

## Syntaxonomy and nomenclatural adjustments of steppe-like vegetation on shallow ultramafic soils in the Balkans included in the order *Halacsyetalia sendtneri*

### Syntaxonomisch-nomenklatorische Änderungen bei den Steppenrasen der Ordnung *Halacsyetalia sendtneri* auf flachgründig-ultramafischen Böden des Balkans

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#### Abstract

Dry open rocky grassland vegetation on shallow ultramafic soils in the Central Balkans represents typical secondary grasslands, which have developed mainly in the zone of thermophilous mixed deciduous broadleaved and pine forests. Although all relevant national and regional syntaxonomic reviews classify these rocky grasslands within the distinct order *Halacsyetalia sendtneri*, the syntaxonomic position of the order in different systems of classification has varied in the past. Considering this as well as the fact that there have been no synoptic works on this specific vegetation type, we gathered all available data on the order *Halacsyetalia sendtnerii* from the serpentinites of the Western and Central Balkan Peninsula for its critical evaluation. The results obtained in our analyses allowed us to propose a new syntaxonomic concept, which is partly in accordance with previously published syntaxonomic schemes. Two alliances can be distinguished: *Centaureo kosaninii-Bromion fibrosi* and *Potentillion visianii*, for which the diagnoses, diagnostic and constant taxa are given. Furthermore, we discussed the syntaxonomic position of the order *Halacsyetalia sendtneri* with respect to the classes *Festuco-Brometea* and *Koelerio-Corynephoretea*, as within the analysed associations, many taxa diagnostic for the class *Koelerio-Corynephoretea* were registered. The thermophytic pioneer grasslands and therophyte sward communities included in the alliance *Thymion jankae* nomen. inval., characterised by the absence of typical species of the order *Halacsyetalia sendtneri* and presence of taxa diagnostic for the class *Koelerio-Corynephoretea*, are temporarily left within the order *Halacsyetalia sendtneri*. Finally, we provided nomenclatural adjustments for the analysed associations when necessary, although a conclusive judgement regarding all the associations currently included within the analysed order can only be made after more detailed field surveys including data on cryptogams as well as joint analyses including all floristically and ecologically similar syntaxa (e.g. *Astragalo-Potentilletalia*, *Festucetalia valesiaca*).

**Keywords:** Central Balkan Peninsula, *Halacsyetalia sendtneri*, serpentine vegetation, syntaxonomy

**Erweiterte deutsche Zusammenfassung am Ende des Artikels**

## 1. Introduction

For numerous reasons vegetation on serpentinites in the Balkans has been considered as a very attractive research object (KOŠANIN 1939, PAVLOVIĆ 1951, KRAUSE & LUDWIG 1956, 1957, RITTER-STUDNIČKA 1963, 1968, 1970; TATIĆ & VELJOVIĆ 1990). The largest serpentine areas in Europe are located on the Balkan Peninsula – Greece, Albania, Bosnia and Herzegovina, Serbia, and to a lesser extent in Montenegro, Bulgaria and Macedonia (STEVANOVIĆ et al. 2003). It should be noted that the traditional term serpentinites is generally accepted and used in botanical literature (BROOKS 1987), and we used it in our paper for all types of serpentinitised ultramafites of the Balkans.

The specific chemical composition, which is characterised by critically low levels of essential plant nutrients and a set of highly toxic trace elements, texture and the dark colour of serpentine bedrock contribute to the extremely dry conditions and the pronounced thermophilic character of these habitats. As a result, plants growing here show characteristic adaptations, such as nanism, purpurescence, glaucescence, stenophyllism etc., often referred to as “serpentine syndrome” (RITTER-STUDNIČKA 1963, 1968; JENNY 1980). Also, the particular complex of the overall ecological conditions, most of which are directly or indirectly conditioned by the properties of the bedrock itself, has resulted in a unique flora and vegetation with a great number of relic and endemic species (TATIĆ & VELJOVIĆ 1990, STEVANOVIĆ et al. 2003, BRKOVIĆ et al. 2015).

The first floristic and vegetation studies in the serpentine areas of this part of the Balkans were published in the 19<sup>th</sup> and the beginning of the 20<sup>th</sup> century by PANČIĆ (1859), BECK (1901), ADAMOVIĆ (1909) and KOŠANIN (1939). Among the first studies of serpentine grasslands in the Serbian mountains were those carried out by PAVLOVIĆ (1951, 1953, 1955). These were followed by the contributions of KRAUSE & LUDWIG (1956, 1957) dealing with serpentine communities in the area of Gostović in Bosnia and Herzegovina. Furthermore, after exploring the specificity of grassland flora and vegetation in Kosovo and Metohia, BLEČIĆ et al. (1969) described a new alliance *Centaureo-Bromion fibrosi* Blečić et al. 1969, in which they included three newly described associations from serpentinites on Mt. Šara (Kosovo). One year later, as a result of studying serpentine rocky grasslands in Central and Eastern Bosnia and Herzegovina, RITTER-STUDNIČKA (1970) introduced a new order for stepic rocky grasslands on serpentine soils of Bosnia & Herzegovina, Serbia and Albania – *Halacsyetalia sendtneri* Ritter-Studnička 1970 –, with two newly described alliances – *Polygonion albanicae* Ritter-Studnička 1970 and *Potentillion visianii* Ritter-Studnička 1970. She classified the order within the class *Festuco-Brometea* Br.-Bl. et Tx. ex Klika et Hadač 1944 due to the presence of characteristic taxa of dry grasslands of the order *Festucetalia valesiaca* Br.-Bl. & Tx. ex Br.-Bl. 1950 within these communities, which were also rich in so-called endemic serpentinophytes. Many associations described from serpentine areas in Serbia and Kosovo were afterwards classified within the alliance *Centaureo-Bromion fibrosi* (for reviews see TATIĆ & VELJOVIĆ 1990 and AČIĆ et al. 2014). Later on BERGMEIER et al. (2009) described four new associations of open serpentine rocky grasslands in Greece and introduced the new alliance *Alysson heldreichii* Bergmeier et al. 2009, which they included in the order *Astragalo-Potentilletalia* Micevski 1970. Finally, in the most recent study of TZONEV et al. (2013) regarding Bulgarian serpentine grasslands, relationships of the Balkan

serpentinite syntaxa were seen in a new light. By comparing the Bulgarian syntaxa with those from neighbouring Balkan countries with respect to their floristic composition and diagnostic species, the authors concluded that Bulgarian and Greek syntaxa are part of the order *Astragalo-Potentilletalia*, while syntaxa from Bosnia and Herzegovina, Serbia and Kosovo are part of the order *Halacsyetalia sendtneri*.

