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Epiphytic communities of open habitats in the western Tian-Shan Mts (Middle Asia: Kyrgyzstan)

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Abstract – The paper presents the results of bryosociological research conducted on the epiphytic vegetation in the western Tian-Shan Mountains in 2013. The surveys on epiphytic bryophyte and lichen communities were done on 115 sites with different quantity of trees (solitary, in alleys or wood plots along river valleys) distributed in several mountain ranges within study area. In total 21 epiphytic moss species were found during research which composes characteristic species combinations making apparent difference between associations. As a result of field research and numerical analyses, three separate groups of samples corresponding to seven associations and one community within three alliances: *Ulotion crispae* and *Syntrichion laevipilae* (*Frullanio dilatatae-Leucodontetea sciuroidis* class) as well as *Neckerion complanatae* (*Neckeretea complanatae* class) have been distinguished. A synopsis of the epiphytic moss communities is proposed. The most interesting is the association of *Orthotrichetum crenulati* which is described here for the first time. Two species of epiphytic mosses (*Orthotrichum crenulatum* and *O. pallens*) are new to Kyrgyzstan.

Lichen / Moss diversity / Moss ecology / Orthotrichetalia/ *Orthotrichetum crenulati* ass. nova / *Orthotrichum*

INTRODUCTION

Kyrgyzstan is a very diverse country in terms of its topography, mountain relief, climatic conditions, and vegetation cover. This environmental uniqueness includes a great variety of habitats suitable for moss species.

Liverworts are represented there only very rarely and as epiphytes almost absent. Also in bryological literature sources (cf. Lazarenko, 1938; Mamatkulov *et al.*, 1998; Ignatov *et al.*, 2006) no liverworts were mentioned.

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The list of Kyrgyz mosses consists 360 taxa (Ignatov *et al.*, 2006). The actual number is likely to be higher, taking into account the topographical and climatic diversity of the country, which is also reflected in its diversity of vascular plants (3500 species in the area of about 200000 km^2; Nikitina *et al.*, 1967).

The earliest attempts to study moss diversity in Kyrgyzstan were made by Lazarenko (1938). However, there is only one available dataset related to moss (liverworts are not mentioned there) distributions in Central Asia. Considerably longer list of the taxa can be found in articles published by Mamatkulov *et al.* (1998), and Rakhmatulina (1970, 1990). However, the data about the distribution of mosses are related to a larger geomorphological units such as mountain ranges and it is not easy to assign them accurately to the particular state of the Central Asia. Later, a review of the bryological literature of Kyrgyzstan was presented by Ignatov *et al.* (2006). In recent years, extensive studies have revealed that the diversity and ecology of Kyrgyz bryophytes are not yet fully understood, and thus further research is required. A typical example is research concerning epiphytic bryophytes, which only in 2013 identified a number of species not previously recorded in this country (Ellis *et al.*, 2014a,b, 2015a-c). After recent studies on mosses in Kyrgyzstan, the present richness of moss flora is 365 taxa.

Unfortunately, no attempts were ever made to study bryophyte communities in Kyrgyzstan, or even in Middle Asia as a whole. This includes studies of all types of microhabitats, including tree trunks. The closest areas in which moss communities have been thoroughly investigated are in Japan (Iwatsuki, 1960), Caucasus (Kürschner *et al.*, 2012), southern Ural (Baisheva *et al*., 1994; Baisheva 1995, 2000) and Middle East (Frey & Kürschner, 1979). This includes studies of epilithic phytocoenosis (Hübschmann, 1984; Vondráček, 1986; Puglisi *et al.*, 2015), and epigeic (Gapon, 2010, 2011), spring mire (Sofron & Šandová, 1972; Tomaselli *et al.*, 2011), and epiphytic moss communities composed largely of *Orthotrichum* species (Mickiewicz, 1965; Peciar, 1965; Iwatsuki & Hattori, 1965, 1970; Hübschmann, 1976; Schlüsslmayr, 2001; Goia & Schumacker, 2003). Several works on moss sociology were dedicated to the particular area under legal conservation (Marstaller, 2001, 2012). Recently, research focusing on the bryophyte communities growing on tree trunks has been conducted in south-western Asia (Alatas & Batan, 2014). A study on the cryptogamic epiphytes of ash (*Fraxinus excelsior* L.) in an ancient pasture-woodland was carried out by Pentecost (2014). Ceschin *et al.* (2015) also investigated floristic and features of aquatic bryophytes in the Western Alps and Central Apennines (Italy).

In the present study, we focused on the open areas of the western Tian-Shan Mountains. Communities of epiphytic mosses and lichens primarily growing on tree trunks were investigated. The aim of this study was to record the diversity of epiphytic moss communities in Kyrgyzstan and compare it to that known from other regions of Eurasia.

MATERIALS AND METHODS

Study area

The researches were conducted in the western Tian-Shan Mountains (Kyrgyzstan), within an area of approximately 200000 km^2 (Fig. 1). The study area is situated at altitudes between 680 and 2800 m above sea level. Generally, the

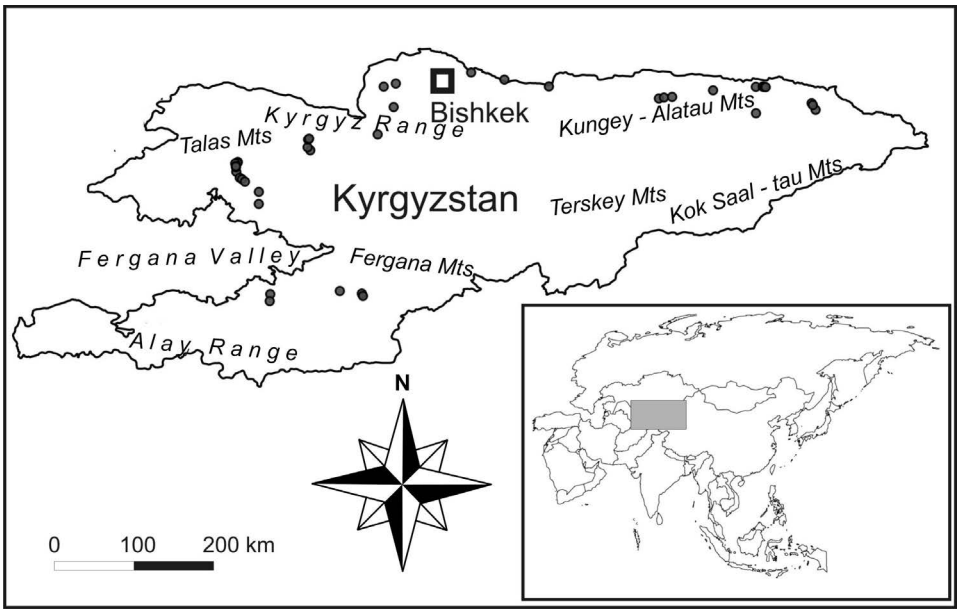

Fig 1. The study area with plot locations (grey circles).

