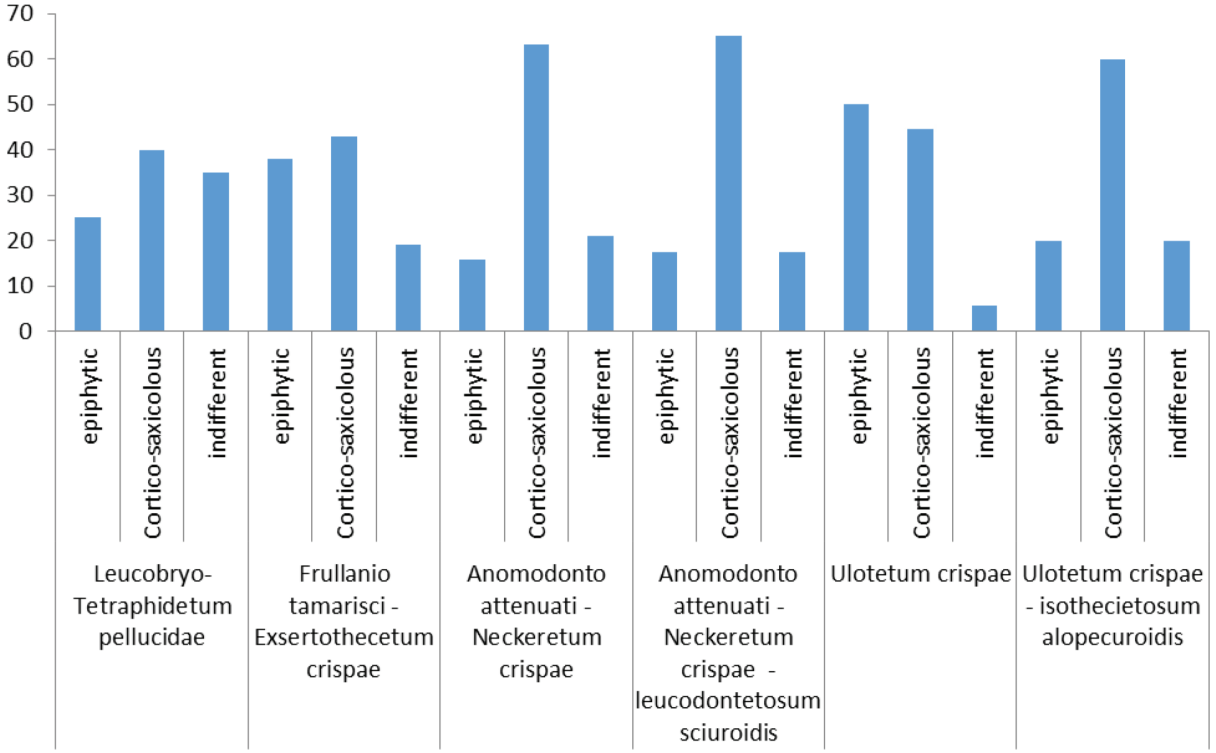

Figure 3. Habitat affinities spectrum of the species of syntaxa.

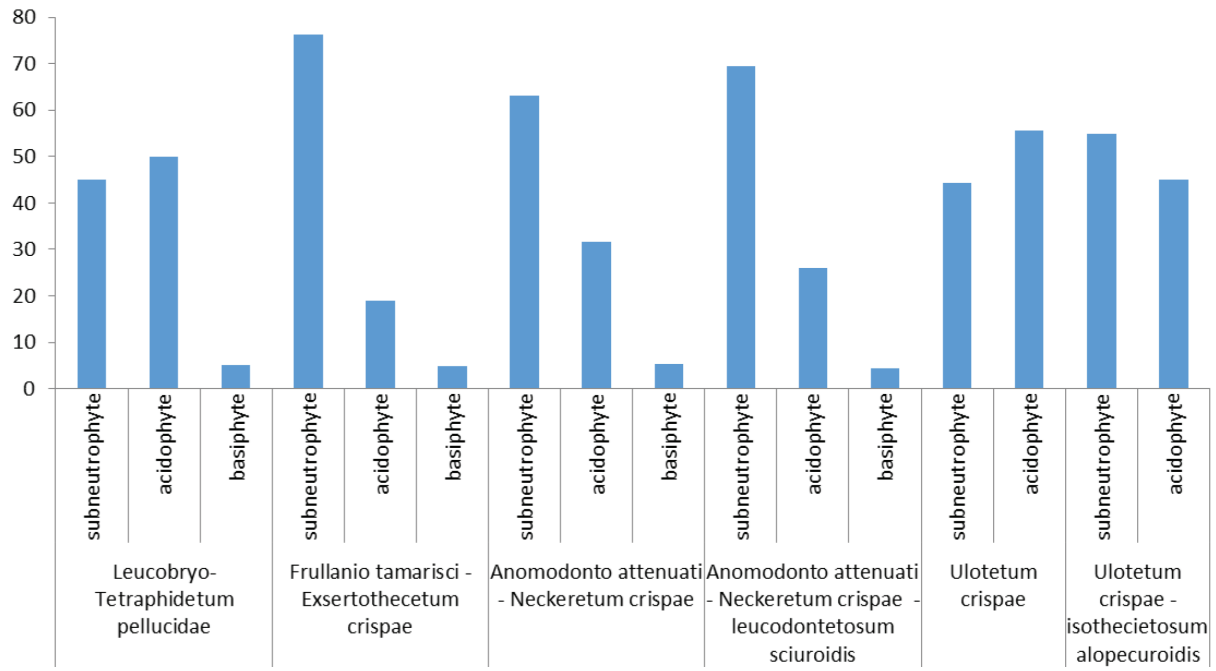

Figure 4. Acidity spectrum of the species of syntaxa.

the northern parts, and the most preferred tree of the association was *Juglans regia* (Table 4; Figure 2). While the coverage of the association was between 83% and 95%, the canopy coverage was estimated at 80% to 100%.