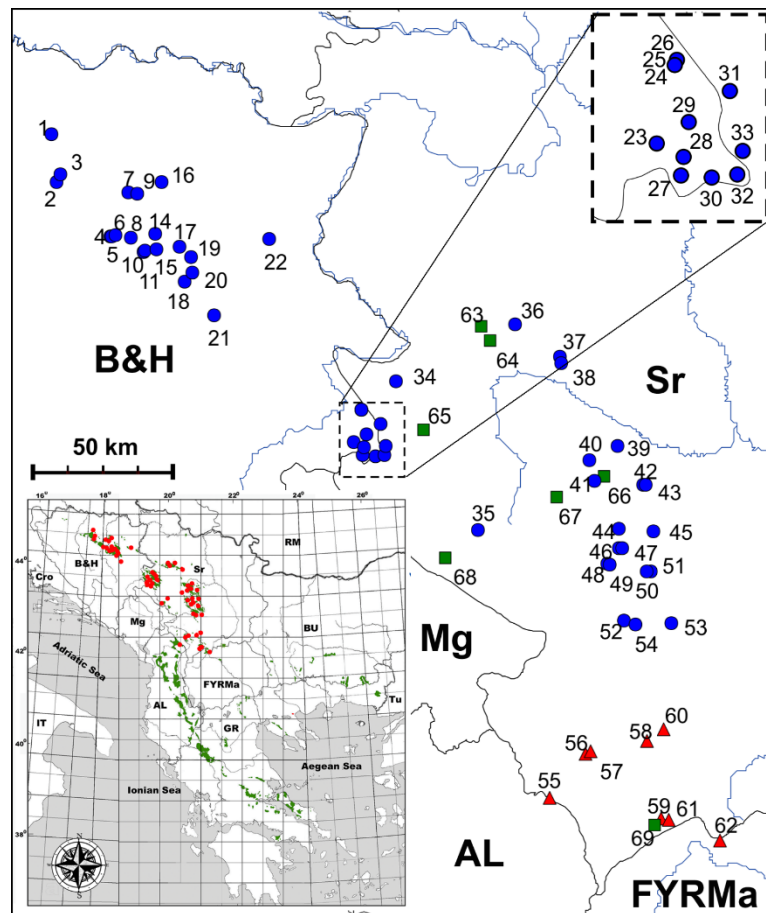
In the present paper we followed the original syntaxonomic concept of RITTER-STUDNIČKA (1970), accepted by RODWELL et al. (2002), ZUPANČIĆ et al. (1986) and KOJIĆ et al. (2004), which was recently supported by the hierarchical classification of a large data set of phytosociological relevés of dry grasslands in the Central Balkans published in AČIĆ et al. (2015), considering vegetation of the order *Halacsyetalia sendtneri* as steppe-like vegetation on shallow ultramafic soils in the Balkans classified within the class *Festuco-Brometea*. At the same time, we accepted the geographical concept of ZUPANČIĆ et al. (1986) and TZONEV et al. (2013), who considered the order *Halacsyetalia sendtneri* to be restricted to the Western and Central Balkans, from Bosnia and Herzegovina to Serbia and Kosovo.

Various phytocoenological data have been published for the investigated area; however, there have not been any synoptic works on this distinct vegetation type. Considering this, synsystematic relationships within the order *Halacsyetalia sendtneri* were not clearly defined, and critical re-evaluation is needed. Therefore, the main aims of our study were (1) to evaluate described alliances traditionally included in the order *Halacsyetalia sendtneri*, (2) to propose a revised syntaxonomic concept for the serpentine steppe-like vegetation on the Central Balkan Peninsula, (3) to provide a diagnosis with a list of diagnostic, dominant and constant species for the analysed order and alliances and finally (4) to provide nomenclatural adjustments for invalidly published syntaxa.

## 2. Study area

The studied area is located in the central part of the Balkan Peninsula (south-eastern Europe). It overlaps with the distribution of serpentinite outcrops in Central Bosnia and Herzegovina, Western and Central Serbia and Kosovo (Fig. 1). According to HORVAT et al. (1974), the studied area belongs biogeographically to the eastern part of the Illyrian (Dinaric Alps) and the northern part of the Scardo-Pindian (Scardian Mts.) subregions of the Middle European floristic region.

The climatic conditions in the Illyrian part of the studied area are influenced by the humid Atlantic climate, which reaches it via the western parts of the Balkans (Dinaric Alps). In this region there is a specific sub-type of the moderately continental humid climate (type VI 2b sensu WALTER & LEITH 1964, 2.1 sensu STEVANOVIĆ & STEVANOVIĆ 1995), characterised by 720 to 900 mm of precipitation during the year and absence of dry and semi-dry periods (occasionally, there are months with semi-dry days). The moderately continental humid climate is also significantly influenced by the mountains; therefore, it may be described as transitional variety in between moderately-continental and mountain climate of the Middle-European type (type VI 2b/X 1 sensu WALTER & LEITH 1964, 2.1/4.1 sensu STEVANOVIĆ & STEVANOVIĆ 1995). The climatic conditions in the Scardo-Pindian part of the studied area are influenced by the arid Mediterranean climate, which reaches it via canyons and gorges of Montenegro and Albania from southwest (influence from the Adriatic Sea) or via valleys and plains of Macedonia (influence from the Aegean Sea). In this region there are specific transitional sub-types between Mediterranean and moderately continental



**Fig. 1.** Map of the localities of analysed syntaxa. Numbers on the map correspond to data given in the Supplement E1. Blue dots – syntaxa belonging to the *Potentillion visianii*; red triangles – syntaxa belonging to the *Centaureo kosaninii-Bromion fibrosi*; green squares – syntaxa belonging to the “*Thymion jankae*” prov. The distribution of the serpentinites in the Balkan Peninsula (green outcrops) and the studied syntaxa (red dots) are provided in the map insert (lower left). B&H – Bosnia and Herzegovina, Sr – Serbia, Mg – Montenegro, AL – Albania, FYRMa – Macedonia, GR – Greece, BU – Bulgaria, RM – Romania, Cro – Croatia, IT – Italy, Tu – Turkey.

**Abb. 1.** Karte der Untersuchungsgebiete. Die Nummern der Gebiete entsprechen denen in Anhang E1. Blaue Punkte – Gesellschaften des *Potentillion visianii*, rote Dreiecke – Gesellschaften des *Centaureo kosaninii-Bromion fibrosi*, Grüne Quadrate – Gesellschaften des “*Thymion jankae*” prov. In der kleinen Karte sind die Vorkommen der Serpentinite auf dem Balkan als grüne Fläche und die Lage der Untersuchungsgebiete als rote Punkte dargestellt. B&H – Bosnien und Herzegovina, Sr – Serbien, Mg – Montenegro, AL – Albanien, FYRMa – Mazedonien, GR – Griechenland, BU – Bulgarien, RM – Rumänien, Cro – Kroatien, IT – Italien, Tu – Türkei.

humid climate (types IV 5 and IV 6 sensu WALTER & LEITH 1964; 1.2./2.1. and 1.3./2.2 sensu STEVANOVIĆ & STEVANOVIĆ 1995), characterised by 500 to 700 mm of precipitation during the year and the presence of a dry period lasting up to two months and a semi-dry period that can last up to four months.

### 3. Methods

#### 3.1 Data collecting

For the purposes of this study, phytocoenological literature on different serpentine areas in the Western and Central Balkans (Bosnia and Herzegovina, Serbia and Kosovo) was studied. More detailed information regarding all analysed syntaxa is given in Table 1. The analysed syntaxa are distributed throughout the area of serpentine outcrops in Bosnia and Herzegovina, Serbia and Kosovo (Fig. 1, Supplement E1).