northern part of Middle Asia is located in the transition zone between the Temperate and Mediterranean macrobioclimates. According to a recently published classification of global bioclimates, which mainly takes into account precipitation rates and temperature values, the study area can be classified as a Mediterranean macrobioclimate. This type of climate is characterized by a period of summer drought lasting for at least two consecutive months, in which P < 2T (Rivaz-Martínez *et al.*, 2011). In the case of Bishkek, a four month period in summer matches this condition (Fig. 2). Other additional bioclimatic features of this study area confirm the Mediterranean macrobioclimate classification: the yearly average temperature is below 25°C (10.3°C) and the Compensated Thermicity Index is below 580 (572.3). As the Continentality Index is Ic = 29, our study area also belongs to a distinct continental

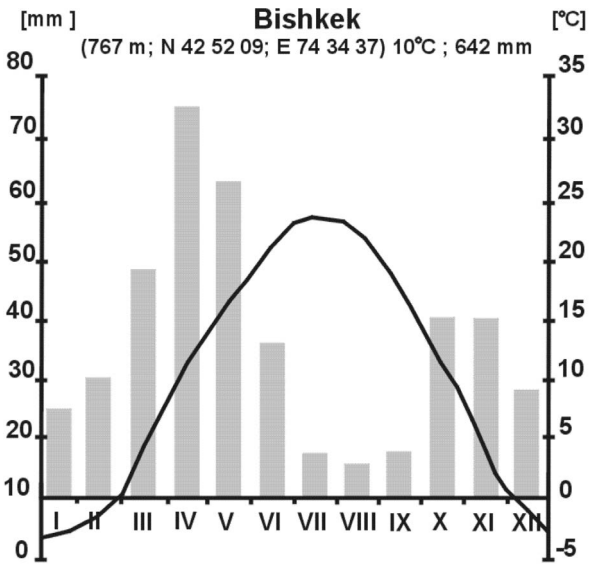

Fig 2. Climatic characteristic of the study area according to the Bishkek hydrometeorological station.

type (eucontinental subtype, weak level). The Ombrotype Index (Io = 2,6) places the study area within the lower dry horizon. According to the thermotype thresholds, the Bishkek region should be classified as a lower infra-Mediterranean zone. As it is typical of a Mediterranean climate, the area generally receives high levels of solar radiation, as well as a low percentage of cloud cover, high-amplitude annual temperatures, and low humidity and precipitation (with the exception of the spring period, during which there is a considerable amount of rainfall) (Fig. 2). In the study area, average temperatures in June are about 22°C, while the annual precipitation is less than 700 mm. In the subalpine zone (the Tian-Shan Mountains), the climate is much harsher, with average temperatures in July between 8.0 and 11.5°C (Narzikulov & Stanjukovich, 1968; Vladimirova, 1968), and annual precipitation ranging from about 500 mm on northern slopes to about 1000 mm on southern slopes. The lower limit of perpetual snow in the western Tian-Shan Mountains is at an altitude of 3000-3300 m (Latipova, 1968). These climatic and bioclimatic conditions determine the vegetation types and plant communities found in study areas where evergreen forests, xerothermophilous swards, and shrubs dominate the lowlands and the colline belt.

Data and analyses

The field research was conducted in 2013 within the colline and montane zones of the western Tian-Shan Mountains. The surveys of epiphytic bryophyte communities were conducted at 115 sites with different quantities of trees (solitary, in alleys, or wood plots along river valleys) distributed across almost the entire country, but particularly around Bishkek, Toktogul Lake, Issyk-Kul Lake, Naryn Valley, Fergan Basin, Dzhalal-Abad, Sary-Tash, Kyzyl-Kiya, and the Sary-Chelek Lake area within Alay Mts, Fergana Mts, Kyrgyz Mts, Kungey Alatau and Terskey Alatau (Fig. 1). At each site, phytosociological relevés were done on at least three different trees. The vegetation plot size was delimited in such a way as to allow for full representation of the bryophyte composition of the moss phytocoenosis. The mosses and lichens were assessed in squares of 625 cm^2 (25 cm × 25 cm) at different heights on the tree trunks: 1 m, 2 m, and 3 m. In total, 298 phytosociological relevés were taken. The bases of trees and buttress roots were both deliberately excluded from the study, because they were covered by terrestrial, rather than epiphytic species of mosses. In addition, the environmental conditions on the lower parts of the tree trunks were considerably affected by the surrounding vegetation, and were very different from the rest of the bole. For each vegetation plot, all cryptogams were recorded with the use of percentage scale. Each species were given a percentage cover value separately to get the most detailed structure of moss and lichen species. Geographical coordinates, elevation above sea level, aspect, and slope inclination were noted for each relevé.

All relevés were stored using the JUICE programme (Tichý, 2002). A modified TWINSPAN analysis (Hill, 1979; Roleček, 2009) provided an initial idea of the data structure and resolution. We then applied pseudospecies cut levels of 0%, 2%, 5%, and 10%. De-trended correspondence analyses (DCA) were performed using the floristic data set (with no down-weighting of rare species) to check the floristic-sociological classification, and to highlight relationships between groups. For the ordination analysis, CANOCO for Windows 4.5 was used (ter Braak & Šmilauer, 2002). The species composition data exhibited a clear unimodal response, with total gradient length of about 5.5.

