ACTA BOTANICA CROATICA

CODEN: ABCRA 25
ISSN 0365-0588
eISSN 1847-8476

ACCEPTED AUTHOR VERSION OF THE MANUSCRIPT

The epiphytic bryophyte succession of *Buxus sempervirens* forests in the Fırtına Valley, Rize (North Türkiye)

DOI: 10.37427/botcro-2023-002

Tülay Ezer[1], Mevlüt Alataş[2], Nevzat Batan[3], Hüseyin Erata[4]

[1] Niğde Ömer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, 51100, Niğde, Türkiye
[2] Munzur University, Tunceli Vocational School, 62000, Tunceli, Türkiye
[3] Karadeniz Technical University, Maçka Vocational School, 61750, Trabzon, Türkiye
[4] Gümüşhane University, Kürtün Vocational School, 29810, Gümüşhane, Türkiye

Please cite this article as: Ezer T., Alataş M., Batan N., Erata H.: The epiphytic bryophyte succession of *Buxus sempervirens* forests in the Fırtına Valley, Rize (North Türkiye). Acta Bot Croat, DOI: 10.37427/botcro-2023-002.

The epiphytic bryophyte succession of *Buxus sempervirens* forests in the Fırtına Valley, Rize (North Türkiye)

Tülay Ezer[1], Mevlüt Alataş[2], Nevzat Batan[3], Hüseyin Erata[4*]

[1] Niğde Ömer Halisdemir University, Faculty of Architecture, Department of Landscape Architecture, 51100, Niğde, Türkiye
[2] Munzur University, Tunceli Vocational School, 62000, Tunceli, Türkiye
[3] Karadeniz Technical University, Maçka Vocational School, 61750, Trabzon, Türkiye
[4] Gümüşhane University, Kürtün Vocational School, 29810, Gümüşhane, Türkiye

*Corresponding author e-mail: huseyin__erata@hotmail.com

Running title: SUCCESSION OF EPIPHYTIC BRYOPHYTES IN TÜRKIYE

Abstract – In this study, the epiphytic bryophyte succession of the *Buxus sempervirens* L. forests in Fırtına Valley (Çamlıhemşin-Rize, North Türkiye), one of the nine biodiversity hotspots in Türkiye, were investigated. For this purpose, a total of 60 sampling plots were taken from the live trunks of the *B. sempervirens* trees of different ages. Twenty-nine epiphytic bryophyte species were determined (24 mosses and 5 liverworts) within the sample plots. Also, six different life form types and four different habitat affinity categories were determined. The mat type life form is in the first place with 34.4% whereas the and cortico-saxicolous species are the most common with 51.7%. Two-Way Indicator Species Analysis (TWINSPAN) classified the epiphytic bryophyte communities on the trunks of the *B. sempervirens* at the second level into two main clusters (A and B) and three sub-clusters (A1, B1 and, B2). Detrended Correspondence Analysis (DCA) axis 1 was interpreted as gradient along the height of the epiphytic habitat (from the lower base to the upper zone) on trunks and the DCA axis 2 was interpreted as gradient of moisture (from mesic to xeric). *Exsertotheca crispa* (Hedw.) S.Olsson, Enroth & D.Quandt was the species with the highest Index of Ecological Significance (IES) value on the lower bases of the aged trees. Species diversity and epiphytic cover in the upper zones were lower than in the basal and middle zones in the study area. While *Metzgeria furcata,* (L.) Corda*, Oxyrrhynchium hians* (Hedw.) Loeske, *Plagiothecium nemorale* (Mitt.) A.Jaeger, and *Radula lindenbergiana* Gottsche ex C.Hartm were only found on old trees, *Ctenidium molluscum* (Hedw.) Mitt. and *Pseudoleskeella nervosa* (Brid.) Nyholm were only found on middle-aged trees.

Keywords: community, index of ecological significance, liverworts, mosses, ordination analyses

Introduction

Bryophytes, the pioneer plants of different substrate types, are one of the most important component of forest ecosystems (Longton 1992, Baldwin and Bradfield 2005, Ezer 2017, Mellado-Mansilla et al. 2017). Bryophytes are poikilohydric organisms whose their moisture content rapidly equilibrating with environmental conditions (Green and Lange1994). Therefore, they are highly sensitive to environmental factors (Schofield 2001). In particular, abiotic ecological factors such as humidity directly or indirectly affect the colonization and the distribution of bryophytes in the epiphytic habitat (Mazimpaka and Lara 1995, Shofield 2001, Mishler 2003, Mazimpaka et al. 2009). In addition to environmental drought, phorophyte-type, physical and chemical properties of bark characteristics such as rugosity, water retention capacity, bark pH, and dust deposition are also important for the spatial distribution of bryophytes on epiphytic habitats (Lara and Mazimpaka 1998, Mazimpaka et al. 2010, Ezer 2017).

Some studies on the succession of epiphytic bryophyte communities have revealed that the succession gradient of epiphytes is highly complex due to changes in positive and negative interactions among species within epiphytic communities as trees age (Mazimpaka et al. 2010, Ódor et al. 2013, Bargali et al. 2014, Ezer 2017, Ezer et al. 2019).

Although phytosociological studies on epiphytic bryophytes in Türkiye have made progress in the last decade (Alataş et al. 2017, 2021, Alataş 2018, Can Gözcü et al. 2018), few studies have been on the spatial distributions and community composition of epiphytic bryophytes in successional stages (Ezer and Kara 2013, Ezer 2017, Ezer et al. 2019).

The present study focuses on the vertical distribution patterns of epiphytic bryophytes and community composition in the successional stages on trunks of *B. sempervirens* trees in Fırtına Valley. This study aimed to reveal the successional trends of bryophyte communities on the epiphytic habitats of boxwood trees and to contribution to the bryo-ecological studies in Türkiye.

The study area

The Çamlıhemşin (Rize, Türkiye) District, in which the study area is located, is surrounded by Pazar and Ardeşen to the north, Çayeli, Hemşin and İkizdere Districts to the west, and Artvin Province Yusufeli District to the east. The distance of the district to Rize city center is 62 km (Udgp 2006). The *B. sempervirens* forests, located in the Fırtına Valley and within the boundaries of the Çamlıhemşin District, are located within the A4 square according to the Henderson (1961) grid-square system and are in the colchic zone of the Euro-Siberian phytogeographic region (Anşin 1983, Fig. 1).