The nomenclature and taxonomy of plant taxa is in agreement with the Flora Europaea Database (TUTIN et al. 2001), except for the species *Bothriochloa ischaemum* (L.) Keng., *Bromus fibrosus* Hack., *Cytisus procumbens* Bojer ex Baker var. *petrovicii* (Adamović) Diklić, *Dianthus sylvestris* Wulfen f. *papillosus* (Vis. & Pančić) Novák, *Echium rubrum* Forssk., *Potentilla arenaria* Borkh. Ex G. Gaertn., *Potentilla tommasiniana* F. W. Schultz, *Sedum serpentini* Janch., *Sesleria serbica* (Adamović) Ujhelyi, *Stachys recta* subsp. *baldaccii* (K. Malý) Hayek, *S. recta* subsp. *rhodopaea* (Velen.) Chrtek, *Thymus jankae* Čelak, *Tulipa serbica* Tatić & Krivošej, *Veronica austriaca* subsp. *jacquinii* (Baumg.) Eb. Fisch and *Viola kopaonikensis* Pančić and for the critical taxa with unresolved relationships, which were included in species complexes (aggregates) – Table 2. Taxa determined at the level of genus were omitted from the analyses, as well as mosses, which were recorded only in synoptic tables of RITTER-STUDNIČKA (1970) and KRAUSE & LUDWIG (1957). The names of infraspecific taxa in tables are presented with the genus name and the infraspecific epithet with an asterisk in between (the specific epithet is omitted; e.g. *Stachys recta* subsp. *baldaccii* = *Stachys* \* *baldaccii*).

All relevés used in this article are stored in the database of Grassland Vegetation of Serbia (GIVD number: EU-RS-002, AČIĆ et al. 2012).

#### 3.2 Data analyses

Prior to the numerical analyses of analytical data and their transformation in synoptic columns, we evaluated the quality of the available information regarding geographical positions and plot sizes of relevés. It turned out that in our dataset we had very different plot sizes, which were unevenly distributed in the study area (Table 3). There were 88 relevés (32%) without any information on the plot size: all relevés from Bosnia and Herzegovina (100%) and 57% from Kosovo. On the other hand, there were 76 relevés (28%) with plot sizes larger than 50 m<sup>2</sup>: 25% of the relevés from Kosovo and 36% of those from Serbia. If we take into consideration (i) the fact that the outcomes of numerical analyses are very sensitive to different plot sizes (for discussion on this topic see DENGLER 2003, CHYTRÝ & OTÝPKOVÁ 2003, MICHL et al. 2010 etc.) and (ii) the recommendation that the maximal plot size for numerical analyses of most types of herbaceous vegetation should not exceed 10 m<sup>2</sup> (DENGLER 2003), 16 m<sup>2</sup> (CHYTRÝ & OTÝPKOVÁ 2003) or 50 m<sup>2</sup> (MICHL et al. 2010), we can conclude that a large part of our data (65% of the total data set: 100% for Bosnia and Herzegovina, 73% for Kosovo and 58% for Serbia) do not meet the afore-mentioned criteria.

Considering the fact that we had two different types of data – 26 associations published in the form of analytical tables (277 relevés) and 7 associations in the form of synoptic columns, data analyses were conducted in four steps: In the first step, we performed several cluster analyses of analytical data with different combinations of distance measures and group linkage methods in order to determine whether all relevés originally published as belonging to particular syntaxa form compact, “floristically well-characterised groups”. Secondly, we prepared 26 synoptic columns for the associations that were published with associated analytical tables. In the third step, synoptic columns for the associations published with accompanying analytical tables (26 synoptic columns) were joined together with the synoptic tables of seven associations published by RITTER-STUDNIČKA (1970) and KRAUSE & LUDWIG (1957). Finally, the classification of the synoptic table (33 synoptic columns and 499 taxa) was carried out based on combined “classical phytosociological methods” (table sorting using simple numerical tools, e.g. calculated frequencies, as proposed by TICHÝ et al. 2012).

**Table 1.** Analysed associations (valid names) per localities with number of analysed relevés and sources of published data (Legend: st – synoptic table). Original names of the associations are provided in the syntaxonomic overview of Ačić et al. (2014) and in section 4.2.2.3 Nomenclatural adjustments at association level.

**Tabelle 1.** Untersuchte Assoziationen mit Lokalitäten, der Anzahl an verwendeten Aufnahmen sowie Quellenangaben. st – Stetigkeitstabelle. Die Originalnamen der Assoziationen werden in der syntaxonomischen Übersicht von Ačić et al. (2014) und im Kapitel 4.2.2.3 angegeben.

No.	Association	Locality	No. relevés	Source of relevés
<b>Bosnia and Herzegovina</b>				
1	<i>Alyssum muralae-Silenetum vulgare</i> H. Ritter-Studnička 1970	Gostović, Knjavaja, Papratnica, Žepce	st	Ritter-Studnička 1970
2	<i>Dorycnio germanicae-Scabietosum cinerariae</i> H. Ritter-Studnička 1970	Duboštica, Krivaja, Maglaj, Ozren, Žepce	st	Ritter-Studnička 1970
3	<i>Erysimo linariifoliae-Jovibarbetum heuffelii</i> H. Ritter-Studnička 1970	Rudo, Varda, Višegrad	st	Ritter-Studnička 1970
4	<i>Euphorbio montenegrinae-Brometum erecti</i> Krause & Ludwig 1956	Gostović	5	Krause & Ludwig 1956
5	<i>Fumano bonapartei-Euphorbietum glabriflorae</i> H. Ritter-Studnička 1970	Hrnska Kosa, Rudo, Vardište, Višegrad	st	Ritter-Studnička 1970
6	<i>Halacsyio sendtneri-Caricetum humilis</i> Krause & Ludwig 1956	Gostović	6	Krause & Ludwig 1956
7	<i>Halacsyio sendtneri-Seselietum rigidae</i> H. Ritter-Studnička 1970	Gostović, Kalesija, Krivaja, Ljeskovica, Maglaj, Olovo, Pribinić, Pnjavor, Velež, Velika Jaovomova, Žepce	st	Ritter-Studnička 1970
8	<i>Scrophulario tristis-Linrietum rubroides</i> H. Ritter-Studnička 1970	Rudo, Uvac, Varda, Višegrad	st	Ritter-Studnička 1970
9	<i>Violo beckettiae-Seslerietum serbicae</i> Krause & Ludwig 1957	Gostović	st	Krause & Ludwig 1957
<b>Serbia</b>				
10	<i>Alyssum markgrafii-Artemisietum albae</i> Ačić et al. 2014	Mt Goč	7	Blaženčić & Vučković 1983
11	<i>Artemisio albae-Achnatheretum calamagrostis</i> Jovanović-Dunjić et S. Jovanović ex Ačić et al. 2014	Mt Goč, Mt Kopaonik (Rajičeva Gora, Vljajkovci)	4	GIVD: EU-RS-002
12	<i>Artemisio albae-Silenetum armeriae</i> D. Lakušić et Kabaš in Ačić et al. 2014	Mt Kopaonik (Vljajkovci)	8	GIVD: EU-RS-002
13	<i>Brometum fibrosi</i> Pavlović 1962	Mt Stolovi, Mt Rogozna	2	Pavlović 1962
14	<i>Bromo fibrosi-Artemisietum albae</i> A. Marković ex Ačić et al. 2014	Mt Suvobor, Brljani Gorge	10	Marković 2007
15	<i>Bromo fibrosi-Chrysogononum grylli</i> Tatić 1969	Mt Studena	13	Tatić 1969
16	<i>Festuco ovinae-Euphorbietum glabriflorae</i> S. Jovanović et R. Jovanović-Dunjić in S. Jovanović et al. ex Ačić et al. 2014	Mt Tara, Mt Zlatibor	11	Jovanović et al. 1992
17	<i>Festuco panicatae-Caricetum humilis</i> Jovanović-Dunjić et S. Jovanović ex Ačić et al. 2014	Mt Kopaonik (Rajičeva Gora)	5	GIVD: EU-RS-002