In the analytic table (Table 1), species constancies are listed for classes I-V (Dierschke, 1994). In cases where a particular species was noted in less than

Table 1. Synoptic table of studied epiphytic moss communities

Synatxonomic unit	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Number of relevés	*52*	*3*	*1*	*4*	*54*	*15*	*167*	*2*
Diagnostic species								
Ass. Pterigynandretum filiformis								
Pterigynandrum filiforme	V 1^{-5}	–	–	–	I^{+-1}	–	I^{+}	–
Ass. Homalothecio sericei–Porelletum platyphyllae								
Homalothecium sericeum	–	3^{3-4}	–	–	–	–	–	–
Comm. *Leucodon sciuroides*								
Leucodon sciuroides	–	–	1^{5}	–	–	–	–	–
Ass. *Orthotrichetum pallentis*								
Orthotrichum pallens	I^{1}	–	–	4^{3-4}	I^{1-3}	–	I^{+-1}	–
Ass. *Orthotrichetum striati*								
Orthotrichum speciosum	II^{+-2}	–	–	3^{1-2}	V^{+-4}	II^{1-2}	I^{+-2}	–
Orthotrichum striatum	I^{+-1}	–	–	–	III^{1-2}	–	I^{+}	–
Ass. *Orthotrichetum falacis*								
Orthotrichum pumilum	–	–	–	1^{1}	I^{+-1}	V^{1-3}	I^{+-2}	–
Ass. *Orthotrichetum crenulati*								
Orthotrichum crenulatum	I^{+-1}	–	–	1^{2}	III^{+-2}	IV^{+-2}	V^{+-5}	2^{2}
Ass. *Syntrichietum pulvinatae*								
Syntrichia virescens	I^{+}	–	–	–	–	–	I^{+-1}	2^{1-4}
O. *Orthotrichetalia*								
Orthotrichum anomalum	IV^{+-4}	3^{1}	–	2^{+-1}	I^{1-2}	I^{1}	I^{+-4}	–
Nyholmiella obtusifolia	I^{+-3}	2^{+-1}	–	–	I^{+-2}	–	I^{+-2}	–
Orthotrichum alpestre	II^{+-2}	–	–	–	I^{+-2}	I^{2}	I^{1}	–
Syntrichia ruralis	I^{1}	–	–	–	I^{1}	I^{1}	I^{+-2}	–
Bryum moravicum	I^{+-2}	–	–	–	–	I^{1}	I^{+-1}	–
Orthotrichum cupulatum	I^{1-3}	–	–	–	–	–	–	–
Orthotrichum pamiricum	–	–	–	–	–	–	I^{1-2}	–
Orthotrichum dagestanicum	–	–	–	–	–	–	I^{+}	–
Orthotrichum revolutum	–	–	–	–	–	I^{2}	I^{2}	–
Others								
Lecanora crenulata	IV^{+-3}	3^{1-2}	–	3^{1-2}	IV^{+-4}	V^{1-4}	V^{+-5}	1^{1}
Candelaria concolor	–				III^{+-3}	–	I^{1-2}	–
Xanthoria fallax	II^{+-3}	1^{+}	–	3^{2-3}	III^{+-3}	V^{+-2}	IV^{+-4}	–
Leptogium saturninum	–	–	–	–	I^{1-2}	–	I^{1-2}	–
Phaeophyscia nigricans	I^{1-2}	–	–	–	I^{1-3}	–	I^{1-3}	1^{1}
Hypnum cupressiforme	I^{1-2}	–	–	–	–	–	–	–
Grimmia sp.	–	–	–	–	–	–	I^{1}	–

Explanations: 1 – *Pterigynandretum filiformis*, 2 – *Homalothecio sericei–Porelletum platyphyllae*, 3 – *Community of Leucodon sciuroides*, 4 – *Orthotrichetum pallentis*, 5 – *Orthotrichetum striati*, 6 – *Orthotrichetum fallacis*, 7 – *Orthotrichetum crenulati*, 8 – *Syntrichietum virescentis*.

8 relevés, the absolute number of species occurrences was specified. Newly identified syntaxa were proposed according to the International Code of Phytosociological Nomenclature (Weber *et al.*, 2000). While distinguishing and ranking the associations, the works of Marstaller (2006) and Hübschmann (1984) were taken into account. The presented communities are arranged in a syntaxonomic overview at the end of the Results section.

The bryophytic nomenclature mainly follows the guidelines established by Ignatov *et al.* (2006) and Ros *et al.* (2013). The plant material collected during field studies was deposited in the Herbarium of the Middle Asia Mountains, University of Ostrava, Czech Republic (OSTR).

RESULTS

A total of 21 moss species were recorded in the relevés. The group of species with the highest frequencies of occurrence includes the following: *Orthotrichum crenulatum* Mitt. (222 occurrences), *O. speciosum* Nees (90), *O. anomalum* Hedw. (72), *Pterigynandrum filiforme* Hedw. (58), *O. pumilum* Sw. *ex* anon. (42), *Nyholmiella obtusifolia* (Brid.) Holmen & Warncke (37), *O. striatum* Hedw. (29), *O. alpestre* Bruch & Schimp. (25), *Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr (18), and *Bryum moravicum* Podp. (13). Other moss taxa were observed only sporadically. No taxa of liverworst was recorded. Of the 7 lichens observed, the most frequently occurring were *Xanthoria fallax* (Hepp *ex* Arnold) Arnold (186), *Lecanora crenulata* (Dicks.) Hook. (121), *Phaeophyscia adscendens* (Fr.) H. Olivier (85), and *Phaeophyscia nigricans* (Florke) Boberg (35). The other three, namely *Leptogium saturninum* (Dickson) Nyl., *Lecidella elaeochroma* (Ach.) Hazsl. and *Candelaria concolor* (Dick.) Stein were rarely observed only.

All moss species observed in this study are native to Kyrgyzstan, however several could undoubtedly thrive on man-made sites; specifically, species such as *Orthotrichum anomalum, Bryum moravicum, Syntrichia virescens* (De Not.) Ochyra, and *S. ruralis*. In general, all recorded mosses are species known to occur across the northern hemisphere (Ignantov & Ignatova, 2003, 2004).

Moss communities have been observed to occur on different tree species. The most commonly inhabited were *Populus* sp., *Salix* sp., *Juglans* sp. and *Ulmus* sp. A total of 17 genera of trees were found to serve as habitat for moss communities (Fig. 3). As was revealed via sampling, mosses are fairly abundant in the study plots. The average cover value per plot was approximately 35%, or twice the lichen coverage (ca. 17.5% per plot). The moss communities were usually found to have developed on the lower sections of tree trunks, at a mean height of 2 m.

Within the study area the bryocoenoses were observed at different elevations, between 682 and 2825 m. We can not exclude that some samples of this type of moss-dominated vegetation could occur outside this range, however, we failed to find any plots on tree trunks in Kyrgyz lowlands or higher elevations. The tree line in Tian-Shan and Pamir Alai Mts is ca. 2500-3000 m a.s.l. and is marked by *Picea schrenkiana, Abies semenovii, Juniperus turkestanica* and *J. zeravschanica,* so there is a potential for epiphytic mosses to occur in higher alpine belt.