The number of taxa in the relevés varied between 4 and 8, and a total of 19 taxa were found in the association. Among them, four taxa were liverworts; fifteen taxa were mosses, thirteen of which were pleurocarpous; and two

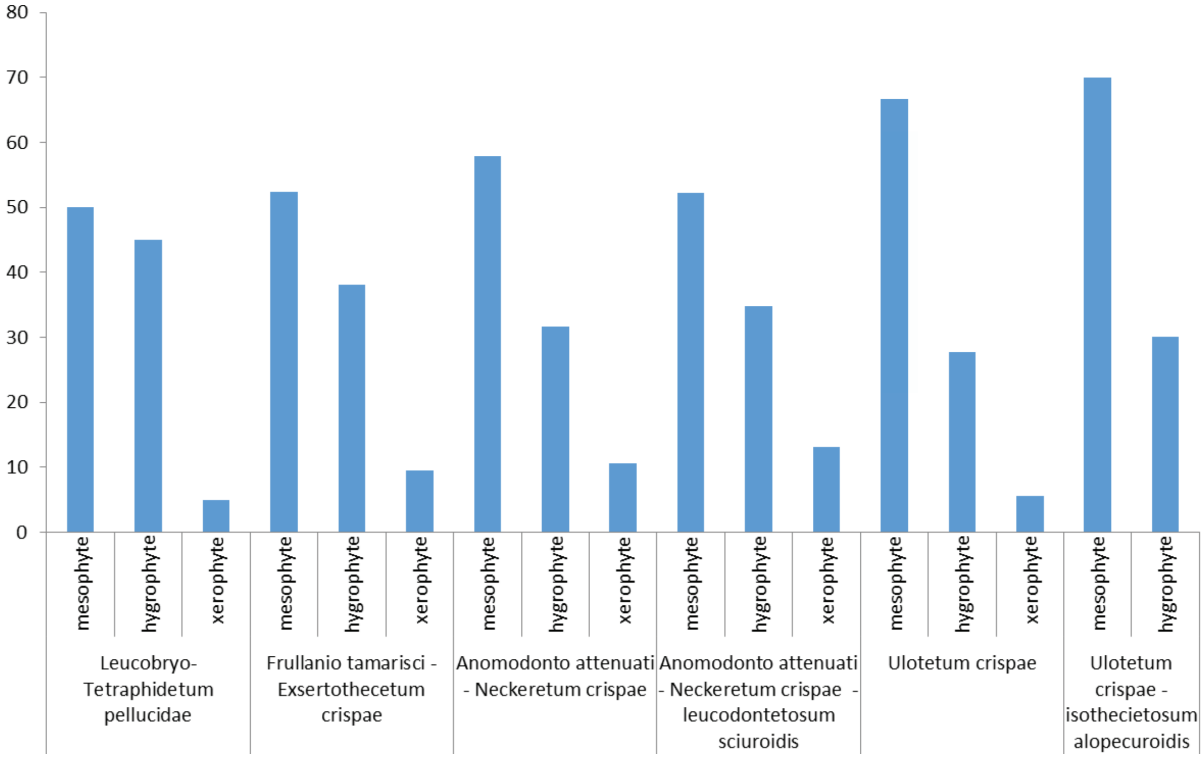

Figure 5. Humidity spectrum of the species of syntaxa.

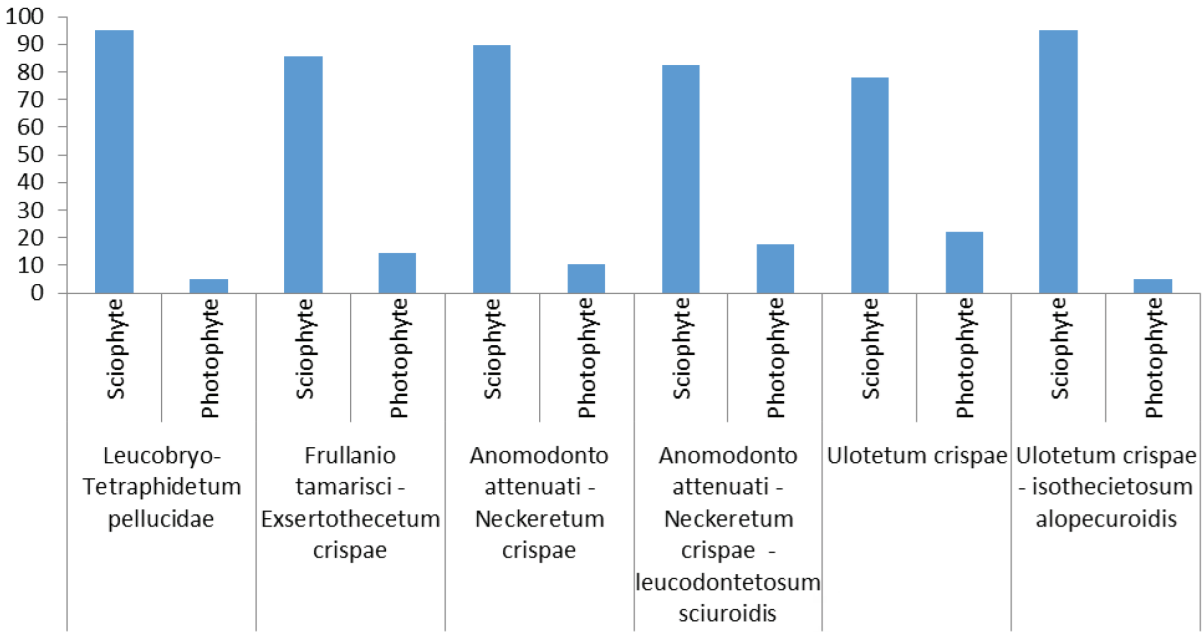

Figure 6. Light spectrum of the species of syntaxa.