No.	Association	Locality	No. relevés	Source of relevés
18	<i>Halacxyo sendineri-Potentilletum mollis</i> Pavlović 1955	Cmi Rzvav-Uvac, Mt Rogozna	2	Pavlović 1962
19	<i>Poo alpinae-Plantaginatum holostei</i> Kojić et Ivanović 1953	Mt. Majjen	1	Cincović & Kojić 1955
20	<i>Poo alpinae-Plantaginatum holostei</i> Kojić et Ivanović 1953	Mt. Majjen (Divčibare)	10	Cincović & Kojić 1956
21	<i>Poo alpinae-Plantaginatum holostei</i> Kojić et Ivanović 1953	Mt. Majjen (Tometino polje)	4	Kojić & Ivanović 1953
22	<i>Poo alpinae-Plantaginatum holostei</i> Kojić et Ivanović 1953	Mt. Radočelo (Rudhijanska visoravan)	2	Kojić et al. 1992
23	<i>Poo molineri-Plantaginatum holostei</i> Pavlović 1951	Mt. Ozren	9	Pavlović 1955
24	<i>Poo molineri-Plantaginatum holostei</i> Pavlović 1951	Mt. Studena	12	Tatić 1969
25	<i>Poo molineri-Plantaginatum holostei</i> Pavlović 1951	Mt. Zlatibor	16	Pavlović 1951
26	<i>Potentillo tomasiniana-Festucetum panicatae</i> D. Lakušić et Kabaš in Ačić et al. 2014	Mt Kopaonik (Kmejljica)	9	GIVD: EU-RS-002
27	<i>Potentillo tomasiniana-Stipetum pennatae</i> A. Marković ex Ačić et al. 2014	Mt Goč, Brdani Gorge	10	Marković 2007
28	<i>Seslerio serbicae-Caricetum humilis</i> D. Lakušić et Kabaš in Ačić et al. 2014	Mt Kopaonik (Kukavica)	8	GIVD: EU-RS-002
29	<i>Stipetum novakii</i> Kabaš et D. Lakušić in Kabaš et al. 2013	Brdani Gorge	11	Kabaš et al. 2013
Kosovo				
30	<i>Centaureo kosaninii-Euphorbietum glabriflorae</i> S. Jovanović et V. Stevanović in Ačić et al. 2014	Mt Šar-Planina (Brezovica)	6	GIVD: EU-RS-002
31	<i>Cynancho vincecoxici-Saponarietum intermediae</i> Blečić et al. 1969	Mt Šar-Planina (Brezovica)	13	Blečić et al. 1969
32	<i>Hyperico barbati-Euphorbietum glabriflorae</i> Rexhepi ex Ačić et al. 2014	Mt Drenica (Nekoc)	10	Krasniqi & Millaku 2007
33	<i>Hyperico barbati-Euphorbietum glabriflorae</i> Rexhepi ex Ačić et al. 2014	Mt Goleš, Mt Koznica	11	Rexhepi 1978
34	<i>Carici kitaibeliana-Euphorbietum glabriflorae</i> (Randelović et al.) D. Lakušić et Kuzmanović in Kuzmanović et al. <i>nov. hoc loco</i>	Mt Kopaonik (Barej)	5	Randelović et al. 1979 and this paper
35	<i>Onosmo echinoidis-Scabrosetum fumaroidis</i> Rexhepi ex Ačić et al. 2014	Koznička Boka	10	Rexhepi 1978, 1985
36	<i>Polygalo döfleri-Genistetum hassertiana</i> Blečić et al. 1969	Koznička Boka	10	Blečić et al. 1969
37	<i>Polygalo döfleri-Genistetum hassertiana</i> Blečić et al. 1969	Dakovica	10	Rexhepi 1978
38	<i>Potentillo tomasiniana-Fumanetum bonapartei</i> Rexhepi ex Ačić et al. 2014	Mt. Kopaonik (Lis Čuka, Belaška), Mt. Rogozna (Banjska)	10	Rexhepi 1979
39	<i>Sedo serpentini-Bornmuellerietum dieckii</i> Blečić et al. 1969	Mt Šar-Planina (Ostrovnica)	11	Blečić et al. 1969
40	<i>Sedo serpentini-Dianthetum serbici</i> Pavlović 1967	Mt Rogozna	7	Pavlović 1967
41	<i>Stipo mayerii-Convolvuletum compacti</i> Millaku et al. 2011	Gurane	10	Millaku et al. 2011

**Table 2.** Species complexes (aggregates) of the critical taxa used in this paper.

**Tabelle 2.** Kritische Artengruppen (Art-Aggregate), die in dieser Studie verwendet werden.

Agreggate taxon	Included taxa
<i>Anthyllis vulneraria</i> agg.	<i>Anthyllis vulneraria</i> , <i>A. vulneraria</i> subsp. <i>carpatica</i> , <i>A. vulneraria</i> subsp. <i>polyphylla</i>
<i>Astragalus onobrychis</i> agg.	<i>Astragalus onobrychis</i> , <i>A. onobrychis</i> var. <i>chlorocarpus</i> , <i>A. onobrychis</i> var. <i>multijugus</i> , <i>A. onobrychis</i> f. <i>kraljevensis</i>
<i>Festuca ovina</i> agg.	<i>Festuca ovina</i> , <i>F. duriuscula</i>
<i>Leontodon crispus</i> agg.	<i>Leontodon crispus</i> , <i>L. crispus</i> subsp. <i>asper</i> , <i>L. crispus</i> subsp. <i>aspermus</i>
<i>Minuartia verna</i> agg.	<i>Minuartia verna</i> , <i>M. verna</i> subsp. <i>montana</i> , <i>M. montana</i> f. <i>glandulosa</i> , <i>M. collina</i>
<i>Poa badensis</i> agg.	<i>Poa badensis</i> , <i>P. badensis</i> var. <i>glaucescens</i> , <i>P. concinna</i> , <i>P. molinieri</i> , <i>P. perconcinna</i>
<i>Sanguisorba minor</i> agg.	<i>Sanguisorba minor</i> , <i>S. minor</i> subsp. <i>minor</i> , <i>S. minor</i> subsp. <i>muricata</i>
<i>Scabiosa columbaria</i> agg.	<i>Scabiosa columbaria</i> , <i>S. dubia</i> , <i>S. portae</i>
<i>Silene vulgaris</i> agg.	<i>Silene anthelopus</i> , <i>S. cucubalus</i> subsp. <i>bosniaca</i> , <i>S. vulgaris</i> , <i>S. willdenowii</i> var. <i>serpentina</i>
<i>Stachys recta</i> agg.	<i>Stachys recta</i> s.l. excluding: <i>S. recta</i> subsp. <i>*baldaccii</i> , <i>S. recta</i> subsp. <i>*rhodopaea</i>

\*Subspecies *S. recta* subsp. *baldaccii* and *S. recta* subsp. *rhodopaea* represent morphologically and geographically distinct entities, which can easily be distinguished from other infraspecific taxa within *S. recta* s.l. They were therefore treated as separate taxa in our study.