Mosses constituting the epiphitic communities in Tian-Shan Mts, are generally widely distributed across the northern hemisphere. The only exception is *Orthotrichum crenulatum,* which has a much narrower range, being confined mostly

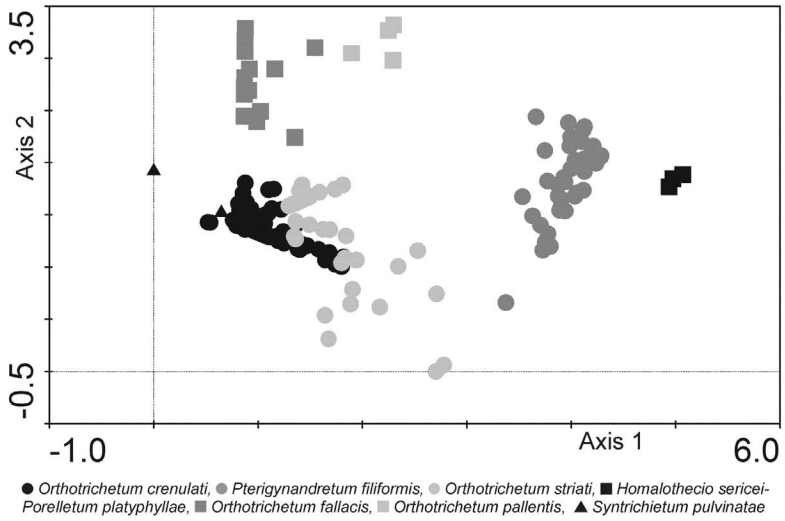

Fig 3. DCA ordination for all samples of epiphytic communities (N = 298).

to Middle and Central Asia, the eastern part of the Mediterranean, and the Irano-Turanian provinces (Lewinsky, 1992; Lara *et al.*, 2010). This species is also rarely reported from Western Europe (Schäfer-Verwimp & Gruber, 2002).

As a result of the numerical analyses, sevenmain types of plots were distinguished, of which six have been identified as associations. One, *Orthotrichetum crenulati,* was defined by an original diagnosis based on species composition and habitat distinctiveness. The axis 1 of the correspondence analysis is mostly influenced by humidity (Fig. 3). Thus, on the right side of the graph, the plots of the most hygrophilous communities of *Neckerion complanatae* are located. *Orthotrichetum striati* and *O. pallentis*, which are less sensitive to drying up in windy conditions, are represented in the central part of the graph. On the left side of the figure, the most xerophytic moss communities were placed with *Orthotrichetum crenulati* and *Orthotrichetum fallacis*. The drivers influencing axis 2 are much less clear. It is likely that the upper part of the figure includes the more nitrophilous (*O. fallacis*) communities and those found in river valleys (*O. pallentis*). Meanwhile, the lower section of the graph is driven by a species constituting *Orthotrichetum striati,* the most heliophilous association.

Epiphytic moss communities on tree trunks in Kyrgyzstan

Based on presented data, we propose the following classification of epiphytic moss communities in Kyrgyzstan:

Pterigynandretum filiformis Hill. 1925

Diagnostic species: *Pterigynandrum filiforme*

Pterigynandrum filiforme is a species known to occur in all Holoarctic regions (Ignatov & Ignatova, 2004). During our study, the association built by

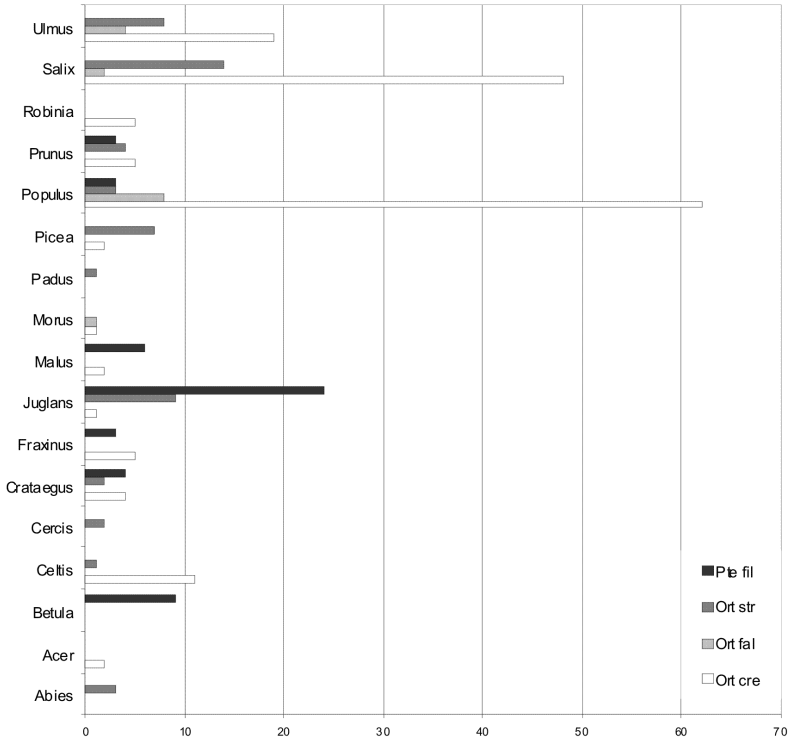

Fig 4. Phorophyte preferences of the studied associations.

Pterigynandrum filiforme was found at many locations (20 locations and 52 plots) in the regions of the Sary-Chelek and Toktogul Lakes, the Ala-Archa and Naryn River valleys, and the region around Osh. The bryocoenosis has been found on different tree species (mainly *Juglans regia* L., *Betula* sp., and *Populus* sp., comp. Fig. 4) with rather moderate bark crevices and fissures. The phytocoenosis develops on the northern side of moderately thick trunks. Plots featuring this association occurred within a relatively narrow altitudinal range, mainly in montane belts at elevations of 1200-1900 m (mean ca. 1700 m). The mean value of moss layer cover was close to 40%, ranging from 10 to almost 100% (Table 1, Fig. 6). Lichens occur in these plots relatively rarely, and have a mean cover value of approximately 5%. The most abundant and frequently-occurring moss species within the plots, besides the diagnostic species, are *Orthotrichum anomalum* and *O. alpestre*. *Pterigynandretum filiformis* is a relatively species-rich community, with a mean value of three species per plot, ranging from 1 to 6 taxa. Plots featuring this association were generally located 2 m high on tree trunks, with some plots being located higher than 3 m.