The Fırtına Valley, which exhibits a unique phytological diversity, hosts many rare species due to the presence of all the main habitats of the region. *Buxus sempervirens*, which has a very wide distribution in the Euro-Siberian Phytogeographic Region, form remarkable communities in the valley (Kurdoğlu et al. 2004). Moreover, in 1999, the WWW (World Wildlife Fund) identified Europe's 100 forest areas valuable in terms of biodiversity and in urgent need of protection (Myers et al. 2000). Nine of these areas, which are called "Hot Spots of European Forests", are located in Türkiye (Satar and Güneş 2014). One of these nine hot spots is the Fırtına Valley. Only one study on bryophytes has been conducted in the valley so far (Abay et al. 2006).

Fırtına Valley, as in the whole Eastern Black Sea Region, is a very open area to natural disasters such as landslides, rockfalls and avalanches due to very steep slope, rainy climatic conditions and, soil cover (Tunçel 1990).

Lithologically, there are units from almost all geological times in the valley (Bayrakdar 2006). In Türkiye, which is not rich in current glaciers, Kaçkar Mountains (3932 m) located in the south of the Fırtına Valley are one of the regions where current glaciers are found (Çiner 2003). The Kaçkar Mountains, the Verçenik (Üçdoruk)

Mountain, the Bulut Mountains and, the Altınparmak Mountains are mountain ranges that limit the study area in the SW-NE direction. In the valley, which is also very rich in terms of rivers, the Fırtına Stream is divided into branches at various degrees and forms the smaller Tunca, Hala, Palovit, Haçivanak and Hemşin creeks. These creeks also forked among themselves and surround the valley like a net system.

The forest formation, which starts at 200 m in the north of the study area, is very rich in terms of under-forest flora, depending on the oceanic and temperate climatic conditions in all seasons. This forest formation, which is dominated by wide-leafy trees, loses its colchic feature with the increase in altitude and leaves its place to mixed forests and then to coniferous forests (Özçağlar et al. 2006). The vegetation in the Fırtına Valley shows a distinct difference from other valleys, especially with certain forest formations and flora richness. There are basically three types of forest formations such as alluvial forests which are a hardwood forest found in river floodplains, and are regularly flooded for a portion of the growing season, boxwood forests and old growth forest formations in the Fırtına Valley (Kurdoğlu et al. 2004).

The *B. sempervirens* forests spread along the Fırtına Stream and its tributaries, between 200-1500 meters of the study area. Although these forests are seen along the streams, they are also found in large groups on the valley slopes. These forests are widely found between 900-1300 meters along the Çamlıhemşin-Meydan road, in Şimşirlik place, within the Kito Forests and Palovit Valley.

The climate of the study area is generally temperate Oceanic climate. The annual average precipitation is 2192 mm and, the annual average temperature is 8.3 ºC in Çamlıhemşin. The hottest month of the year is August and the coldest is January. The absence of a dry season indicates that the Fırtına Valley is under the influence of Oceanic climate (Akman 2011).

Materials and methods

Field sampling procedures

The epiphytic bryophyte specimens were collected from the living trunks of *B. sempervirens* in Fırtına Valley during the field studies in 2020. The locality details are given in Tab. 1. A total of 60 sampling plots taken in 20 from boxwood trees of different ages were sampled within the valley. Spatial distributions and community structures of epiphytic bryophytes in successional stages on boxwood trees were investigated according to tree diameter at breast height (dbh) and tree age. The trees were divided into three age classes using an indirect method as young (dbh 20-35 cm, 21 plots), middle-aged (dbh 40-50 cm, 18 plots), and aged trees (dbh 60-80 cm, 21 plots). Each boxwood tree was divided into the lower base zone (0-40 cm from the ground), the middle zone (40-120 cm), and the upper zone (120-180 cm) as proposed by Moe and Botnen (2000).

Sampling plots from tree zones were defined by 20 × 20 cm^2 which, was determined depending on the species diversity in the living trunks of *B. sempervirens* The sample plots were not taken from the branches of the boxwood trees in the present study, but only from the trunks. The percentage cover of the species within the each sample plot was visually estimated and ecological data such as humidity, aspect and light of the epiphytic habitat were recorded.

The nomenclature of the epiphytic bryophyte species determined within the sample plots follows Ros et al. (2013) and Hodgetts et al. (2020) (Tab. 2). Habitat affinity types of bryophytes were established following Mazimpaka and Lara (1995) and Draper et al.

(2003). Life forms of the taxa were determined according to Mägdefrau (1982). Voucher specimens were deposited in the herbarium of Niğde Ömer Halisdemir University.

Data analysis

The relative frequency of each taxa in the sample plots was determined by the Index of Ecological Significance (IES) described by Lara and Mazimpaka (1998), Albertos et al. (2001) and Mazimpaka et al. (2009). The formula used to calculate the IES values for each taxon is as follows:

$$IES = F\,(1 + C)$$
$$C = \Sigma\, ci / x$$

where F is the relative frequency (100 x / n), and C is the cover of the taxon (Σ ci / x). x represents the number of sample plots containing the taxon, n is total number of sample plots, and ci is cover class assigned to the taxon in each sample plot. Cover classes of taxa were established using the six-point Lara and Mazimpaka (1998) scale [0.5 (< 1%), 1 (1-5%), 2 (6-25%), 3 (26-50%), 4 (51-75%) and, 5 (76-100%)]. In addition, the IES values were combined in the following abundance classes: very scarce (< 25), scarce (26-50), moderately abundant (51-100), abundant (101-200), and dominant (> 200).

Here, TWINSPAN and DECORANA (Hill 1979, Seaby and Henderson 2007) were used to explore the community composition and spatial patterns of epiphytic bryophyte communities and their relationship with the associated environmental factors of the epiphytic habitat. In this context, TWINSPAN and DECORANA were applied to the matrix of cover in 60 sample plots according to the computer program CAP (Community Analysis Package-5) of Seaby and Henderson (2007).

Results

Floristical results

Twenty-nine species belonging to 17 families and 25 genera were determined as a result of the identifications of 362 specimens. Among them 24 are mosses (21 pleurocarpous and 3 acrocarpous), and 5 are liverworts. Neckeraceae (6 species, 20.6%) and Brachytheciaceae (5 species, 17.2%), both pleurocarpous moss families, are the most species-rich families found in epiphytic habitats on boxwoods trees in the study area (Tab. 2). *Exsertotheca crispa* (Hedw.) S.Olsson, Enroth & D.Quandt is the most common species in the *B. sempervirens* forests of Fırtına Valley.

Ecological results

A total of six different life forms were determined. Among them, the mat life from prevailed (34.4%), followed by the weft life form (24.1%). The life form dendroid was negligible (3.4%) (Tab. 2). In addition, four different habitat affinity categories as cortico-saxicolous, indifferent, customary epiphyte and, preferentially not corticolous were determined belonging to the species. While cortico-saxicolous species were the most common with 51.7% within the sample plots, preferentially not corticolous type habitat affinity is least common with one species (Tab. 2).