taxa were acrocarpous. Both the rate of coverage and the redundancy of the pleurocarpous taxa indicate that the association has mesohygrophilic characteristics and is widespread in shaded environments.

The main characteristic species of the association include *Anomodon attenuatus* and *Exsertotheca crispa*, which are the mesophilic taxa with the highest rate of occurrence and a permanency of 92% in the relevés. These

Table 4. *Anomodonto attenuati-Neckeretum crispae* Plăm. 1982 association (a) and *-leucodontetosum sciuroidis* Grgić 1972 subassociation (b).

(a)

Number of relevés	2	3	4	10	17	18	26	37	19	5	58	59	9	6	7	8	11
Altitude (m)	513	513	513	513	565	565	285	672	565	513	570	570	513	513	513	513	430
Size of relevés (dm^2)	24	30	15	24	16	18	16	12	16	15	12	9	15	12	24	25	12
Phorophyte	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*C.b.*	*A.g.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*
Trunk (m)	2.3	2.3	1.8	1.7	2.1	1.9	1.8	1.8	2.6	1.6	2.2	1.9	1.9	1.8	2.4	2.2	1.6
Exposition	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Position of relevés	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Covering (%)	95	93	95	93	90	90	85	85	83	92	85	90	95	88	95	90	95
Closure (%)	80	80	90	90	90	90	90	90	100	90	90	90	90	90	90	90	90
Base (B)/trunk (T)	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T
Number of species	4	5	7	5	6	6	6	7	8	8	4	7	8	5	7	8	7
ChAss.																	
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt	4	4	5	5	4	5	4	4	3		4	4	3	4	4	4	4
Anomodon attenuatus (Hedw.) Huebener	3	3	2	2	4	2	2		2	2	2	2	2	3	1	1	3
Leucodon sciuroides (Hedw.)Schwägr.														2	2	2	3
Radula complanata (L.) Dumort.			1		1	1	1	1	1	1		1					1
Frullania dilatata (L.) Dumort.																	
ChAll. Neckerion complanatae																	
Anomodon viticulosus (Hedw.) Hook. & Taylor			1	1											2	2	
Metzgeria furcata (L.) Dumort.				3	1	1				1		1	1	8			
Ch.Cl. Neckeretea complanatae and ChO. Neckeratalia complanatae order																	
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt	3	3	2	2	2	2	3	2		3		4	2	2	2	2	
Porella platyphylla (L.) Pfeiff.			2												2	2	
Pseudoamblystegium subtile (Hedw.) Vanderp. & Hedenäs			1		1	1			1	1	1	1	1				
Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen									2								
Hypnum cupressiforme var. *cupressiforme* Hedw.							3	2	2	2							2
Plagiomnium cuspidatum (Hedw.) T.J.Kop.															2		
Orthotrichum pumilum Sw. ex anon.																	1
Others																	
Dicranum scoparium Hedw.								1									
Homomallium incurvatum (Schrad. ex Brid.) Loeske																	

Table 4. (Continued).

Alleniella besseri (Lobarz.) S.Olsson, Enroth & D.Quandt									3		4						
Palamocladium euchloron (Müll.Hal.) Wijk & Margad.		3								4			4				
Pseudoleskeella nervosa (Brid.) Nyholm												1					
Ptychostomum moravicum (Podp.) Ros & Mazimpaka																	
Isothecium myosuroides Brid.								3									
Rhizomnium punctatum (Hedw.) T.J.Kop.		2											1				
Thuidium tamariscinum (Hedw.) Schimp.																	
Ctenidium molluscum (Hedw.) Mitt.							2										
Plagiochila porelloides (Torrey ex Nees) Lindenb.	2							2	2								
Plagiomnium ellipticum (Brid.) T.J.Kop.																2	2
Plagiomnium undulatum (Hedw.) T.J.Kop.																	
Thamnobryum alopecurum (Hedw.) Gangulee													2			1	

(b)

Number of relevés	24	12	61	14	13	41	62	42	63	43	64	44	65	46	60	52
Altitude (m)	285	430	420	430	430	592	420	592	420	592	420	592	420	656	420	1009
Size of relevés (dm^2)	4	6	12	6	12	12	9	6	9	6	6	6	16	6	12	16
Phorophyte	*M.s.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*C.s.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*J.r.*	*P.c.*	*J.r.*	*C.s.*	*J.r.*	*F.o.*
Trunk (m)	0.9	0.9	1.8	0.9	1.2	3.4	1.2	1.3	1.8	1.7	1.6	1.4	2.4	1.2	1.6	3.6
Exposition	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Position of relevés	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Covering (%)	73	87	85	85	90	90	85	85	90	80	80	85	90	95	88	85
Closure (%)	90	90	90	90	90	100	90	100	90	100	90	80	90	90	90	90
Base (B)/trunk (T)	T	T	T	B	B	T	T	T	T	T	T	T	T	T	T	T
Number of species	5	6	5	7	7	6	5	4	6	5	5	5	6	4	6	4
ChAss.																
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt	4		3		4		2		3		4		4			
Anomodon attenuatus (Hedw.) Huebener		3		2		3		3		2		4		4	3	
Leucodon sciuroides (Hedw.)Schwägr.	3	4	3	4	2	4	4	5	4	4	4	4	3	4	3	4
Radula complanata (L.) Dumort.	1	1	1		1		2			1		1			1	
Frullania dilatata (L.) Dumort.				1												
ChAll. Neckerion complanatae																
Anomodon viticulosus (Hedw.) Hook. & Taylor									2		2		1			

Table 4. (Continued).