Homalothecio sericei-Porelletum platyphyllae Størm. 1938

Diagnostic species: *Homalothecium sericeum*

The moss *Homalothecium sericeum* (Hedw.) Schimp. is widely distributed across the northern hemisphere, and some aspects of their distribution in Middle

Asia are already known (Konstantinova *et al*., 1992; Ignatov & Ignatova, 2004). During our study, we found only three plots featuring this community, at one site near Sary-Chelek Lake. Plots of this association were found to occur on *Juglans regia*. The trees were relatively young, with trunk diameters of approximately 50 cm and fairly even bark. The phytocoenosis were found on surfaces with north-eastern exposure. Despite the *Homalothecium sericeum* being the only diagnostic species within the researched plots, *Orthotrichum anomalum* and *Nyholmiella obtusifolia* were also found to be relatively abundant in the moss layer (mean cover of approx. 60%). *Homalothecio sericei-Porelletum platyphyllae* was noted to occur at moderate elevations (approximately 1350 m) in the montane belt. Lichens contribute to the vegetation plots with a low abundancy of *ca* 7-15% cover. The only lichen species observed was *Lecanora crenulata*.

Orthotrichetum pallentis Ochsn. 1928

Diagnostic species: *Orthotrichum pallens*

The primary diagnostic moss species is widely distributed, generally across all Holoarctic regions (Ignatov & Ignatova, 2004). However, although *Orthotrichum pallens* Bruch *ex* Brid. seems to be common at least in some parts of Kyrgyzstan, the species has not been reported before from the country. The distribution of the association is restricted to the middle section of the Chichkal River valley, where it was found at an elevation of about 1830 m on *Abies semenovii*. The second plot of *Orthotrichetum pallentis* was found on a *Malus sieversii* M.Roem. tree in the colline belt near Toktogul Lake, at an elevation of about 850 m. The plots of this association occupy the northern and north-eastern surfaces of young trees with trunk diameters between 10 and 40 cm. On average, the association consists of three species of mosses (*Orthotrichum anomalum, O. pallens, O. speciosum*) and two lichens (*Xanthoria fallax* and *Lecanora crenulata*). The mean cover value of the moss layer was relatively high, reaching approximately 55% (Fig. 6). Coverage by lichens species was considerably lower, at an average value of about 15%.

Orthotrichetum striati Gams 1927

Diagnostic species: *Orthotrichum striatum, O. speciosum*

The two diagnostic moss species are widely distributed across all Holoarctic regions (Ignatov & Ignatova, 2004). *Orthotrichum speciosum* is continuously distributed throughout North America, Europe, and all of non-tropical Asia. Recently, it was also reported to have been found in northern Africa (Draper *et al*., 2003). Recent investigation also bring new data about occurrence of the species in Poland (Fojcik & Stebel, 2014). The area of distribution of *Orthotrichum striatum* includes the Pacific Northwest region of North America, Europe, northern Africa, and Central Asia (Lewinsky, 1992). The phytocoenoses of *Orthotrichetum striati* have been found at several locations in the Gulcho River Valley (to the SE from Osh), in the Chichkal River valley, around the eastern part of Issik-Kul Lake, and the Kara-Balta River valley. The elevational distribution of the association is among the highest of all *Orthotrichetalia* communities. While the mean altitude is approximately 1600 m, the most high-elevation plots were found above 2800 m. The plots of this association were found on *Salix* sp., *Juglans regia,* and *Ulmus* sp. growing as a loose river valley woodland. The tree trunks were not particularly thick, with the diameters

ranging between 10 and 100 cm, and a mean of approximately 45 cm. Phytocoenoses of *Orthotrichetum striati* are rather species-poor both for mosses and lichens. On average, this community includes only two moss taxa and two lichens. Occasionally, more than four moss taxa were found in a sample plot. Despite the presence of both diagnostic *Orthotrichum* species, the most frequently occurring species are *O. crenulatum* and *Nyholmiella obtusifolia*. The covers of the moss and lichen layers were inconsiderable. Both moss and lichen covers are rather open, 25% and 10% respectively. The most common lichens found in this community are *Xanthoria fallax, Candelaria concolor, Phaeophyscia nigricans,* and *Leptogium saturninum.*

Orthotrichetum crenulati ass. nova

Type relevé hoc loco: Chychkan Valley, to the N of Toktogul; 10.06.2013., N 42° 00′ 58″; E 72° 51′ 11″; 1262 m above sea level; on *Populus alba* trunk, northern side; *Orthotrichum crenulatum* 4, *Orthotrichum anomalum* 2, *Orthotrichum pumilum* +, *Xanthoria fallax* 1, *Candelaria concolor* 1.

Diagnostic species: *Orthotrichum crenulatum*

Orthotrichum crenulatum had been considered endemic to the region around northeastern Afghanistan, northern India, western Tibet, Middle Asia, and Kazakhstan (Lewinsky, 1992), yet in 1991, it was found in France but published as *O. flowersii* Vitt (Boudier & Pierrot, 1992). Schäfer-Verwimp & Gruber (2002) reported that *O. crenulatum* was found in Pakistan by Gruber in (1998). Subsequently, the species was also reported to occur in Tajikistan (Ellis *et al.*, 2011) and Kyrgyzstan (Ellis *et al.*, 2014a). The phytocoenoses of *Orthotrichetum crenulati* have been observed to occur on solitary trees in the relatively arid regions around Bishkek, Osh, Sary-Chelek Lake, Issik-Kul Lake, Toktogul-Lake, Tash-Kumyr, Kara-Kol, Tokmok, Dzhalalabad, Nookat, and the Gulczo and Naryn River valleys. It grows mainly at colline and montane elevations with several plots found up to 2000 m above sea level. This type of moss-dominated vegetation inhabits *Populus* sp., *Salix* sp., *Celtis* sp. and *Ulmus* sp. trees of moderate diameter (mean value of approximately 55 cm) (Fig. 6). The phytocoenosis inhabits lower sections of tree trunks (mean height of 2 m), generally north-facing. However, many plots of this association occurred on trunks with north-eastern and north-western exposure, and few occurred on trunks with southern exposure (Fig. 5). The mean value of the total cover of the moss layer is relatively low, ranging from 5% to 85% (mean approximately 25%; Fig. 6). In addition, the number of species per plot is fairly low, with a mean of two taxa. The most abundant and frequently-occurring species within bryocenoses representing this association, with exclusion of the diagnostic species are, *O. anomalum, O. pumilum,* and *Nyholmiella obtusifolia*. Lichens are relatively more abundant, having an average coverage of about 50%, and 2 to 3 species. Among them, the most frequent are *Candelaria concolor, Xanthoria fallax, Phaeophyscia nigricans,* and *Leptogium saturninum.*

Syntrichietum virescentis Pec. 1965 nom. mut. propos.