Lower base

The spatial distributions and community structures analyses showed that a total of 11 species, all of them are mosses, were found on the base zone of young boxwood trees (dbh 20-35 cm). Among of the mosses *E. crispa* was the most frequent and the most dominant one with the highest IES value (271). *Isothecium alopecuroides* was co-dominant with 214 IES values. *Homalia trichomanoides* and *Sciuro-hypnum flotowianum* were abundant species with 171 and 143 IES values on the lower base of trunks of *B. sempervirens*. *Brachythecium rutabulum, S. populeum* and *Thamnobryum alopecurum* which have the lowest IES values (43) were scarce on lower base (Tab. 3). Whereas the weft life form was the most dominant (36.3%) in the base zone, the life forms mat and fan were co-dominant (27.2%). Also, the cortico-saxicolous type habitat affinity of the species was the most common with 54.5% on the base zones of the young boxwood trees.

Fifteen mosses were collected from the lower base of the middle-aged *B. sempervirens* (dbh 40-50 cm). Among them, *E. crispa* (266 IES value) and *H. trichomanoides* (216 IES value) were the most dominant two species. *Sciuro-hypnum flotowianum* was the most abundant on the base zones of the middle-aged trees with the 183 IES value. *Anomodon viticulosus, Pseudoleskeella nervosa* and *S. populeum* were scarce with the lowest IES values (33). Moreover, *Ctenidium molluscum* and *P. nervosa* were only found on the lower bases of middle-aged trees (Tab. 3). While the life form fan is the most dominant (33.3%), the life forms mat and weft were co-dominant (26.6%) on the lower base of middle-aged boxwood trees. Cortico-saxicolous type affinity of epiphytic habitats (60%) were the most common on the basal zone of middle-aged trees conspicuously.

Twelve species (11 mosses, one liverwort) were determined on the lower bases of aged boxwood trees (dbh 60-80 cm). Only one of them was liverwort, whereas the others were mosses. *Exsertotheca crispa* was still the most frequent and the most dominant with the highest IES value (371). This value is also the highest among all tree-size groups (Tab. 3). While, *Hypnum cupressiforme, I. alopecuroides, Pseudanomodon attenuates* and, *S. flotowianum* were abundant, *Fissidens serrulatus, Oxyrrhynchium hians* and, *Plagiothecium nemorale* usually not epiphytic, were scarce with the lowest IES values (28). The life form mat was the most dominant with 41.6% and cortico-saxicolous species (50%) were still the most common on base zones of aged *B. sempervirens*.

Middle zone

Twelve species (11 mosses, one liverwort) were determined on the middle zones of the young boxwood trees. *Alleniella besseri* and *A. complanata* were the most frequent and the most dominant with the highest IES values (328). While *E. crispa* was co-dominant with 314 IES values, *Radula complanata* (200), *P. attenuatus* (128) and, *Palamacladium euchloron* (128) were abundant on the middle parts on the trunks of the young *B. sempervirens* (Tab. 3). The life form mat with 33.3% and the cortico-saxicolous type habitat affinity with 83.3% were still most dominant on middle parts on trunks of the young boxwood trees.

Twelve species were collected from the middle zones of the middle-aged boxwood trees. *Alleniella besseri* was the most dominant with the highest IES values (316). *Alleniella complanata* and *E. crispa* were co-dominant, both with 266 IES values. *Frullania tamarisci, I. alopecuroides* and, *Pseudoamblystegium subtile* were scarce with the same IES values (33) on the middle zones of middle-aged trees (Tab. 3). The life form mat was the most dominant with 41.6% and the cortico-saxicolous species were conspicuously the most common with the rate of 91.6% on middle parts of the middle-aged *B. sempervirens*.

A total of sixteen species, five of which were liverworts, were determined in the middle zones of the aged boxwood trees. All of the liverworts, which were determined in the epiphytic habitats of the boxwood forests, were found on the middle parts of the old trees. While, *A. complanata* was the most frequent and the most dominant with the highest IES value (342), *E. crispa* and *A. besseri* were co-dominant with the same IES values (314) (Tab. 3). The life form mat (50%) and the cortico-saxicolous type affinity (68.75%) were the most dominant on the middle zones of aged trees.

Upper zone

Ten species were found on the upper zones of young trees. Among them, eight were mosses and, two were liverworts. *Exsertotheca crispa* was still the most frequent and the most dominant with the highest IES value (357). *Alleniella complanata, A. besseri* and, *Leucodon sciuroides* were co-dominant with the higher IES values (>200) on the upper zones of the young *B. sempervirens.* While *Orthotrichum pumilum* (IES value 200), *Ulota crispa* (200) and, *R. complanata* (114) were abundant on these zones, *S. flotowianum* (28) was scarce with the least IES value (Tab. 3). The life form mat (40%) and the habitat affinity type cortico-saxicolous (70%) were the most common on the upper parts of young trees.

Eleven species (nine mosses, two liverworts) were collected from upper zones of the middle-aged boxwood trees. While *E. crispa* was still the most frequent and the most dominant with the highest IES value (366), *A. besseri*, *A. complanata* and, *L. sciuroides* were co-dominant (> 200). And also, *U. crispa* (167) was abundant on the upper zones of the middle-aged *B. sempervirens* (Tab. 3). The mats (45.45%) and cortico-saxicolous species (72.72%) were the most dominant.

A total of thirteen species were determined on the upper zones of the old *B. sempervirens*. Among them, four were liverworts and nine were mosses. *Alleniella complanata* was the most frequent and the most dominant with the highest IES value (342). While, *A. besseri* (IES value 300), *E. crispa* (328) and, *L. sciuroides* (300) were co-dominant with the higher IES values, *O. pumilum* (200), *R. complanata* (143) and, *U. crispa* (200) were abundant on the upper parts of aged boxwood trees (Tab. 3). The life form mat (30.7%) and the habitat affinity type cortico-saxicolous (53.8%) were the most common again on the upper parts of old trees.

TWINSPAN classification

TWINSPAN classified the epiphytic bryophyte communities on the trunks of *B. sempervirens* in the Fırtına Valley at the second level into two main clusters (A and B) and three sub-clusters (A1, B1 and, B2) (Fig. 2). These main and sub-clusters were named according to the dominant, co-dominant and abundant species which were the distinctive species within the communities. The main cluster A occurred of lower-base communities and it was characterized by dominant species *E. crispa* and *H. trichomanoides*, co-dominant *I. alopecuroides* and abundant *P. attenuatus* and *S. flotowianum*. The second main cluster B occurred of middle and upper zones communities. Cluster B was characterised by dominant species *A. besseri* and *A. complanata*, co-dominant *E. crispa* and *L. sciuroides,* abundant species *O. pumilum, P. euchloron*, *R. complanata*, and *U. crispa*.