**Table 3.** Plot sizes and their distribution in the analysed syntaxa in the study area. No – number of relevés.

**Tabelle 3.** Flächengrößen der analysierten Aufnahme und ihre Verteilung innerhalb des Untersuchungsgebiets.

Area [m <sup>2</sup> ]	Total		Bosnia and Herzegovina		Kosovo		Serbia	
	No	%	No	%	No	%	No	%
No data	88	32	18	100	65	57	5	4
1–15	4	1	0	0	2	2	2	1
16–25	80	29	0	0	23	20	57	41
26–50	25	9	0	0	0	0	25	18
51–100	76	28	0	0	25	22	51	36
Σ	273	100	18	100	115	100	140	100

In the cluster analyses of analytical tables (273 relevés × 455 taxa × 24 associations), the original cover-abundance values for individual taxa were transformed into an ordinal scale as proposed by VAN DER MAAREL (1979). Cluster analyses (Bray-Curtis & Paired group average, Euclidean & Ward's method, Relative Euclidean & Flexible beta,  $\beta = -0.25$ ) were done in the programme packages PAST (HAMMER et al. 2001) and Juice (TICHÝ 2002). Criterion for floristically well-characterised groups of relevés derived from analytical tables was that in different cluster analyses, groups of relevés belonging to particular syntaxa formed compact clusters regardless of the method applied in the cluster analysis. In the cases when relevés that were *a-priori* classified as one association formed more than one compact cluster, each cluster was treated as a separate association for which its own synoptic column was formed. In contrast, in the cases when relevés that were *a-priori* classified into two or more syntaxa



formed one compact cluster, this cluster was treated as a unique syntaxon for which its own synoptic column was formed. In this way we prepared 24 synoptic columns for the associations that were published with associated analytical tables. Two additional synoptic columns were formed for the two associations described by PAVLOVIĆ (1955, 1962), each on the basis of two relevés from different localities (ass. 1.1.22 – *Brometum fibrosi* and ass. 1.1.23 – *Halacsyo sendtneri-Potentilletum mollis*). It should be emphasised, however, that a conclusive judgement regarding these associations can only be made after more comprehensive analyses of dry grasslands on the Balkans – a study being in course (Vassilev et al., in prep.), as well as the critical revision of the currently used association concept. Since the aim of our study was not to evaluate syntaxa at association level, we used in our analyses practically all known associations traditionally classified within the order *Halacsyetalia sendtneri*, which were treated in the same form in more recent studies of AČIĆ et al. (2015) and VASSILEV et al. (2016).

Considering the above-mentioned shortcomings of our dataset, numerical approaches of phytosociological classification based on the direct translation of the results of statistical analyses into a syntaxonomic scheme could not be applied. Consequently, the classification of the synoptic table (on the basis of which we proposed a new syntaxonomic concept) was carried out based on combined “classical phytosociological methods” (table sorting using simple numerical tools, e.g. calculated frequencies, as proposed by TICHÝ et al. 2012) including the determination of a relative diagnostic/fidelity value, which was used as additional parameter while sorting the columns of the synoptic table.

Taxa in the synoptic table were represented by constancy (expressed in percentage) and relative fidelity (written as a superscript of the constancy value: \*\* if *phi* was  $\geq 0.5$  and \* if it was  $\geq 0.25$ ). *Phi* values are given only for synoptic columns of analytical tables.

The approach of “relative fidelity” has been used to search for the optimum occurrence of a species among a group of floristically similar communities (WILLNER 2006, WILLNER et al. 2009). In this case, we calculated the diagnostic value (*phi*) not taking into account the distribution of species in all types of vegetation in a geographically defined region, but their distribution within a syntaxon of higher hierarchical level (order *Halacsyetalia sendtneri* as abstract vegetation unit) that includes lower-level syntaxa for which diagnostic species are to be determined.

Criteria for diagnostic and constant species in the diagnosis of syntaxa were as follows:

- Species with *phi* values higher than  $\geq 0.25$  have been taken into account in the selection of diagnostic species. We considered species as highly diagnostic when *phi* was  $\geq 0.50$  and as diagnostic when *phi* was  $\geq 0.25$  (CHYTRÝ 2007).
- The threshold frequency values for constant species were 30% for the order and 40% for the alliances.
- The diagnostic species of classes were determined by use of the EuroVegChecklist Expert System, using the ESL1 species list (MUCINA et al. in press) in the programme JUICE (TICHÝ et al. 2012), except for the species that are not classified yet in the ESL1 (e.g. *Genista hassertiana*, *Polygala doerfleri*).

The diagnostic species of the order *Halacsyetalia sendtneri* proposed by RITTER-STUDNIČKA (1970) as well as possible diagnostic characters of highly frequent and dominant serpentrophytes from our dataset were tested by the analysis of their distribution in the main types of grasslands in Serbia (*Molinio-Arrhenatheretea*, *Festucetalia valesiaca*, *Festucetalia vaginatae*, *Astragalo-Potentilletalia*, *Halacsyetalia sendtneri*) stored in the database of Grassland Vegetation of Serbia (GIVD number: EU-RS-002, AČIĆ et al. 2012). For that purpose we analysed the distribution of 33 obligate or facultative serpentrophytes within 3,346 relevés formally classified in 5 groups, which correspond to the main types of grasslands in Serbia recognised and characterised in the study of AČIĆ et al. (2015).

## 4. Results and Discussion

### 4.1 Cluster analysis of analytical tables

Various algorithms and (dis)similarity measures yielded a very similar clustering topology (resulting clusters not shown). Apart from the associations *Halacsyo sendtneri-Caricetum humilis*, *Euphorbio montenegrinae-Brometum erecti* and *Hyperico barbati-Euphorbietum glabriflorae*, all other analysed associations appeared as “floristically homogenous and well-characterised groups” forming compact clusters regardless of the method applied in the cluster analysis.

The two associations described by KRAUSE & LUDWIG (1956) – *Halacsyo sendtneri-Caricetum humilis* and *Euphorbio montenegrinae-Brometum erecti* – were joined together in one compact cluster in all numerical analyses. Therefore, we treated them as one association (Ass. 1.1.1) in our study. Furthermore, relevés belonging to the association *Hyperico barbati-Euphorbietum glabriflorae* formed two distinct clusters, allowing us to treat relevés recorded on Mt. Kopaonik as belonging to a different association, named here provisionally as *Carici kitaibelianae-Euphorbietum glabriflorae* (Ass. 1.1.21).