Diagnostic species: *Syntrichia virescens* (=*S. pulvinata*)

Syntrichia virescens is a broadly distributed moss in the areas of Europe, northern Africa, Asia Middle East, and North America with a Mediterranean climate (Ignatov & Ignatova, 2004; Ros *et al.*, 2013; Rams *et al.*, 2014). *Syntrichietum virescentis* was only found at two locations in close proximity to each other, by

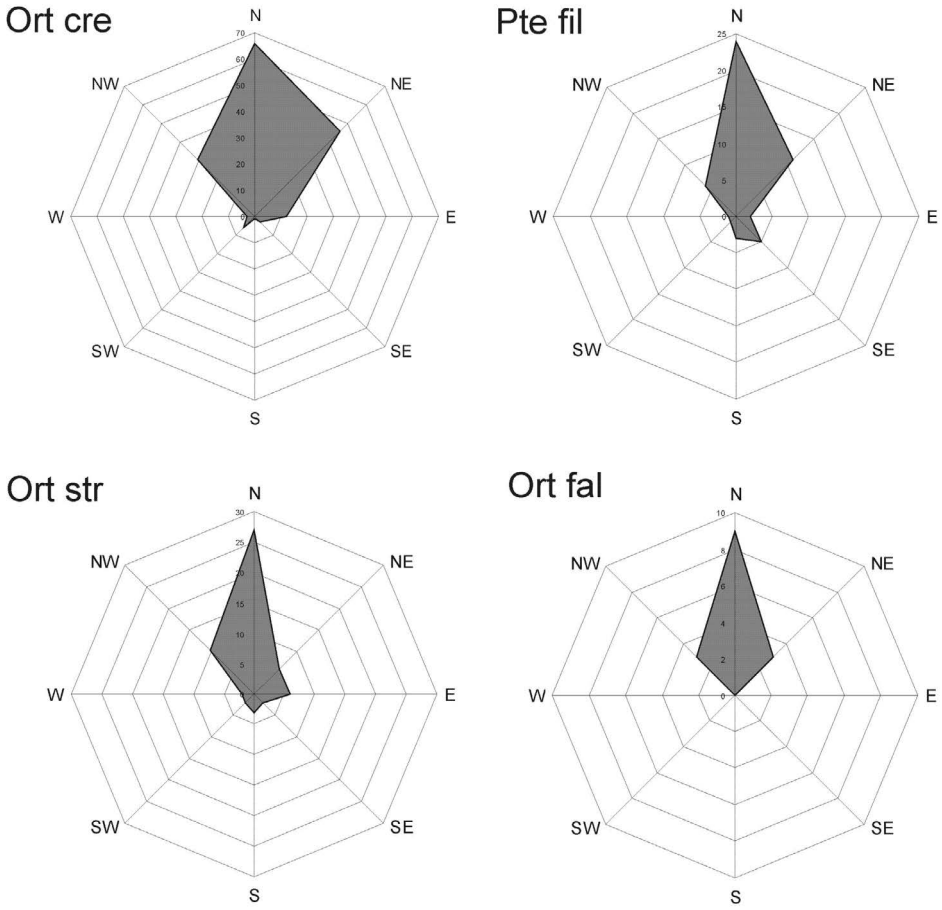

Fig 5. The exposition preferences of the studied associations. Ortcre – *Orthotrichetum crenulati*, Ptefil – *Pterigynandretum filiformis*, Ortstr – *Orthotrichetum striati*, Ortfal – *Orthotrichetum fallacis.*

Khodzhaata village near Sary-Chelek, and to the NW of Tashkumyr. The phytocoenoses were found in the colline zone at about 1000-1100 m above sea level. The plots were located on the northern and north-eastern sides of young *Celtis* sp. and *Crataegus* sp. trees. The tree diameters as measured 1.3 m from the ground were approx. 40 cm (Fig. 6). The vegetation plots studied were rather underdeveloped and only composed of about 2-3 moss taxa and 1 species of lichen. Besides the diagnostic moss species, *Orthotrichum crenulatum* and *O. striatum* were also included in the association. Remarkably, *Syntrichia virescens* dominated the patches of phytocoenoses, allowing lichens to cover only a small portion of the area. *Phaeophyscia nigricans* and *Lecanora crenulata* were observed in the lichen layer with a mean coverage of 5%.

In view of the fact that in recent literature generally the name *Syntrichia virescens* is used as valid, rather than *S. pulvinata* (Ochyra, 1992), we propose to adapt the name of the association. The new name of the association is in accordance with Article 45 (nom. mut. propos.) of the Code (Weber *et al*., 2000).