Metzgeria furcata (L.) Dumort.																
Ch.Cl. Neckeretea complanatae and ChO. Neckeratalia complanatae order																
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt	3	3	4	2	3		4		2		2				4	
Porella platyphylla (L.) Pfeiff.			2			2								3	2	2
Pseudoamblystegium subtile (Hedw.) Vanderp. & Hedenäs				1	2	1	2	2		3				2	2	
Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen		2				2				3						
Hypnum cupressiforme var. *cupressiforme* Hedw.		2		3	3											3
Plagiomnium cuspidatum (Hedw.) T.J.Kop.																
Orthotrichum pumilum Sw. ex anon.	1															
Others																
Dicranum scoparium Hedw.																
Homomallium incurvatum (Schrad. ex Brid.) Loeske								1								
Alleniella besseri (Lobarz.) S.Olsson, Enroth & D.Quandt													3			
Palamocladium euchloron (Müll.Hal.) Wijk & Margad.					1				2							
Pseudoleskeella nervosa (Brid.) Nyholm												2				3
Ptychostomum moravicum (Podp.) Ros & Mazimpaka												1				
Isothecium myosuroides Brid.																
Rhizomnium punctatum (Hedw.) T.J.Kop.																
Thuidium tamariscinum (Hedw.) Schimp.						3										
Ctenidium molluscum (Hedw.) Mitt.				2												
Plagiochila porelloides (Torrey ex Nees) Lindenb.																
Plagiomnium ellipticum (Brid.) T.J.Kop.													2			
Plagiomnium undulatum (Hedw.) T.J.Kop.									1		1		3			
Thamnobryum alopecurum (Hedw.) Gangulee																

species also grow on tree trunks and epilithic habitats such as rock surfaces in semineutral shaded environments. The characteristic features of the taxa belonging to the association are highly compatible with the ecological characteristics (i.e. acidity, humidity, and light) of the association (Figures 4–6).

The class and order characteristics of *Neckeretalia complanatae*, such as *Alleniella complanata*, *Metzgeria furcata*, *Anomodon viticulosus*, *Pseudoamblystegium subtile*, and *Porella platyphylla*, are highly represented within the association. Therefore, the association was classified within the Neckeretea complanatae class, the Neckeretalia complanatae order, and the Neckerion complanatae alliance syntaxonomically (Table 4). The cortico-saxicolous taxa are dominant (63%), and this supports the affiliation of the association to this classification in terms of habitat affinity (Figure 3).

Synonyms of this association, according to Marstaller (2006), are *Isothecetum myuri* Hil. 1925, *Anomodonto viticulosi-Leucodontetum sciuroidis* Wiśn. 1930, and *Anomondontetum attenuati* (Barkm. 1958) Pec. 1965. When the association was compared with that of Marstaller (2006), it coincided strongly in terms of alliance, order, class, and other characteristics.

3.1.3. *Anomodonto attenuati-Neckeretum crispae* Plăm. 1982-***leucodontetosum sciuroidis*** Grgić 1972 (Table 4)

This subassociation is represented by a total of 20 relevés in the study area. The relevés were taken from tree trunks between 285 and 1009 m. The most preferred tree species of this subassociation was *Juglans regia* (Figure 2).

While the bryophyte coverage of the subassociation ranged from 73% to 95%, the canopy coverage ranged from 80% to 100% and the number of taxa in the relevés ranged between 4 and 8. A total of 23 species were found in the subassociation. Among these, three were liverworts and twenty were mosses. The five moss members were pleurocarpous and the others were acrocarpous.

The mesophilic *Leucodon sciuroides*, which separates the subassociation *leucodontethosum sciuroidis* from the association, has the highest rate of occurrence, and its permanency in the relevés was 100% (Table 4). In addition, this species grows as both an epiphytic and an epilithic and prefers acidic and semiarid environments and open areas.

On evaluating the habitat tendencies of the species belonging to the subassociation, 65% were of the cortico-saxicolous taxa, and the epiphytes and those preferring all habitats were 17% (Figure 3). In terms of ecological features, the syntaxon was cortico-saxicolous, mesohygrophilic, acidic, and widespread in semineutral shaded areas (Figures 4–6).

3.1.4. *Frullanio tamarisci-Exsertothecetum crispae* Pilous 1961 em. Gillet 1986 (Table 5)

The association was determined from a total of 8 relevés that were taken from tree trunks at 285 to 835 m in the study area. *Fagus orientalis*, *Castanea sativa*, *Malus sylvestris*, and *Alnus glutinosa*, on which the relevés were located, were widespread in the northern part of the area. *Castanea sativa* was the most preferred phorophyte species in the association (Figure 2). Its trunks are gray in color and crack-free when they are young, but with advanced age chestnut trunks are cracked (Mamıkoğlu, 2007); old, cracked tree trunks provide different microhabitats for different epiphytic bryophytes.