### 4.2 Syntaxonomy and nomenclatural adjustments

#### 4.2.1 Syntaxonomy and delimitation of the order *Halacsyetalia sendtneri*

Land use and related anthropogenic influences on the Balkan Peninsula have been very intensive in the past. As a result, naturally occurring forest vegetation types have been degraded, leading to an expansion of secondary grasslands. Dry open rocky grassland vegetation on thin scelelogenous shallow ultramafic soils in the central Balkans (steppic vegetation on ultramafic soils in the Balkans) included in the order *Halacsyetalia sendtneri* represents typical secondary grasslands, which have developed mainly in the zone of thermophilous mixed deciduous broadleaved forests [*Quercion frainetto* Horvat 1954, *Quercion petraea-cerris* (Lakušić et Jovanović 1980) Čarni et al. 2009] and pine forests (*Erico-Pinetalia* Horvat 1959) and sporadically on south-exposed slopes in the zone of montane to subalpine beech forests (*Fagetalia sylvaticae* Pawlowski et al. 1928, HORVAT et al. 1974). The presence of woody (*Cotinus coggygria*, *Fraxinus ornus*, *Pinus nigra*, *Prunus mahaleb*, *Quercus cerris*, *Quercus pubescens*) and shrub species (*Genista ovata*, *Genista tinctoria*, *Juniperus oxycedrus*, *Lembotropis nigricans*, *Rosa pendulina*, *Rosa pimpinellifolia*) within the analysed syntaxa indicates that in some of them the progressive succession could continue in the direction of re-establishment of the afore-mentioned forests.

Although all relevant national (LAKUŠIĆ et al. 1978, ZUPANČIĆ 1986, KOJIĆ et al. 1998, 2004, LAKUŠIĆ & SABOVLJEVIĆ 2005, AČIĆ et al. 2014, 2015) and regional (RODWELL et al. 2002, MUCINA et al. in press) syntaxonomic reviews treat secondary open rocky grasslands developed on shallow scelelogenous ultramafic soils in the central Balkans as unique independent order *Halacsyetalia sendtneri* as proposed by RITTER-STUDNIČKA (1970), the syntaxonomic position of this order in different systems of classification has varied in the past. Namely, even though in the original description RITTER-STUDNIČKA (1970) classified the order *Halacsyetalia sendtneri* within the class *Festuco-Brometea*, LAKUŠIĆ et al. (1978) listed it within *Thero-Brachypodietea* Br.-Bl. 1947, ZUPANČIĆ (1986) and KOJIĆ et al. (1998) considered it to be part of *Festucetea vaginatae* Soó 1968, while LAKUŠIĆ & RANĐELOVIĆ (1996), RODWELL et al. (2002), KOJIĆ et al. (2004), and AČIĆ et al. (2014, 2015) classified it

back in *Festuco-Brometea*. Finally, a recent proposal by MUCINA et al. (in press) changed the position of this syntaxon classifying it within the class *Koelerio-Corynephoretea* Klika in Klika et Novák 1941. However, in the classification of the vegetation of South-Eastern Europe proposed by HORVAT et al. (1974), this type of vegetation was discussed in the context of azonal pine forests (*Erico-Pinetea* Horvat 1959).

Regardless of the fact that within the analysed associations many taxa diagnostic for the class *Koelerio-Corynephoretea* are registered (e.g. *Arenaria leptoclados*, *A. serpyllifolia*, *Festuca ovina*, *Logfia arvensis*, *Petrorhagia prolifera*, *P. saxifraga*, *Plantago holosteum*, *Potentilla inclinata*, *Rumex acetosella*, *Scleranthus annuus*, *S. perennis* subsp. *perennis*, *Sedum acre*, *S. rupestre*, *S. sexangulare*, *Sideritis montana*, *Trifolium arvense*, *T. campestre* etc.), which was the main argument of some authors to exclude the order *Halacsyetalia sendtneri* from the class *Festuco-Brometea*, the EuroVegChecklist Expert System assigned 98% of analysed relevés to the class *Festuco-Brometea* and only 1% to the class *Koelerio-Corynephoretea*. This formal classification is consistent with the fact that within the analysed associations, taxa diagnostic for the class *Festuco-Brometea* (e.g. *Allium flavum*, *Artemisia alba*, *Asperula cynanchica*, *A. purpurea*, *Astragalus onobrychis*, *Carex caryophyllea*, *C. humilis*, *Centaurea biebersteinii*, *Chrysopogon gryllus*, *Danthonia alpina*, *Dorycnium pentaphyllum* subsp. *germanicum*, *Festuca panciciana*, *F. valesiaca*, *Hippocrepis comosa*, etc.) have the highest frequency and abundance (Supplement S1).

The uniqueness of the order *Halacsyetalia sendtneri* is unambiguously confirmed in a recently published study on classification, ecology and biodiversity of Central Balkan dry grasslands, which analysed a large data set of phytosociological relevés (1,897 relevés with 1,323 species) of grasslands included in the classes *Festuco-Brometea* and *Festucetea vaginatae* (AĆIĆ et al. 2015). This study has shown that the main core of diagnostic species of the order are obligate serpentinophytes endemic to the Balkan. Many of them are stenoendemic plants or Tertiary relicts with a wider distribution on serpentinite areas of the Central Balkan Peninsula (BLEČIĆ et al. 1969, RITTER-STUDNIČKA 1970, STEVANOVIĆ et al. 2003, TOMOVIĆ et al. 2014, AĆIĆ et al. 2015).

In our dataset 499 taxa were registered within the analysed associations. Forty nine of them represent obligate or facultative serpentinophytes, of which forty are endemics of the Balkan Peninsula: *Alyssum montanum* subsp. *serbicum*, *Alyssum markgrafii*, *Alyssum bertolonii* subsp. *scutarinum*, *Aster albanicus*, *Bornmuellera dieckii*, *Centaurea kosaninii*, *Convolvulus boissieri* subsp. *compactus*, *Dianthus sylvestris* f. *papillosus*, *Dianthus pinifolius* subsp. *serbicus*, *Dianthus giganteus* subsp. *croaticus*, *Eryngium serbicum*, *Euphorbia glabriflora*, *Euphorbia montenegrina*, *Euphorbia serpentina*, *Fumana bonapartei*, *Genista hasertiana*, *Halacsysa sendtneri*, *Haplophyllum boissierianum*, *Linaria rubioides*, *Linum tauricum* subsp. *serbicum*, *Polygala doerfleri*, *Polygonum albanicum*, *Potentilla mollis*, *Potentilla visianii*, *Sanguisorba albanica*, *Saponaria sicula* subsp. *intermedia*, *Scabiosa fumaroides*, *Scrophularia canina* subsp. *tristis*, *Sedum serpentina*, *Sesleria serbica*, *Silene bupleuroides* subsp. *staticifolia*, *Stachys recta* subsp. *baldaccii*, *Stachys scardica*, *Stipa mayeri*, *Stipa novakii*, *Tragopogon pterodes*, *Tulipa serbica*, *Verbascum glabratum* subsp. *bosnense*, *Viola beckiana* and *Viola kopaonikensis* (STEVANOVIĆ et al. 2003, TOMOVIĆ et al. 2014).

Given that many of these taxa were proposed by RITTER-STUDNIČKA (1970) as diagnostic for the order *Halacsyetalia sendtneri* and that many highly frequent and dominant serpentinophytes from our dataset have diagnostic character, we analysed their distribution in other types of grasslands stored in the database of Grassland Vegetation of Serbia (GIVD number: EU-RS-002, AĆIĆ et al. 2012). In fact we analysed the distribution of 33 obligate or facultative

tive serpentinophytes within 3,346 relevés formally classified in 5 groups, which correspond to the main types of grasslands in Serbia (*Molinio-Arrhenteretea*, *Festucetalia valesiaca*, *Festucetalia vaginatae*, *Astragalo-Potentilletalia* and *Halacsyetalia sendtneri*). The results of this analysis have shown that all analysed serpentinophytes, both endemic and non-endemic, are almost completely restricted to dry open rocky grasslands on shallow skeletal ultramafic soils and that they may be considered as diagnostic for the order *Halacsyetalia sendtneri* and associated alliances (Table 4).