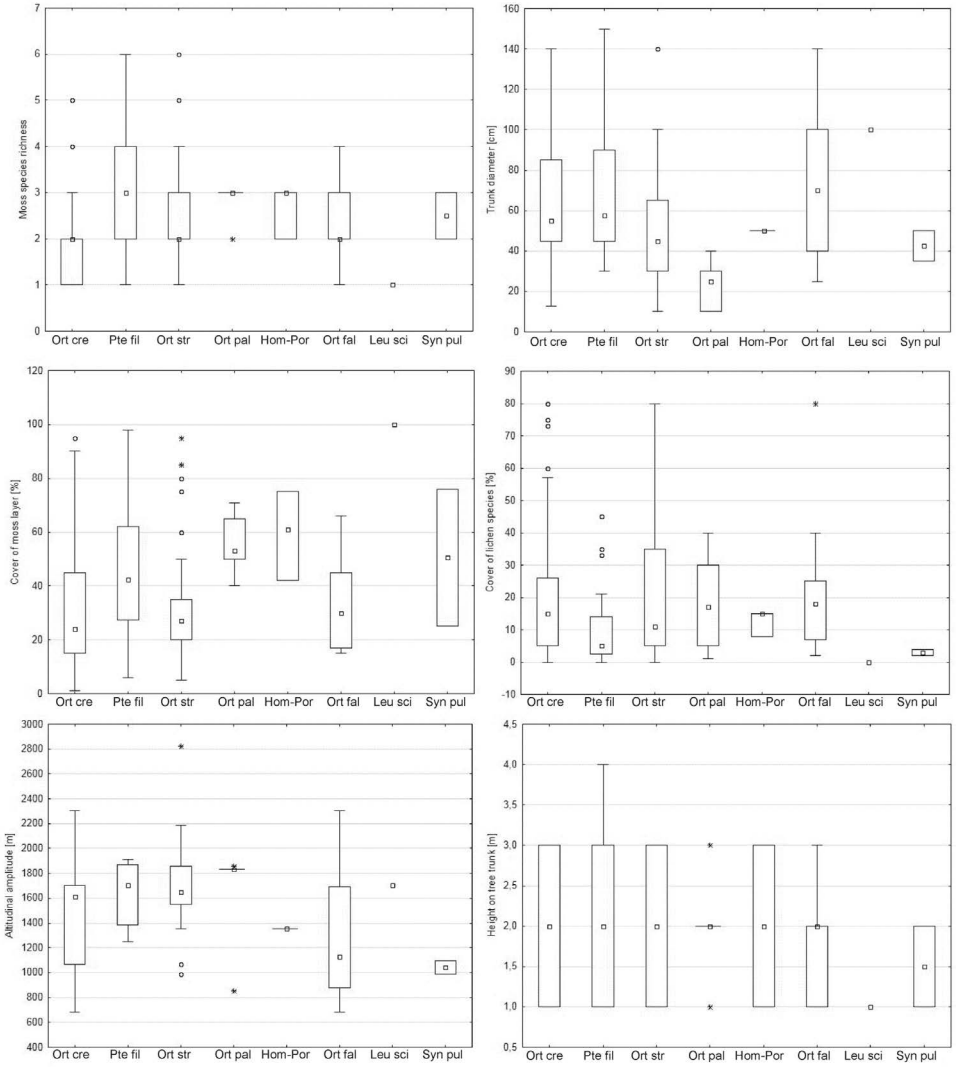

Fig 6. Evaluation of ecological requirements of the studied associations.

Community of *Leucodon sciuroides*

Leucodon sciuroides (Hedw.) Schwägr. is widely distributed across the northern hemisphere. In Kyrgyzstan, the species has mainly been reported to occur in the Tian-Shan foothills (Mamatkulov *et al.*, 1998). The *Leucodon sciuroides* community has been observed once near the Sary-Chelek River valley, within a forested area close to the course of the mountain river. On the lower section of the *Juglans regia* trunk, the entire surface of the bark was covered in *L. sciuroides.* There were no other species of mosses or lichens within the plot. This part of the valley has an elevation of approximately 1700 m.

Synopsis of syntaxa

C: *Neckeretea complanatae* Marst. 1986
O: *Neckeretalia complanatae* Jez. & Vondr. 1962
All. *Neckerion complanatae* Šm. & Had. *in* Kl. & Had. 1944
1. Ass. *Pterigynandretum filiformis* Hill. 1925
2. Ass. *Homalothecio sericei-Porelletum platyphyllae* Størm. 1938
3. Comm. of *Leucodon sciuroidis*

C: *Frullanio dilatatae-Leucodontetea sciuroidis* Mohan 1978 *ex* Marst. 1985
O: *Orthotrichetalia* Had. *in* Kl. & Had. 1944.
All. *Ulotion crispae* Barkm. 1958
4. *Orthotrichetum pallentis* Ochsn. 1928
5. *Orthotrichetum striati* Gams 1927
All. *Syntrichion laevipilae* Ochsn. 1928
6. *Orthotrichetum fallacis* v. Krus. 1945
7. *Orthotrichetum crenulati* A. Nowak, V. Plášek, M. Nobis & S. Nowak ass. nova
8. *Syntrichietum virescentis* Pec. 1965

DISCUSSION

Species characteristic and ecology

In the deforested areas of western Tian-Shan, the most commonly recorded epiphytic bryophytes are taxa of the genus *Orthotrichum*, which mainly colonize solitary trees, but can also be found in alleys or woodlots along the roads and rivers. Surprisingly, *Orthotrichum crenulatum,* the most commonly occurring and widespread epiphytic species, with a broad spectrum of relevant phorophytes was not previously known to occur in Kyrgyzstan (cf. Ignatov *et al*., 2006, Ellis *et al*., 2014a). The species was reported to occur on 15 taxa of trees, mainly *Salix* sp. (in 35% of cases), *Populus* sp. (20%), and *Ulmus* (12%), its populations were abundant and richly fertile, and their occurrence was recorded with approximately the same coverages at all observed heights on the trunk (1, 2, and 3 m). The presence of *Orthotrichum crenulatum* in purely natural habitats was recorded, though it sometimes entered mesic *Juglans regia* forest edges or river valley woods with *Betula* sp. or *Fraxinus* sp. However, the species could also thrive in habitats under significant anthropogenic pressure (bark of trees along roadsides or near villages).

In contrast to *Orthotrichum crenulatum*, *O. speciosum* exhibits a preference for shady habitat that is at least partially humid, situated mainly at forest edges or near watercourses. The phorophytes which most frequently host this species include *Populus* sp. (in 30% cases) and *Juglans* sp. (14%). *Orthotrichum speciosum* prefers to grow on these phorophytes at a height of about 1.5-2.0 m from the ground.

Orthotrichum anomalum is generally considered as epilithic moss, but recently has increasingly been found growing on the bark of trees. In Kyrgyzstan, it grows in two different types of habitats. Either it occurs at forest edges (mainly *Juglans* forest) or, more frequently, along public roads and near settlements (mainly on *Salix* sp.). The latter areas are characterized by higher rates of dust deposition, which may explain the epilithic moss' affinity for the bark of these trees. *Orthotrichum*

anomalum rather grows on the lower parts phorophytes, at a height of about 1-1.5 m from the ground. In mountainous areas situated over 2000 m above sea level, it is predominantly found growing on boulders or rocks.

Other *Orthotrichum* species recorded in the study area showed similar environmental requirements as in the rest of its range. They differ only by host specificity, due to unique tree species composition in the Middle Asia. Spectrum of recorded epiphytic mosses is accompanied by *Pterigynandrum filiforme*, *Syntrichia ruralis*, *S. virescens*, and *Bryum moravicum*. These species accompany the epiphytic taxa discussed above, particularly in anthropogenically affected localities.