While the general coverage of the association differed between 85% and 98%, the canopy coverage ranged from 90% to 100%. A total of 21 taxa (including 5 liverworts and 16 mosses) were found within the association. Among the 6 mosses, ten taxa were pleurocarpous and the others were acrocarpous. The average taxa number is 7 within the association. The difference between pleurocarpous and acrocarpous taxa numbers reveals that the study area encompasses both humid and semiarid habitats.

While cortico-saxicolous taxa occurred most frequently (43%), the epiphytic taxa were the second most prolific (38%) within the association (Figure 3). Therefore, cortico-saxicolous and epiphytic species were dominant due to the habitat preferences of the alliance and class and order characteristics.

The association characteristics were highly compatible with the ecological characteristics (i.e. acidity, humidity, and light) of species belonging to the association. In terms of ecological characteristics, *Frullanio tamarisci-Exsertothecetum crispae* exhibited mesohygrophilic characteristics and spread over the semineutral shaded habitats of the study area (Figures 4–6). The climate, habitat, and other ecological characteristics of the area are strongly compatible with the association characteristics.

Frullanio tamarisci-Exsertothecetum crispae is generally epilithic, growing on the vertical surfaces of rocks. On the other hand, Neckeretea complanatae can grow on tree trunks as an epiphytic in humid and shaded habitats. Therefore, the association in this study was classified within Neckeretalia and Neckerion complanatae (Table 5).

With respect to its floristic composition and ecological characteristics, the association is similar to that of Pétrequin (1997) and has common characteristics with *Alleniella complanata*, *Isothecium myosuroides*, and *Hypnum cupressiforme*.

3.1.5. *Ulotetum crispae* Ochsn. 1928 (Table 6)

Ulotetum crispae was represented in a total of 9 relevés from the study area. It spreads between 285 and 1157 m, especially in the northern parts of the area. *Alnus glutinosa* was the tree species most preferred by the association (Figure 2).

While the general bryophyte coverage of the association ranged from 83% to 95%, the canopy coverage alternated between 80% and 90% and the number of

Table 5. *Frullanio tamarisci-Exsertothecetum crispae* Pilous 1961 em. Gillet 1986.

Number of relevés	30	34	29	23	53	36	33	38
Altitude (m)	460	460	285	285	835	672	460	672
Size of relevés (dm^2)	16	15	9	3	16	16	15	12
Phorophyte	*C.s.*	*C.s.*	*C.s.*	*M.s.*	*F.o.*	*A.g.*	*C.s.*	*A.g.*
Trunk (m)	2.6	2.6	1.4	0.8	4.2	2.2	2.4	1.4
Exposition	N	N	N	N	N	N	N	N
Position of relevés	N	NE	NE	N	N	N	N	N
Covering (%)	98	97	85	93	94	91	98	92
Closure (%)	100	100	90	90	90	90	100	90
Base (B)/trunk (T)	T	T	B	T	T	T	T	T
Number of species	10	7	6	6	10	9	7	7
ChAss.								
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt	4	4	4	4	4	4	4	4
Frullania tamarisci (L.) Dumort.	1	2	2	2	2	2	2	2
ChAll. Neckerion complanatae								
Anomodon attenuatus (Hedw.) Huebener	1	1		2			1	2
Metzgeria furcata (L.) Dumort.			1			1		
Ch.Cl. Neckeretea complanatae and ChO. Neckeratalia complanatae order								
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt	2		3	3	3	2		
Pseudoamblystegium subtile (Hedw.) Vanderp. & Hedenäs			1			1		
Radula complanata (L.) Dumort.	1	1		1				
Metzgeria conjugata Lindb.					1			1
Hypnum cupressiforme var. *cupressiforme* Hedw.			3		2		3	
Anomodon tristis (Ces.) Sull. & Lesq.								
Isothecium alopecuroides (Lam. ex Dubois) Isov.	2				1	2		1
Others								
Dicranum scoparium Hedw.						2		
Plagiochila porelloides (Torrey ex Nees) Lindenb.					1	1		2
Orthotrichum affine Schrad. ex Brid.				1				
Hypnum resupinatum (Taylor) Schimp.								
Ctenidium molluscum (Hedw.) Mitt.	2	2					2	
Orthotrichum pallens Bruch ex Brid.					1			
Palamocladium euchloron (Müll.Hal.) Wijk & Margad.	2							
Isothecium myosuroides Brid.						3		3
Plagiomnium ellipticum (Brid.) T.J.Kop.	2	3					2	
Orthotrichum tenellum Bruch ex Brid.					1			
Habrodon perpusillus (De Not.) Lindb.					1			
Plagiomnium undulatum (Hedw.) T.J.Kop.	2	2					2	

taxa in the association ranged from 5 to 8. The total number of taxa in the association was 18 (6 liverworts and 12 mosses). Among the mosses, nine taxa were pleurocarpous and three were acrocarpous. Both the rate of coverage and the redundancy of the pleurocarpous taxa within the association indicate that it has mesohygrophilic characteristics and is widespread in shaded habitats.

The mesophilic taxa *Ulota crispa*, a characteristic species of the association, had the highest rate of occurrence, and its permanence within the relevés was 100%. *Ulota crispa*

Table 6. *Ulotetum crispae* Ochsn. 1928 association (a) and - *isothecietosum alopecuroidis* Marst. 1985 subassociation (b).