Epiphytic bryophyte communities

The A1 community was named as *Exsertotheca crispa-Isothecium alopecuroides* due to the frequency, constancy and, dominancy of these species within the lower-base community. Both of *E. crispa* and *I. alopecuroides* had the highest IES value on the lower bases of all tree-size groups (young, middle-aged and, old boxwood trees) (Tab. 3). The community was represented with 19 moss species in a total of 20 sample plots. Moderately abundant *R. complanata* was the only liverwort in the lower-base community. *Exsertotheca crispa-Isothecium alopecuroides* community was co-dominated by *H. trichomanoides*. In this community, *P. attenuatus* and *S. flotowianum* were also abundant. While the dominant life forms within the community were weft and mat (31.5%), cortico-saxicolous species (47.3%) were dominant and indifferent type affinity was also co-dominant (42.1%).

The B1 community was named as *Alleniella complanata-Exsertotheca crispa* according to its dominant and co-dominant species. It was represented with 19 species (15 mosses, 4 liverworts) in a total of 17 sample plots from the middle parts of the young, middle-aged and old boxwood trees. The liverwort *R. complanata* was still present in the middle parts of the trunks with relatively high IES values. Also, *P. euchloron* was abundant in the community B1 on middle zones of young and middle-aged trees particularly (Table 3). While mats were the most dominant with the rate of 42.1% within the middle parts of community B1, the cortico-saxicolous species were the most common with 63.1%.

The B2 community was named as *Alleniella besseri-Leucodon sciuroides* according to its co-dominant species. This community, consisting of 17 species (13 mosses and four liverworts), was found on the upper zones of boxwood trees. The community B2 was represented by a total of 23 sample plots. *Orthotrichum pumilum*, *R. complanata*, and *U. crispa* were abundant species in the upper zones community. While mats were the most dominant with the rate of 41.1% within the middle parts of community B2, the cortico-saxicolous type habitat affinity was the most common with 70.5%.

DECORANA ordination

The DECORANA grouped the sample plots on axis 1 and axis 2 according to the similarity and the environmental gradients (Fig. 3). While the DCA axis 1 was interpreted as gradient along the height of the epiphytic habitat (from the lower base to the upper zone) on trunks and the DCA axis 2 was interpreted as gradient of moisture (from mesic to xeric) (Fig. 3).

Discussion

When the epiphytic habitats on the boxwood trees in the Fırtına Valley were examined in terms of species diversity and species composition, while the lower bases and the middle-parts were the richest zones with equal number of species (19 species), the upper zones contains 17 epiphytic species. Large pleurocarp mosses such as *E. crispa*, *H. trichomanoides,* and *I. alopecuroides* were common on the basal parts of the trunks of *B. sempervirens*. These strong competitor members of pleurocarpous type mosses are more sensitive to drought, have a faster growth habit than acrocarpous mosses and spreads horizontally in a carpet-like appearance on the substratum (Schofield 2001, Ezer 2017). The basal parts of the trunks are usually more humid and more nutrient rich when compared with the other parts (middle and upper) due to soil proximity. Therefore, basal zones allow early establishment and rapid colonization of bryophytes due to higher water retention capacity, higher soil humidity, low evapotranspiration rate and low insolation

(Lara and Mazimpaka 1998, Mazimpaka et al. 2009, Ezer and Kara 2013, Ezer 2017). In this respect, the lower base parts of the trees can be considered as an extension of the forest floor (groundlayer) environment. For this reason, species such as *B. rutabulum, C. molluscum*, *O. hians, P. nemorale, P. nervosa, S. populeum, T. alpecurum*, *Thuidium delicatulum,* and *F. serrulatus*, which usually grows on the soil, were encountered only in this part. This caused the weft life form and indifferentt type habitat affinity to co-dominate with the mats and cortico-saxicolous species were the strong competitor robust pleurocarpous in basal parts of boxwood trees.

Alleniella besseri, *A. complanata* and *E. crispa* were most dominant on the middle zones of the boxwood trees. Also, the mesophytic species *P. euchloron*, which was not present in the base zone, was abundant in the middle zone. Therefore, *P. euchloron* can be considered as the characteristic and distinctive species of the communities in the middle zones. The customary epiphyte xerophytic species *O. pumilum*, which in the present study was generally abundant in the upper zones, in the present study was found for the first time only in the middle zones of old trees. As the middle and upper parts of the trunks move away from the soil effect, they are periodically exposed to higher insolation and desiccation that makes it difficult to colonize of the species on epiphytic habitats (Moe and Botnen 2000). Therefore, as in the present study, small cushion-type mosses which have xerophytic characters such as Orthotrichaceae members and photophilous or heliophilous species such as *A. besseri*, *A. complanata,* and *L. sciuroides* are most common species within the middle and upper zone communities. Mat type life form were predominant in the middle parts of old trees, due to the presence of cortico-saxicolous liverworts.

Although mesoscale climatic factors such as seasonal climatic variables are among the most important determinants of bryophyte species richness and species diversity, forest structure and habitat characteristics are also important for community compositions and spatial distributions of epiphytic bryophytes on epiphytic habitats (Medina et al. 2014, Ezer 2017). Species diversity and epiphytic cover on the upper zones were found to be lower than in the base and middle zones. The xerophytic robust pleurocarpic species *L. sciuroides* was dominant on the upper parts on of all tree-size groups. Besides, *A. besseri*, *A. complanata* and *E. crispa* were other dominant peurocarpic species in the upper zones of boxwood trees in the Fırtına Valley. Therefore, weak competitor species such as liverworts *Frullania dilatata* and *Metzgeria furcata* and small cushion-type mosses (such as *O. pumilum* and *U. crispa*) remain under these large pleurocarpous and decreased or disappeared from the epiphytic habitats in the valley.