Species composition, chorology, and habitat of epiphytic moss communities on tree trunks in Kyrgyzstan

The relatively high diversity of ecological niches found on 17 examined taxa of trees and the associated variability of microclimatic conditions both influence the considerable floristic richness and diversity of moss vegetation in Kyrgyzstan compared to other regions of Eurasia. In total 21 epiphytic moss species were found during this study. These species make up characteristic species combinations with obvious differences. Detrended correspondence analysis reveals clear differences according to species composition (Fig. 3). Three separate groups of samples are visible along axis 1, which is driven mainly by humidity. The associations *Pterigynandretum filiformis* and *Homalothecio sericei-Porelletum platyphyllae* are grouped on the right side of the graph. These communities prefer high-humidity sites under a relatively dense tree canopy. Conversely, *Orthotrichetum fallacis*, *Orthotrichetum crenulati*, and *Syntrichietum virescentis* are located on the left side of the graph. These phytocoenoses inhabit the arid environments found on trunks exposed to solar radiation. In the plots of these communities, heliophilous moss species were abundant (mainly *Orthotrichum pumilum*, *O. crenulatum*, *O. alpestre*, *O. anomalum*, and *Syntrichia virescens*). This represents a considerable overlap between the left-side group and the central group made up of the moss communities preferring relatively moderate microclimate humidity or aridity. This could be because in Kyrgyzstan, *Orthotrichum striatum* and *O. speciosum* more commonly co-occur in plots with *O. crenulatum* than in plots with *Pterigynandrum filiforme*. In Europe the situation is quite different. Both diagnostic species for *Orthotrichetum striati* sometimes inhabit more hygrophilous and shadowed plots dominated by *Pterigynandrum filiformis* (Schlüsslmayr, 2001).

Despite the fact that Kyrgyzstan is a typical mountainous country, there are none of the considerable differences between the above associations in terms of altitudinal range that have often been reported for vascular plant associations in Middle Asia (Fig. 6; Nowak *et al.*, 2013, 2014a, 2014b). Only *Orthotrichetum fallacis*, known as one the most thermophilous moss communities, seems to prefer the warmest areas of southern Kyrgyzstan, occurring in plots distributed around a mean elevation of about 1100 m.

The epiphytic moss associations of Kyrgyzstan exhibit considerable similarities to those of middle and southern Europe, especially those inhabiting Mediterranean and mountainous areas. Several of them are characterised by a relatively rich and abundant moss layer, and occupy the trunks of shaded or moderately sunny sides highly comparable to those of Europe (Peciar, 1965; Hübschmann, 1976; Schlüsslmayr, 2001; Marstaller, 2001, 2012; Gola & Schumacker, 2003). The only exception is *Orthotrichetum crenulati*, which is generally restricted

to a significantly smaller area compared to other important epiphytic moss taxa in the country. However, even in this case, we could expect to find this association in the Middle East as well as across the Irano-Turanian province.

Position of the described syntaxa in relation to other epiphytic moss communities on tree trunks in Eurasia

As mentioned above, there are no available creditable works or even basic data on moss communities from Middle Asia. However, because of the wide range of the most frequently occurring species in Kyrgyz epiphytic moss communities, we can use the European syntaxonomical system to establishing the relationships between the associations described (Marstaller, 2006). As in Europe, the moss syntaxa can be divided according to habitat characteristics, especially humidity. Communities of the *Neckeretea complanatae* class and *Neckerion complanatae* alliance were found to occur within the forest complexes of central Kyrgyzstan and often along river valleys bottoms. Both associations, namely *Pterigynandretum filiformis* and *Homalothecio sericei-Porelletum platyphyllae,* are distinctly visible on the DCA diagram what is driven by relatively higher species abundancies and composition. In Kyrgyzstan, the most frequent was apparently *Pterigynandretum filiformis.* However, forest epiphytic bryocoenoses inhabiting shadowy, humid, and relatively eutrophic microhabitats within the base sections of tree trunks in Kyrgyzstan require further study to be fully understood.

With respect to microhabitat conditions, particularly light availability and humidity, epiphytic bryocoenoses from the *Frullanio dilatatae-Leucodontetea sciuroidis* class should be divided into two alliances. Moderately hydrophilous, heliophilous, thermophilous, and humidity-dependent bryocoenoses belonging to the *Orthotrichetum pallentis* and *Orthotrichetum striati* associations should be included, as in Europe, in the *Ulotion crispae* alliance. However, the most xerothermophilous epiphytic moss communities in Kyrgyzstan, namely *Orthotrichetum fallacis*, *Orthotrichetum crenulati,* and *Syntrichietum pulvinatae* should be grouped in the *Syntrichion laevipilae* alliance. They inhabit mostly dry microhabitats exposed to solar radiation, on trees growing in relatively arid areas, (e.g. the surrounding of the western part of Issik-Kul Lake). The climate in that area resembles the warm Mediterranean type comparable to those of the montane belts in the Near East region of the country. The most interesting plots are those dominated by *Orthotrichum crenulatum*. All of the collected plots due to occurrence of several diagnostic taxa as *Bryum moravicum, Nyholmiella obtusifolia, Orthotrichum anomalum, O. alpestre, O. cupulatum, O. dagestanicum, O. pamiricum, O. revolutum,* and *Syntrichia ruralis* could be classified within the Eurasian *Orthotrichetalia* order.

CONCLUSIONS

The study presented here contributes to the knowledge of the epiphytic moss communities found on tree trunks in the colline and montane belts of Middle Asia. Most bryocoenoses described from the western Tian-Shan Mountains, are widely distributed, and correlate to relevant communities found in Europe. The exception is the *Orthotrichetum crenulati* association, which was described here for

the first time. All associations recorded in the western Tian-Shan Mountains are well defined by their floristic composition and habitat features, although they are mainly made up of mosses distributed across the northern hemisphere. Nevertheless, many of these species are still considered to be rare in Kyrgyzstan, because of the generally poor knowledge of moss diversity and distributions in that country. The epiphytic moss communities generally inhabit the northern sides of different tree species. The bryocoenoses were found at different elevations, mainly between 1000 and 1800 m. The epiphytic vegetation with a considerable share of moss species still awaits further investigation in Kyrgyzstan, especially in forest complexes. Finally, two species of epiphytic mosses (*Orthotrichum crenulatum* and *O. pallens*) new to Kyrgyzstan, were found during this study (cf. Ellis *et al*., 2014a). Presence of *Orthotrichum crenulatum* was known untill now from northeastern Afghanistan, Pakistan, northern India, western Tibet, Turkestan, and Kazakhstan (Lewinsky, 1992; Schäfer-Verwimp & Gruber, 2002), as well as from France (Boudier & Pierrot, 1992). During the recent field investigation in the Middle Asia the taxa was found by authors in Tajikistan (cf. Ellis *et al.*, 2011). *Orthotrichum crenulatum* seems to be one of the most common epiphytic species there. A similar situation is with *O. pallens*, which is known as locally common species in most countries of the Middle Asia (Lazarenko, 1938; Mamatkulov, 1975; Sakauova, 1992; Mamatkulov *et al*., 1998).

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