Number of relevés	48	16	49	45	47	25	55	51	54	15	20	21	32	50
Altitude (m)	1157	565	1157	656	656	285	835	1009	835	565	565	565	460	1009
Size of relevés (dm^2)	2	15	4	12	3	5	9	12	8	24	20	16	16	12
Phorophyte	*A.g.*	*A.g.*	*A.g.*	*C.s.*	*A.g.*	*M.s.*	*F.o.*	*F.o.*	*F.o.*	*A.g.*	*A.g.*	*A.g.*	*C.s.*	*F.o.*
Trunk (m)	0.9	1.6	1.4	1.8	1.2	1.2	3.4	3.9	4.2	2.2	1.8	1.6	2	3.9
Exposition	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Position of relevés	N	N	N	N	NE	NE	N	N	NE	N	N	N	N	N
Covering (%)	85	88	90	83	85	85	90	95	80	88	95	85	90	85
Closure (%)	90	90	90	90	90	80	90	90	90	90	100	100	100	90
Base (B)/trunk (T)	B	T	T	T	B	T	T	T	T	T	B	T	T	T
Number of species	7	8	7	5	5	8	7	8	8	10	9	7	7	7
ChAss.	a									b				
Ulota crispa (Hedw.) Brid.	1	2	2	2	3	2	1	1	1	1	1	2		
Isothecium alopecuroides (Lam. ex Dubois) Isov.										2	3	2	1	1
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt						2	3	3	3					
Pterigynandrum filiforme Hedw.			1				3							
ChAll. Ulotion crispae														
Hypnum andoi A.J.E.Sm.		3		3	4	2	4	3	2			3	2	
Frullania tamarisci (L.) Dumort.	3	4				2	2	2	2	2	3	3	2	2
Metzgeria furcata (L.) Dumort.		1								1				
ChAll. Syntrichion laevipilae														
Orthotrichum pumilum Sw. ex anon.	2		3	1			1		1					
Ch.Cl. Frullanio dilatatae-Leucodontetea sciuroidis and ChO. Orthotrichetalia order														
Frullania dilatata (L.) Dumort.	1	1	2											
Leucodon sciuroides (Hedw.)Schwägr.	4		4	4		4		2	3					
Radula complanata (L.) Dumort.	1	1	1	2	1	1	1		1	1				
Others														
Plagiomnium ellipticum (Brid.) T.J.Kop.										2	2		2	
Plagiomnium undulatum (Hedw.) T.J.Kop.													1	
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt										3			3	
Porella platyphylla (L.) Pfeiff.					2						1			

Table 6. (Continued).

Ctenidium molluscum (Hedw.) Mitt.													4	
Plagiochila porelloides (Torrey ex Nees) Lindenb.								2				2		2
Brachytheciastrum velutinum (Hedw.) Ignatov & Huttunen.	2									2				
Eurhynchium striatum (Hedw.) Schimp.											2	2		
Herzogiella seligeri (Brid.) Z. Iwats.					2									
Anomodon tristis (Ces.) Sull. & Lesq.														1
Homomallium incurvatum (Schrad. ex Brid.) Loeske											1			
Hypnum resupinatum (Taylor) Schimp.						2				2				4
Pseudoamblystegium subtile (Hedw.) Vanderp. & Hedenäs						1								
Ptychostomum moravicum (Podp.) Ros & Mazimpaka									1					
Isothecium myosuroides Brid.								2			2			3
Thuidium delicatulum (Hedw.) Schimp.										2	2	2		
Anomodon attenuatus (Hedw.) Huebener														2

generally grows on tree trunks as an epiphyte and prefers acidic, humid, and shaded habitats. Moreover, the rate of occurrence of epiphytic taxa within the association was 50% and the cortico-saxicolous members constituted 44% (Figure 3). Therefore, the association was epiphytic.

Because of the high occurrence of characteristic species such as *Radula complanata* (88%), *Hypnum andoi* (75%), *Frullania tamarisci* (63%), *Leucodon sciuroides* (63%), and *Frullania dilatata* (38%) in terms of the class, order, and alliance found in the association, it was classified within Frullanio dilatatae-Leucodontetea sciuroidis, Orthotrichetalia, and Ulotion crispae (Table 6).

When the association is evaluated in terms of ecological characteristics, it exhibits mesophilic characteristics and is widespread in acidic and shaded habitats in the study area (Figures 4–6). This may be explained by the abundance of mesophilic, shade-tolerant taxa within the association and the presence of abundant humid and semiarid microhabitats.

In the study area the association demonstrated a high degree of similarity with those of Fuertes Lasala (1988) and Marstaller (2006) in terms of floristic composition and ecological characteristics. Similarly, the characteristic species of the association that were determined in this study were *Metzgeria furcata*, *Frullania dilatata*, *Leucodon sciuroides*, *Pterigynandrum filiforme*, *Frullania tamarisci*, *Orthotrichum pumilum*, and *Hypnum cupressiforme*. Furthermore, the association grew mainly on the trunks of *Fagus orientalis* in the study area, as in the work of Fuertes Lasala (1988).

3.1.6. *Ulotetum crispae* Ochsn. 1928-***isothecietosum alopecuroidis*** Marst. 1985 (Table 6)

This subassociation was represented by a total of 5 relevés that were taken from tree trunks at 460 to 1009 m in the study area. *Alnus glutinosa* is the phorophyte species most preferred by the subassociation, and it is also common on the trunks of *Fagus orientalis* and *Castanea sativa* (Figure 2).

While the rate of coverage of the subassociation ranged from 85% to 95%, the canopy coverage alternated between 90% and 100% and the taxa numbers in the relevés ranged between 7 and 10. The total number of taxa in the subassociation was 20 (5 liverworts and 15 mosses). Among the mosses, three taxa were acrocarpous and the others were pleurocarpous.