Some studies on the succession of epiphytic bryophyte communities have demonstrated that variables of the epiphytic bryophyte composition in the successional stages are closely related to tree age, trunk height (basal, middle and upper zones) and bark characteristics (Lara and Mazimpaka 1998, Mazimpaka et al. 2010, Ódor et al 2013, Bargali et al. 2014, Ezer 2017). However, in the present study, trunk height rather than tree age and bark characteristics were effective in the variability of epiphytic bryophyte composition in the per successional stage. Hygrophytic pleurocarpous species that usually growing on soil, such as *B. rutabulum*, *C. molluscum*, *F. serrulatus, O. hians*, *P. nemorale P. nervosa*, *S. populeum*, *T. alpecurum*, and *T. delicatulum* were particularly the pioneer colonizers in the early successional stages on the basal parts of middle aged *B. sempervirens* particularly. While the xerophytic small cushions *O. pumilum* and *U. crispa* were the pioneer colonizers in the early successional stages, large pleurocarpous *L. sciuroides* was secondary colonizer in the advanced stages on the upper parts of all tree-size groups. In addition, cortico-saxicolous species *P. euchloron*, characteristic and distinctive species on the middle zones, was pioneer colonizers in the early successional stages on the middle parts of all tree-size groups. In this study, *A. besseri, A. complanata*, and *E. crispa* were other colonizers in the advanced successional stages on the middle zones. Considering the morphological physiognomy of the bryophyte communities on trunks of *B. sempervirens* in the Fırtına Valley; all communities were dominated by large pleurocarpous mosses. Especially, *E. crispa* was the most constant and the most dominant one within all communities in the *B. sempervirens* forests. In sum, the succession of the epiphytic bryophyte communities of the boxwood forests in the Fırtına Valley has reached the climax.

References

Abay, G., Uyar, G., Çetin, B., Keçeli, T., 2006: The moss flora of the communities of *Buxus sempervirens* L. in Fırtına Valley (Çamlihemşin, Rize). Süleyman Demirel University Journal of the Faculty of Forestry A (2), 37–49 (in Turkish).

Akman, Y. 2011: Climate and Bioclimate (Bioclimate methods and Climates of Turkey). Palme Publishing, Ankara (in Turkish).

Alataş, M., Batan, N., Ezer, T., Uyar, G., 2017: The epiphytic bryophyte flora and vegetation of Boraboy and Destek Forests (Amasya, Turkey). Pakistan Journal of Botany 49, 1779–1786.

Alataş, M., 2018: Checklist of Turkish bryophyte vegetation. Botanica Serbica 42, 173–179.

Alataş, M., Batan, N., Ezer, T., Özdemir, T., Erata H. 2021: Epiphytic bryophyte communities of forests dominated by *Alnus glutinosa* (L.) Gaertner in Altindere Valley National Park (Trabzon, Turkey). Cryptogamie, Bryologie 42, 155–167.

Albertos, B., Garilleti, R., Draper, I., Lara, F., Mazimpaka, V., 2001: Index of ecological significance (IES), a useful tool for the estimate of relative abundance of bryophyte populations. Novitates botanicae Universitatis Carolinae 15, 69–76.

Anşin, R., 1983: Flora regions of Turkey and primary vegetation types spread to these regions. Karadeniz University Journal 6, 318–339 (in Turkish).

Baldwin, L.K., Bradfield, G.E. 2005: Bryophyte community differences between edge and interior environments in temperate rain-forest fragments of coastal British Columbia. Canadian Journal of Forest Research 35, 580–592.

Bargali, R., Awasthi, V., Pande, N., 2014: Ecological study of bryophytes on *Platanus orientalis* L. trees in Nainital (Western Himalaya). American Journal of Plant Sciences 5, 3880–3888.

Bayrakdar, C., 2006: Applied Geomorphology Study of the Fırtına Stream Basin. Istanbul University, Istanbul University Institute of Social Sciences, MSc Thesis (in Turkish).

Can Gözcü, M., Uyar, G., Alataş, M., Ezer, T., Ören, M., 2018: Epiphytic bryophyte vegetation of the Samanlı Mountains (Sakarya-Kocaeli-Yalova-Bursa) in Northwest Turkey. Botanica Serbica 42(2), 157–171.

Çiner, A., 2003: Current glaciers of Turkey and Late Quaternary glacial sediments. Türkiye Jeoloji Bülteni 46, 55–78 (in Turksih).

Draper, I., Lara, F., Albertos, B., Garilleti, R., Mazimpaka, V., 2003: The epiphytic bryofora of the Jbel Bouhalla (Rif, Morocco), including a new variety of moss, *Orthotrichum speciosum* var. *brevisetum.* Journal of Bryology 25, 271-280.

Ezer, T., Kara, R., 2013: Succession of epiphytic bryophytes in *Cedrus libani* forest on the Meydan Plateau (Aladağ). Turkish Journal of Botany 37, 389–397.

Ezer, T., 2017: Epiphytic bryophyte communities and succession on *Platanus orientalis* trees in Kadıncık Valley (Mersin/Turkey). Pakistan Journal of Botany 49, 623–630.

Ezer, T., Alataş, M., Batan, N., 2019: Successional trends of some epiphytic bryophytes in Mediterranean Basin. Acta Biologica Turcica 32, 181–193.

Green, T.G.A., Lange, O.L. 1994: Photosynthesis in poikilohydric plants: a comparison of lichens and bryophytes. In: Schulze, E.D., Caldwell, M.M. (eds.), Ecophysiology of photosynthesis, 319–337. Springer, Berlin.

Henderson, D.M., 1961: Contribution to the bryophyte flora of Turkey: IV. Notes Royal Botanic Garden, Edinburgh 23, 263–278.

Hill, M.O., 1979: TWINSPAN: AFORTRAN program for arranging multivariate data in ordered two-way table by classification of the individuals and attributes. Ecology and Systematics. Cornell University, Ithaca, NY.

Hodgetts, N.G., Söderström, L., Blockeel, T.L., Caspari, S., Ignatov, M.S., Konstantinova, N.A., Lockhart, N., Papp, B., Schröck, C., Sim-Sim, M., Bell, D., Bell, N.E., Blom, H.H., Bruggeman-Nannenga, M.A., Brugués, M., Enroth, J., Flatberg, K.I., Garilleti, R., Hedenäs, L., Holyoak, D.T., Hugonnot, V., Kariyawasam, I., Köckinger, H., Kučera, J., Lara, F., Porley, R.D., 2020: An annotated checklist of bryophytes of Europe, Macaronesia and Cyprus. Journal of Bryology 42, 1–116.

Kurdoğlu, O., Kurdoğlu, B., Eminağaoğlu, Ö., 2004: The Importance of Kaçkar Mountains National Park for the Protection of Natural and Cultural Values and Current Environmental Threats, Eastern Black Sea Forestry Research Journal 21, 134–150 (in Turkish).

Lara, F., Mazimpaka, V., 1998: Succession of epiphytic bryophytes in a *Quercus pyrenaica* forest from the Spanish Central Range (Iberian Peninsula). Nova Hedwigia 67, 125–138.