Although large serpentine areas are also present in the southern and southeastern part of the Balkan Peninsula (large areas in Greece and smaller portions in Bulgaria and Macedonia, see Figure 1 and STEVANOVIĆ et al. 2003), where similar dry grasslands on metalliferous soils are found, recent studies have shown that associations from Greece and Bulgaria should be assigned to the order *Astragalo-Potentilletalia* (BABALONAS et al. 1997, TZONEV et al. 2013).

#### 4.2.2 Nomenclatural adjustments

##### 4.2.2.1 Nomenclatural adjustments at order level

###### ***Halacsyetalia sendtneri* Ritter-Studnička 1970 (*Festuco-Brometea*)**

Name-giving species: *Halacsysa sendtneri* (Boiss.) Dörfler

Typus: *Potentillion visianii* Ritter-Studnička 1970 (*lectotypus hoc loco*)

Diagnostic taxa: *Alyssum markgrafii*, *A. montanum* subsp. *serbicum*, *Asplenium cuneifolium*, *Bromus fibrosus*, *B. pannonicus*, *Dianthus sylvestris* f. *papillosus*, *Echium rubrum*, *Euphorbia glabriflora*, *Fumana bonapartei*, *Halacsysa sendtneri*, *Linum tauricum* subsp. *serbicum*, *Notholaena marantae*, *Potentilla australis*, *P. visianii*, *Scabiosa fumarioides*, *Sedum serpentinum*, *Silene bupleuroides* subsp. *staticifolia*, *S. paradoxa*, *Stachys recta* subsp. *baldaccii*, *S. scardica*.

Constant taxa: *Acinos alpinus*, *Aethionema saxatile*, *Allium flavum*, *Alyssum montanum* subsp. *serbicum*, *A. markgrafii*, *A. murale*, *Artemisia alba*, *Asperula cynanchica*, *A. purpurea*, *Asplenium cuneifolium*, *Astragalus onobrychis*, *Bromus fibrosus*, *Carex caryophyllaea*, *C. humilis*, *Centaurea biebersteinii*, *Chrysopogon gryllus*, *Dorycnium pentaphyllum* subsp. *germanicum*, *Echium rubrum*, *Euphorbia cyparissias*, *E. glabriflora*, *Festuca valesiaca*, *Fraxinus ornus*, *Galium lucidum*, *Halacsysa sendtneri*, *Hieracium bauhinii*, *Hypericum barbatum*, *Iris reichenbachii*, *Juniperus oxycedrus*, *Leontodon crispus*, *Lotus corniculatus*, *Medicago prostrata*, *Melica ciliata*, *Minuartia verna*, *Notholaena marantae*, *Petrorhagia saxifraga*, *Plantago holostium*, *Poa badensis*, *Potentilla australis*, *P. pedata*, *Rumex acetosella*, *Sanguisorba minor*, *Scabiosa columbaria*, *Scleranthus perennis* subsp. *dichotomus*, *Sedum hispanicum*, *Sedum serpentinum*, *Silene bupleuroides* subsp. *staticifolia*, *Silene paradoxa*, *Stachys recta*, *Stachys recta* subsp. *baldaccii*, *Stachys scardica*, *Stipa novakii*, *Teucrium montanum*, *Thymus jankae*, *T. longicaulis*.

Distribution: Central part of the Balkan Peninsula, in the territories of Bosnia and Herzegovina, Serbia and Kosovo, Montenegro and Albania (probably also in N Macedonia). From a synchorological viewpoint, the *Halacsyetalia sendtneri* vegetation belongs to the two main Balkan biogeographical provinces: Illyrian (Dinaric Alps) and the northern part of Scardopindian (Scardian Mts.) (sensu HORVAT et al. 1974).

Diagnosis: Rocky steppic grasslands over shallow soils on ultramafic bedrocks in the Central Balkans.

**Table 4.** Distribution of 33 obligate or facultative serpentinophytes within the main types of grasslands in Serbia. Legend: Hal – diagnostic for the order *Halascyetalia sendtneri*, Pvis – diagnostic for the alliance *Potentillion visianii*, CBfib – diagnostic for the alliance *Centaureo kosaninii-Bromion fibrosi*, Tjan – diagnostic for the alliance “*Thymion jankae*”.

**Table 4.** Verbreitung von 33 obligaten oder fakultativen Serpentinophyten innerhalb der Haupt-Graslandtypen Serbiens. Hal – diagnostische Arten der Ordnung *Halascyetalia sendtneri*, Pvis – diagnostische Arten des Verbands *Potentillion visianii*, CBfib – diagnostische Arten des Verbands *Centaureo kosaninii-Bromion fibrosi*, Tjan – diagnostische Arten des Verband “*Thymion jankae*”.

Group No.		1	2	3	4	5		
Syntaxon		<i>Molinio-Arrhenetetea</i>	<i>Festucetalia valesiatae</i>	<i>Festucetalia vaginatae</i>	<i>Astragalo-Potentilletalia</i>	<i>Halascyetalia sendtneri</i>		
No. of releves		1351	1066	619	162	148		
Taxon		% phi	% phi	% phi	% phi	% phi	% phi	% phi
Hal	<i>Alyssum markgrafii</i>	. –	2 –	2 –	. –	<b>58</b>	<b>28</b>	
Hal	<i>Euphorbia glabriflora</i>	. –	. –	1 –	. –	<b>55</b>	<b>38</b>	
Hal	<i>Stachys recta</i> incl. <i>S.*baldaccii</i>	. –	5 –	22 1.5	7 –	<b>49</b>	<b>15</b>	
Hal	<i>Stachys scardica</i>	. –	6 –	. –	. –	<b>46</b>	<b>23</b>	
Hal	<i>Bromus fibrosus</i>	. –	1 –	2 –	1 –	<b>45</b>	<b>25</b>	
Hal	<i>Silene bupleuroides</i> incl. <i>S.*staticifolia</i>	. –	1 –	3 –	. –	<b>28</b>	<b>18</b>	
Hal	<i>Echium rubrum</i>	. –	1 –	. –	. –	<b>27</b>	<b>18</b>	
Hal	<i>Sedum album</i> (incl. <i>S. serpentinii</i> )	. –	1 –	3 –	. –	<b>27</b>	<b>25</b>	
Hal	<i>Potentilla australis</i>	. –	2 –	. –	. –	<b>26</b>	<b>16</b>	
Hal	<i>Halacsya sendtneri</i>	. –	. –	. –	. –	<b>18</b>	<b>19</b>	
Hal	<i>Dianthus sylvestris</i> incl. <i>D.*papillosus</i>	. –	. –	1 –	. –	<b>16</b>	<b>17</b>	
Hal	<i>Silene paradoxa</i>	. –	. –	. –	. –	<b>16</b>	<b>16</b>	
Hal	<i>Fumana bonapartei</i>	. –	. –	. –	. –	15	15	
Hal	<i>Linum*serbicum</i>	. –	1 –	. –	. –	15	12	
Hal	<i>Notholaena marantae</i>	. –	. –	. –	. –	12	14	
Hal	<i>Scabiosa fumarioides</i>	. –	1 –	. –	. –	<b>10</b>	<b>21</b>	
Hal	<i>Dianthus*serbicus</i>	. –	. –	. –	. –	<b>9</b>	<b>18</b>	
Hal	<i>Alyssum*serbicum</i>	. –	. –	. –	. –	6	9.7	
Hal	<i>Asplenium cuneifolium</i>	. –	. –	. –	. –	5	8.2	
Pvis	<i>Tragopogon pterodes</i>	. –	. –	. –	. –	7	10	
Pvis	<i>Stipa novakii</i>	. –	. –	. –	. –	3	7.8	
Pvis	<i>Alyssum*scutarinum</i>	. –	. –	. –	. –	2	5.7	
Pvis	<i>Eryngium serbicum</i>	. –	. –	. –	. –	1	6.7	
Pvis	<i>Haplophyllum boissieranum</i>	. –	. –	. –	. –	1	4.2	
CBfib	<i>Centaurea kosaninii</i>	. –	. –	. –	. –	<b>16</b>	<b>21</b>	
CBfib	<i>Polygala doerfleri</i>	. –	. –	. –	. –	9	11	
CBfib	<i>Saponaria*intermedia</i>	. –	. –	. –	. –	9	12	
CBfib	<i>Convolvulus*compactus</i>	. –	. –	. –	. –	<b>7</b>	<b>21</b>	
CBfib	<i>Stipa mayeri</i>	. –	. –	. –	. –	7	13	
CBfib	<i>Genista hassertiana</i>	. –	. –	. –	. –	5	12	
CBfib	<i>Aster albanicus</i>	. –	. –	. –	. –	1	4.6	
CBfib	<i>Sanguisorba albanica</i>	. –	. –	. –	. –	1	4.2	
Tjan	<i>Bornmuellera dieckii</i>	. –	. –	. –	. –	<b>13</b>	<b>19</b>	