The mesophilic *Isothecium alopecuroides*, the characteristic species of the subassociation, had the highest rate of occurrence, and its permanence within the relevés was 100% (Table 6). *Isothecium alopecuroides* grows in epiphytic habitats and on rock surfaces, especially in semineutral and shaded environments. The subassociation characteristics were highly compatible with the ecological characteristics (i.e. acidity, humidity, and light) of the

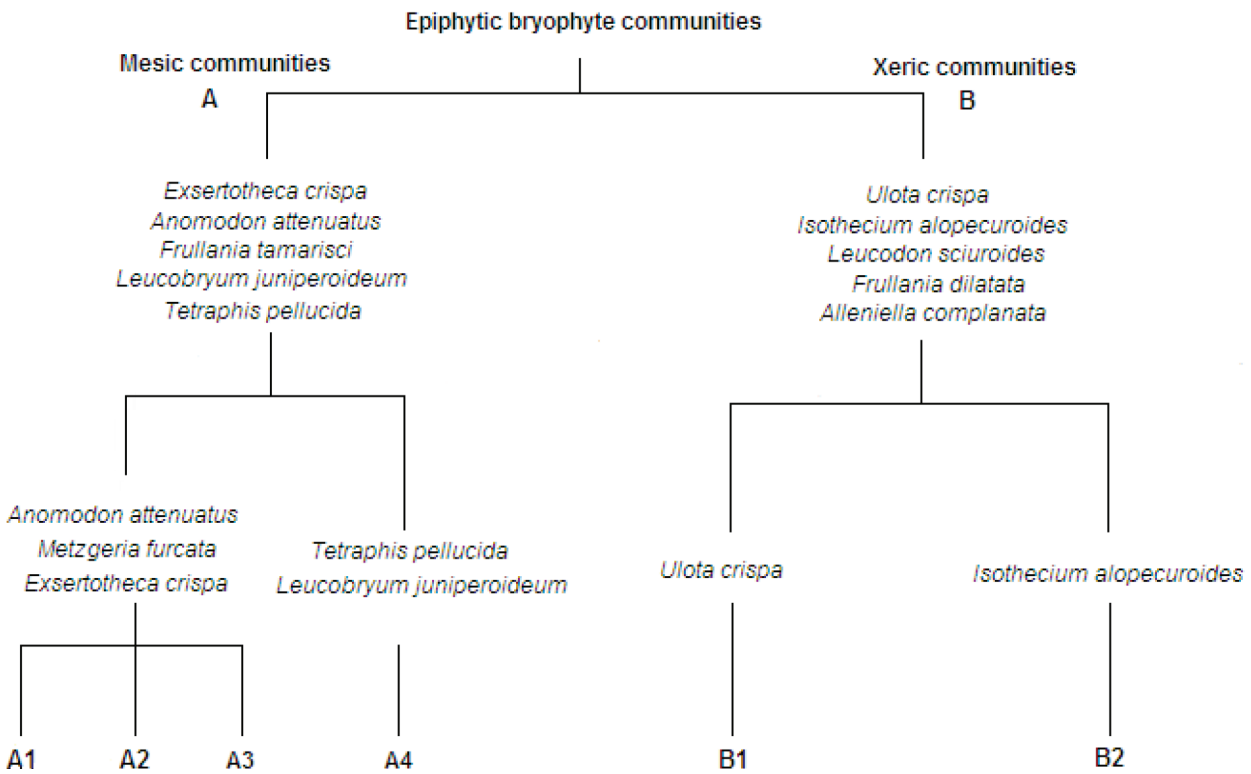

Figure 7. Epiphytic bryophyte communities classified by TWINSPAN.