Longton, R.E. 1992: The role of bryophytes and lichens in terrestrial ecosystems. In: Bates, J.W., Farmer, A.M. (eds.), Bryophytes and Lichens in a Changing Environment, 32–76. Clarendon Press, Oxford.

Mägdefrau, K., 1982: Life forms of bryophytes. In: Smith, A.J.E. (ed.), Bryophyte ecology. Chapter 2, 45–58. Chapman and Hall, London.

Mazimpaka, V., Lara, F., 1995: Corticolous bryophytes of *Quercus pyrenaica* forests from Gredos Mountains (Spain): vertical distribution and ecological afnity for epiphytic habitats. Nova Hedwigia 61, 431–446.

Mazimpaka, V., Medina, N.G., Draper, I., Lara, F., 2009: Epiphytic bryophyte fora in dry environments from the Western Mediterranean: The special case of Sierra Alhamilla (Almeria, South-eastern Spain). Plant Biosystems 143, 113–125.

Mazimpaka, V., Medina, N.G., Lo Guidice, R., Garilleti, R., Lara F., 2010: Tree age-dependent changes among epiphytic bryophyte communities in Mediterranean environments. A case study from Sicily (Italy). Plant Biosystems 144, 241–249.

Medina, N.G., Albertos, B., Lara, F., Mazimpaka, V., Garilleti, R., Draper, D., Hortal, J., 2014: Species richness of epiphytic bryophytes: Drivers across scales on the edge of the Mediterranean. Ecography 37, 80–93.

Mellado-Mansilla, D., León, C.A., Ortega-Solís, G., Godoy-Güinao, J., Moreno, R., Díaz, I.A., 2017: Vertical patterns of epiphytic bryophyte diversity in a montane

Nothofagus forest in the Chilean Andes. New Zealand Journal of Botany 55, 514–529.
Mishler, B.D., 2003: The biology of bryophytes, with special reference to water. Fremontia 31, 34–38.
Moe, B., Botnen, A., 2000: Epiphytic vegetation on pollarded trunks of *Fraxinus excelsior*in four different habitats at Grinde, Leikanger, western Norway. Plant Ecology 151, 143–159.
Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A., Kent, J., 2000: Biodiversity hotspots for conservation priorities. Nature 403, 853–858.
Ódor, P., Király, I., Tinya, F., Bortignon, F., Nascimbene, J., 2013: Patterns and drivers of species composition of epiphytic bryophytes and lichens in managed temperate forests. Forest Ecology and Management 306, 256–265.
Özçağlar, A., Özgür, E.M., Somuncu, M., Bayar, R., Yılmaz, M., Yüceşahin, M.M., Yavan, N., Akpinar, N., Karadeniz, N., 2006: Land use decisions developed based on natural and human resources determination in Çamlıhemşin District. Coğrafi Bilimler Dergisi 4, 1–27 (in Turkish).
Tunçel, H., 1990: Avalanches as a natural environmental problem and avalanche events in Turkey. Atatürk Culture, Language and History High Institution, Geography Science and Practice Branch. Coğrafya Araştırmaları Dergisi 2, 43–70 (in Turkish).
Ros, R.M., Mazimpaka, V., Abou-Salama, U., Alefi, M., Blockeel, T.L., Brugués, M., Cros, R.M., Dia, M.G., Dirkse, G.M., Draper, I., El-Saadawi, W., Erdağ, A., Ganeva, A., Gabriel, R., González-Mancebo, J.M., Granger, C., Herrnstadt, I., Hugonnot, V., Khalil, K., Kürschner, H., Losada-Lima, A., Luís, L., Mifsud, S., Privitera, M., Puglisi, M., Sabovljević, M., Sérgio, C., Shabbara, H. M., Sim-Sim, M., Sotiaux, A., Tacchi, R., Vanderpoorten, A., Werner, O., 2013: Mosses of the Mediterranean, an annotated checklist. Cryptogamie Bryologie 34, 99–283.
Satar, İ., Güneş, G., 2014: Turkey's Biodiversity Hotspots. Nature and Human 48, 22–34. (in Turkish).
Seaby, R., Henderson, P., 2007: Community Analysis Package 4.0: searching for structure in community data. PISCES Conservation Ltd., Lymington, UK.
Schofield, W.B., 2001: Introduction to Bryology. The Blackburn Press, New Jersey.
Udgp (Long Term Development Plan), 2006: Kaçkar Mountains National Park long-term development plan. Ministry of Environment, Forestry, General Directorate of Natural Life Conservation and National Parks, Ankara (in Turkish).

Tab. 1. Sampling localities and their characteristics.

Localities		Altitude (m)	Date	GPS Coordinates
1	Çat Valley, Doğa Village	1275	17.05.2020	N 40º51'48.95" E 40º55'58.08"
2	Between Çatköy and Meydanköy	1231	17.05.2020	N 40º51'59.44" E 40º55'46.26"
3	Meydanköy Exit	1176	17.05.2020	N 40º52'13.82" E 40º55'37.52"
4	Meydanköy	1108	26.08.2020	N 40º52'48.29" E 40º55'43.37"
5	Meydankoy Entrance	1061	26.08.2020	N 40º53'20.49" E 40º55'51.11"
6	Meydanköy, Pul Place	1026	26.08.2020	N 40º53'40.83" E 40º56'31.71"
7	Gito Plateau- Southeast slopes	1018	09.10.2020	N 40º54'18.08" E 40º56'52.30"
8	Between Zilkale and Meydanköy	1004	09.10.2020	N 40º54'27.30" E 40º56'53.71"
9	Zilkale Place	956	09.10.2020	N 40º54'47.61" E 40º56'52.38"

Tab. 2. List of epiphytic bryophyte species found on the *Buxus sempervirens* trees, their families and life form types and affinity for epiphytic habitats (Mägdefrau 1982, Mazimpaka and Lara 1995, Draper et al. 2003).

Species	Family	Life Form	Affinity for Epiphytic Habitats	Frequency (%)
MOSSES				
Alleniella besseri (Lobarz.) S.Olsson, Enroth & D.Quandt	Neckeraceae	fan	Cortico-saxicolous	65
Alleniella complanata (Hedw.) S.Olsson, Enroth & D.Quandt	Neckeraceae	fan	Cortico-saxicolous	76.6
Anomodon viticulosus (Hedw.) Hook. & Taylor	Anomodontaceae	tail	Cortico-saxicolous	3.3
Brachythecium rutabulum (Hedw.) Schimp.	Brachytheciaceae	weft	Preferantially not corticolous	5
Ctenidium molluscum (Hedw.) Mitt.	Myuriaceae	weft	Indifferent	3.3
Exsertotheca crispa (Hedw.) S.Olsson, Enroth & D.Quandt	Neckeraceae	fan	Cortico-saxicolous	93.3
Fissidens serrulatus Müll.Hal.	Fissidentaceae	fan	Indifferent	5
Homalia trichomanoides (Hedw.) Brid.	Neckeraceae	fan	Cortico-saxicolous	16.6
Hypnum cupressiforme Hedw.	Hypnaceae	weft	Indifferent	20
Isothecium alopecuroides (Lam. ex Dubois) Isov.	Lembophyllaceae	mat	Cortico-saxicolous	28.3
Leucodon sciuroides (Hedw.) Schwägr.	Leucodontaceae	tail	Cortico-saxicolous	33.3
Orthotrichum pumilum Sw. ex anon.	Orthotrichaceae	cushion	Customary epiphyte	30
Oxyrrhynchium hians (Hedw.) Loeske	Brachytheciaceae	weft	Indifferent	1.6
Palamocladium euchloron (Müll.Hal.) Wijk & Margad.	Brachytheciaceae	tail	Cortico-saxicolous	15
Plagiothecium nemorale (Mitt.) A.Jaeger	Plagiotheciaceae	mat	Indifferent	1.6
Pseudanomodon attenuatus (Hedw.) Ignatov & Fedosov	Neckeraceae	mat	Cortico-saxicolous	31.6
Pseudoamblystegium subtile (Hedw.) Vanderp. & Hedenäs	Amblystegiaceae	weft	Cortico-saxicolous	6.6
Pseudoleskeella nervosa (Brid.) Nyholm	Pseudoleskeellaceae	mat	Cortico-saxicolous	1.6

Pterigynandrum filiforme Hedw.	Pterigynandraceae	tail	Cortico-saxicolous	6.6
Sciuro-hypnum flotowianum (Sendtn.) Ignatov & Huttunen	Brachytheciaceae	mat	Cortico-saxicolous	35
Sciuro-hypnum populeum (Hedw.) Ignatov & Huttunen	Brachytheciaceae	weft	Indifferent	3.3
Thamnobryum alopecurum (Hedw.) Gangulee	Neckeraceae	dendroid	Indifferent	5
Thuidium delicatulum (Hedw.) Schimp.	Thuidiaceae	weft	Indifferent	6.6
Ulota crispa (Hedw.) Brid.	Orthotrichaceae	cushion	Customary epiphyte	31.6
LIVERWORTS				
Frullania dilatata (L.) Dumort	Frullaniaceae	mat	Cortico-saxicolous	10
Frullania tamarisci (L.) Dumort.	Frullaniaceae	mat	Cortico-saxicolous	8.3
Metzgeria furcata (L.) Dumort.	Metzgeriaceae	mat	Indifferent	5
Radula complanata (L.) Dumort	Radulaceae	mat	Customary epiphyte	51.6
Radula lindenbergiana Gottsche ex C.Hartm.	Radulaceae	mat	Customary epiphyte	1.6

Tab. 3. Index of ecological significance (IES) values in each tree-size groups according to tree diameter at breast height (dbh) and tree age at lower base, middle zone and top zone.

	Young trees (dbh 20-35 cm)			Middle-aged trees (dbh 40-50 cm)			Aged trees (dbh 60-80 cm)		
Species	**Lower base**	**Middle zone**	**Upper zone**	**Lower base**	**Middle zone**	**Upper zone**	**Lower base**	**Middle zone**	**Upper zone**
Mosses									
Alleniella besseri	-	328	271	50	316	233	-	314	300
Alleniella complanata	100	328	285	115	266	250	71	342	342
Anomodon viticulosus	-	43	-	33	-	-	-	-	-
Brachythecium rutabulum	43	-	-	50	-	-	57	-	-
Ctenidium molluscum	-	-	-	67	-	-	-	-	-
Exsertotheca crispa	271	314	357	266	216	366	371	314	328
Fissidens serrulatus	-	-	-	67	-	-	28	-	-
Homalia trichomanoides	171	-	-	216	50	-	57	-	-
Hypnum cupressiforme	71	71	-	-	-	-	128	114	28
Isothecium alopecuroides	214	43	-	130	33	33	171	85	-
Leucodon sciuroides	-	-	257	-	50	300	-	-	300
Orthotrichum pumilum	-	-	200	-	-	100	-	28	200
Oxyrrhynchium hians	-	-	-	-	-	-	28	-	-
Palamacladium euchloron	-	128	-	-	150	-	-	85	28
Plagiothecium nemorale	-	-	-	-	-	-	28	-	-
Pseudanomodon attenuatus	85	128	71	100	150	33	114	57	-
Pseudoamblystegium subtile	-	28	-	-	33	-	-	43	28
Pseudoleskeella nervosa	-	-	-	33	-	-	-	-	-
Pterygynandrum filiforme	-	71	-	-	-	-	-	57	-
Sciuro-hypnum flotowianum	143	86	28	183	116	33	128	28	-
Sciuro-hypnum populeum	43	-	-	33	-	-	-	-	
Thamnobryum alopecurum	43	-	-	83	-	-	-	-	-
Thuidium delicatulum	85	-	-	100	-	-	-	-	--
Ulota crispa	-	-	200	-	-	167	-	-	200
Liverworts									
Frullania dilatata	-	-	57	-	-	33	-	28	57
Frullania tamarisci	-	-	-	-	33	-	-	86	43

Metzgeria furcata	-	-	-	-	-	-	-	57	28
Radula complanata	-	200	114	-	133	100	71	171	143
Radula lindenbergiana	-	-	-	-	-	-	-	28	-