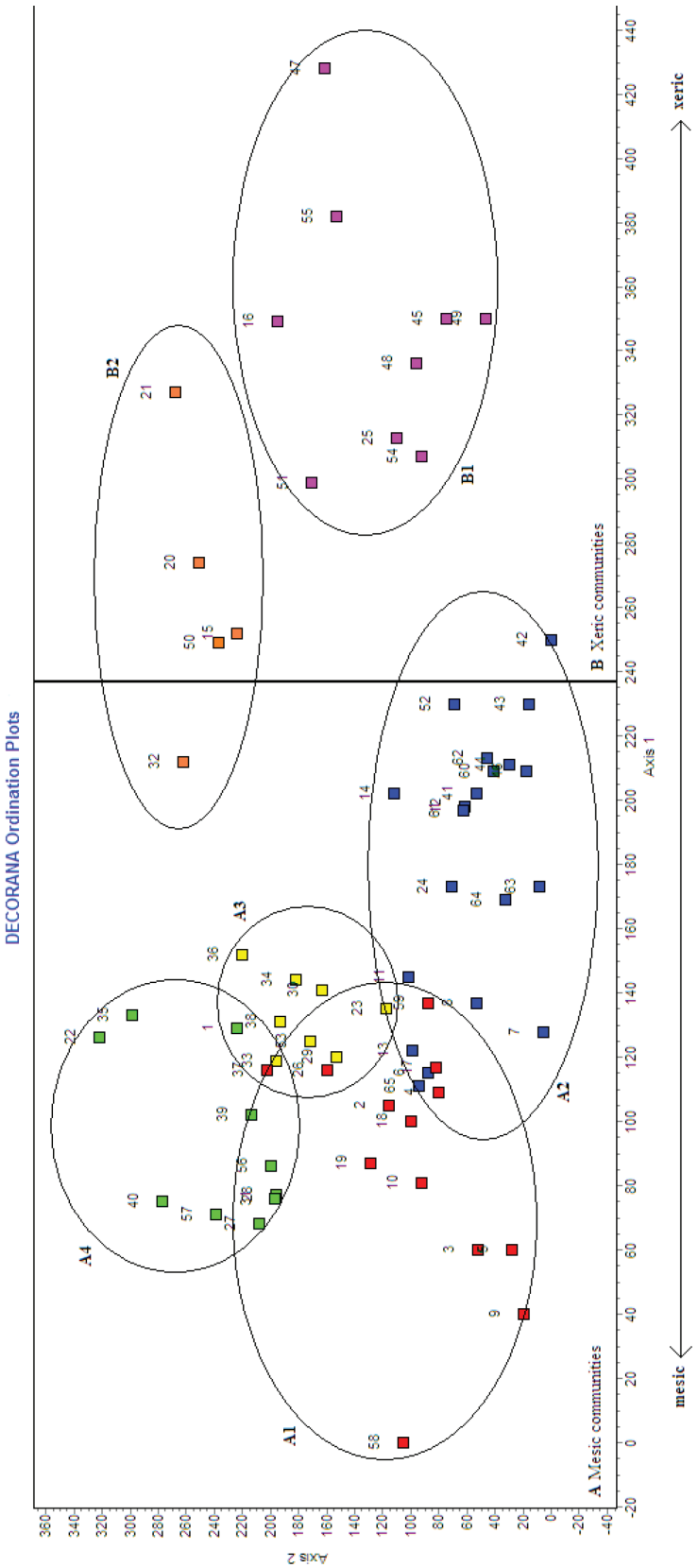

Figure 8. DECORANA ordination of epiphytic bryophyte communities for 65 relevés. The first axis spans mesic to xeric habitats on phorophytes.

species belonging to the subassociation (Figures 4–6).

When the habitat tendencies of the taxa found in the subassociation were evaluated, the presence of cortico-saxicolous taxa was 60%, while the epiphytes (obligate epiphytes) and indifferent species occurred at 20% (Figure 3). As a result, the syntaxon was determined as cortico-saxicolous.

In terms of ecological characteristics, the subassociation grows in mesophilic and semineutral shaded habitats in the study area (Figures 4–6). At the same time, the abundance of mesophilic and semineutral shaded habitats in the area provided favorable conditions for the growth of species belonging to the subassociation, such as *Isothecium alopecuroides*, *Eurhynchium striatum*, *Homomallium incurvatum*, *Plagiochila porelloides*, *Alleniella complanata*, and *Ptychostomum moravicum*.

3.2. Multivariate analysis

With the evaluation of the phytosociological data obtained from 65 relevés using multivariate classification techniques (TWINSPAN and DECORANA), the TWINSPAN analysis divided the data set into six vegetation subgroups at level 3 and two vegetation groups at level 2 (Figure 7). The TWINSPAN dendrogram shows that the similarity structure among the two main groups and six subgroups corresponds to the Braun-Blanquet classification (Figure 7). The first major epiphytic bryophyte community (group A) was characterized by the dominant mesophilic pleurocarpous species *Exertotheca crispa*, as well as an abundance of *Anomodon attenuatus*. Moreover, the majority of the species within the group were cortico-saxicolous. On the other hand, the second major group (group B) consisted of xerophytic species and was characterized by the acrocarpous species *Ulota crispa*, which occurs in compact tufts on the bark of trees (Figure 7).

The six TWINSPAN subclusters within the two major clusters were designated A1, A2, A3, A4, B1, and B2. The epiphytic bryophyte communities were then named according to the Braun-Blanquet approach. The A1 plant community *Anomodonto attenuati-Neckeretum crispae* was characterized by mesophilic and cortico-saxicolous species, such as *Exsertotheca crispa* and *Anomodon attenuatus* mosses and the liverwort *Radula complanata*, while the A2 community (*-leucodontetosum sciuroidis*) was characterized by the pleurocarpous moss *Leucodon sciuroides*, with a high presence (100%). Moreover, *Frullanio tamarisci-Exsertothecetum crispae* (group A3) was characterized by *Exertotheca crispa* and the strong competitor liverwort species *Frullania tamarisci*. The epiphytic community A4 (*Leucobryo-Tetraphidetum pellucidae*), on the other hand, was characterized by the hygromesophilic species *Tetraphis pellucida*, which grows on humid, acidic substrates and is more frequently found on well-rotted stumps and wood. Within this group (A4), the hygromesophilic species *Leucobryum juniperoideum* was codominant, while the other epiphytic bryophyte communities (groups B1 and B2) were characterized by the acrocarpous *Ulota crispa* and pleurocarpous *Isothecium alopecuroides*.

The DECORANA ordination of the 65 relevés and 51 species produced axis 1 and axis 2 with eigenvalues of 0.56 and 0.39; the ordination of the sample plots is shown in Figure 8. The application of DECORANA confirmed the separation of these communities and indicated relationships between the environmental gradients. In this regard, axis 1 of the DECORANA ordination was interpreted as a moisture gradient, from mesic to xeric. As far as the second ordination axis is concerned, the relevés tended to be ordinated as not clearly represented. The sample plots were not ordinated with respect to the ordination of tree diameter, phorophyte species, or height of the epiphytic habitat on the phorophyte.

In conclusion, the results from the multivariate classification techniques (TWINSPAN and DECORANA) applied in this study revealed that the effect of humidity of epiphytic habitats on the phorophyte was the most important environmental factor for the distribution and differentiation of epiphytic bryophyte communities.

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