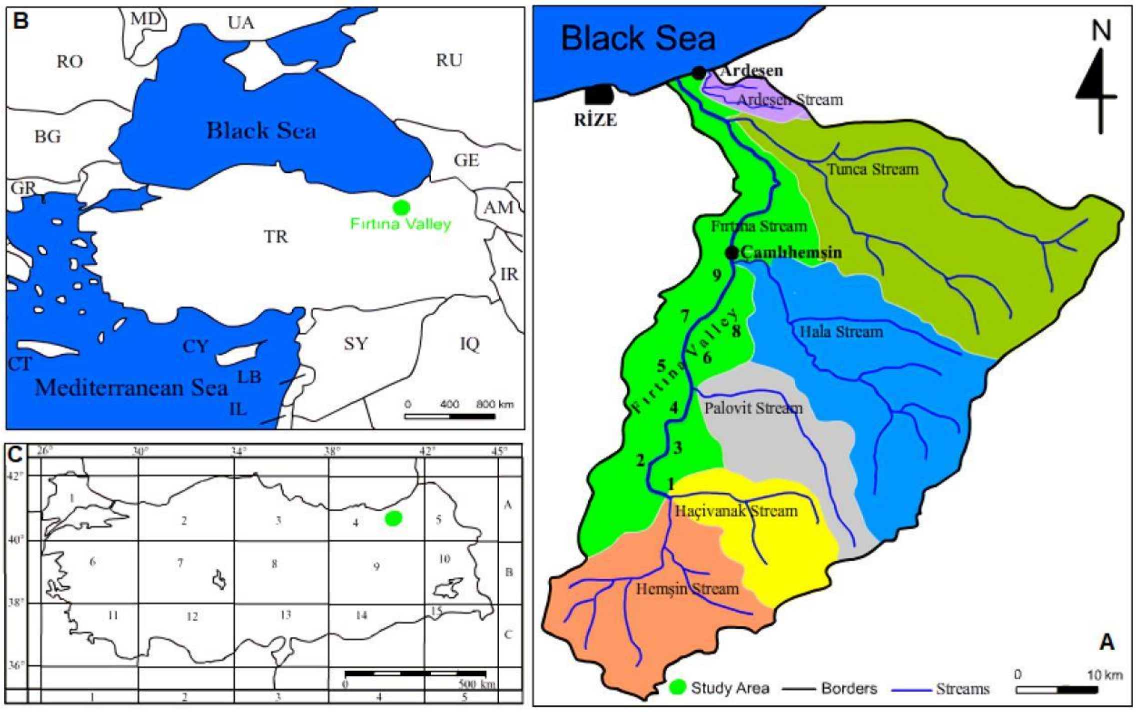

Fig. 1. The Fırtına Valley (A) and its location in Türkiye (B) and in the Henderson's grid system (1961) (C).

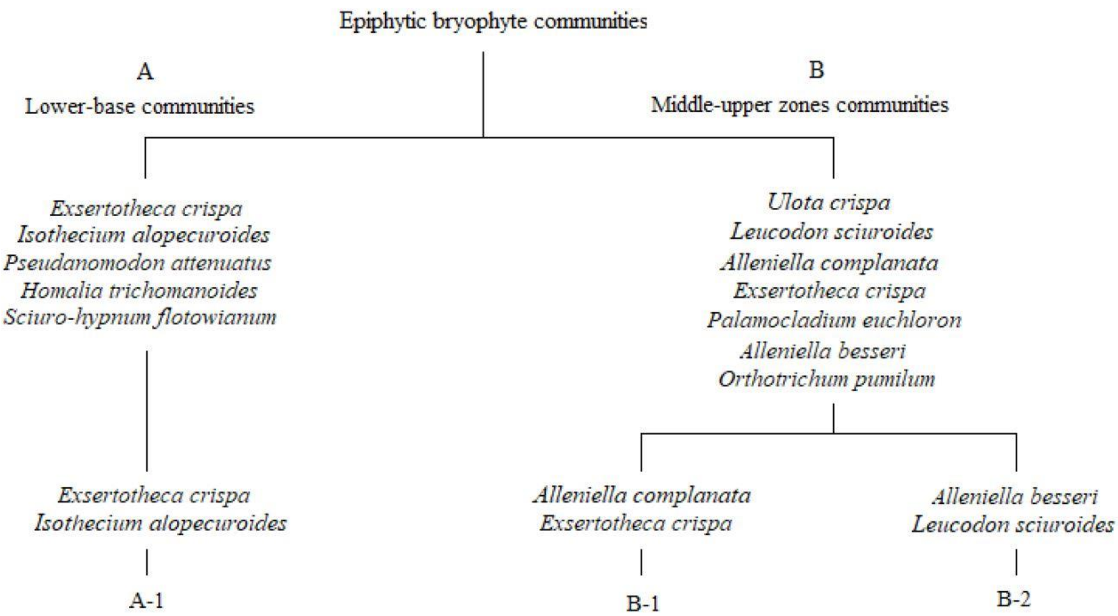

Fig. 2. Classification of TWINSPAN based on the matrix of 29 species over 60 sample plot

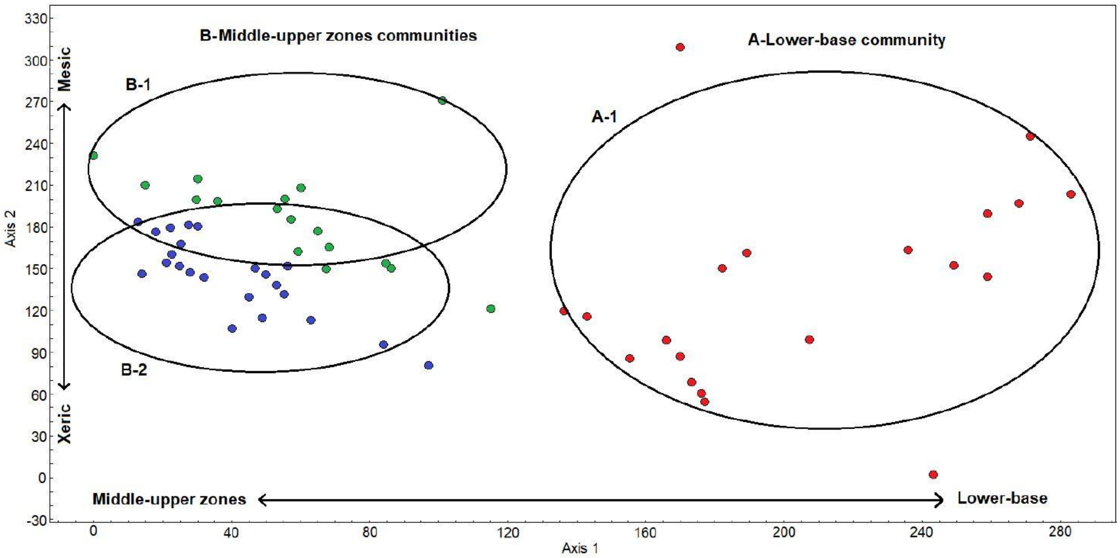

Fig. 3. The relationship between the three epiphytic bryophyte groups generated after the application of TWINSPAN classification technique on 60 sample plots and the distribution of the groups along the environmental gradient on the first and second axes of DECORANA. A–1: *Exsertotheca crispa-Isothecium alopecuroides*, B–1: *Alleniella complanata-Exsertotheca crispa*, B–2: *Alleniella besseri-Leucodon sciuroides*, axis 1: the gradient of height of the epiphytic habitat, axis 2: the gradient of moisture.