Syntaxonomy and nomenclature: Although many taxa diagnostic for the class *Koelerio-Corynephoretea* are present in the analysed associations, the results of our study confirmed the opinion of the authors who classified the analysed order in the class *Festuco-Brometea* (RITTER-STUDNIČKA 1970, LAKUŠIĆ & RANĐELOVIĆ 1996, RODWELL et al. 2002, KOJIĆ et al. 2004, AČIĆ et al. 2014, 2015).

The order *Halacsyetalia sendtneri* was originally described along with two alliances. Later the alliance *Centaureo-Bromion fibrosi* Blečić et al. 1969 (ZUPANČIĆ 1986, KOJIĆ et al. 1998) was also included in this order, the same concept being applied in an overview of European vegetation proposed by RODWELL et al. (2002).

In the original description, RITTER-STUDNIČKA (1970) proposed 18 taxa as diagnostic for the order. According to the results of our analyses, eight taxa can maintain the status of “diagnostic for the order” (*Alyssum markgrafii*, *Asplenium cuneifolium*, *Bromus pannonicus*, *Dianthus sylvestris* f. *papillosus*, *Halacsya sendtneri*, *Notholaena marantae*, *Silene bupleuroides* subsp. *staticifolia*, *Stachys recta* subsp. *baldaccii*), two can be considered as “diagnostic for the alliance” *Potentillion visiani* (*Dianthus giganteus* subsp. *croaticus*, *Scrophularia canina* subsp. *tristis*), while others can be considered as “diagnostic for the class” *Festuco-Brometea* in the area of the Central Balkan peninsula (*Alyssum murale*, *Asperula cynanchica*, *Medicago prostrata*, *Minuartia verna*, *Silene armeria*) or *Koelerio-Corynephoretea* (*Rumex acetosella*, *Scleranthus perennis* subsp. *perennis*, *Sedum ochroleucum*). At the same time, the results of our analyses showed that twelve new taxa can be considered as diagnostic for the order (Supplement S1). Some of them were previously proposed as diagnostic for the alliances, while some were proved as diagnostic for the first time in this work (e.g. *Alyssum montanum* subsp. *serbicum*, *Linum tauricum* subsp. *serbicum*, *Potentilla australis*, *Scabiosa fumarioides*, *Sedum serpentini*, etc.).

#### 4.2.2.2 Nomenclatural adjustments at alliance level

***Potentillion visianii* Ritter-Studnička 1970 (*Halacsyetalia sendtneri*, *Festuco-Brometea*) incl. *Polygonion albanicae* Ritter-Studnička 1970**

Name-giving species: *Potentilla visianii* Pančić

Nomenclature type: *Fumano bonapartei-Euphorbietum glabriflorae* Ritter-Studnička 1970 (lectotypus hoc loco)

Diagnostic taxa: *Alyssum bertolonii* subsp. *scutarinum*, *Cardamine plumieri*, *Dianthus giganteus* subsp. *croaticus*, *Eryngium serbicum*, *Euphorbia montenegrina*, *Haplophyllum boissierianum*, *Linaria rubioides*, *Polygonum albanicum*, *Potentilla mollis*, *Scrophularia canina* subsp. *tristis*, *Sesleria serbica*, *Stipa novakii*, *Tragopogon pterodes*, *Tulipa serbica*, *Verbascum glabratum* subsp. *bosnense*, *Viola beckiana*, *Viola kopaonikensis*.

Constant taxa: *Alyssum markgrafii*, *A. murale*, *Artemisia alba*, *Asperula cynanchica*, *A. purpurea*, *Asplenium cuneifolium*, *Astragalus onobrychis*, *Bromus fibrosus*, *Carex humilis*, *Centaurea biebersteinii*, *Dorycnium pentaphyllum* subsp. *germanicum*, *Euphorbia glabriflora*, *Festuca valesiaca*, *Fraxinus ornus*, *Halacsya sendtneri*, *Leontodon crispus*, *Lotus corniculatus*, *Medicago prostrata*, *Melica ciliata*, *Minuartia verna*, *Notholaena marantae*, *Petrorhagia saxifraga*, *Poa badensis*, *Rumex acetosella*, *Sanguisorba minor*, *Silene bupleuroides* subsp. *staticifolia*, *Silene paradoxa*, *Stachys recta* subsp. *baldaccii*, *Stipa novakii*, *Teucrium montanum*, *Thymus jankae*.

**Distribution:** Central part of the Balkan peninsula, in the territories of C & E Bosnia and Herzegovina, C & W Serbia. From a synchorological viewpoint, the *Potentillion visianii* vegetation is restricted to the Illyrian biogeographical province (Dinaric Alps) (sensu HORVAT et al. 1974).

**Diagnosis:** Rocky steppic grasslands over ultramafic bedrocks in Bosnia and Herzegovina and C & W Serbia.

**Syntaxonomy and nomenclature:** The alliance *Potentillion visianii* was described by RITTER-STUDNIČKA (1970). Following the original diagnosis, RODWELL et al. (2002) defined this alliance as “rocky steppic grasslands over ultramafic bedrocks in Eastern Bosnia”. In the same paper, RITTER-STUDNIČKA (1970) described another alliance under the name *Polygonion albanicae* Ritter-Studnička 1970, which was also treated in the overview of RODWELL et al. (2002), defined as “rocky steppic grasslands over ultramafic bedrocks in Central Bosnia”.

Although the above-mentioned alliances were validly published as being accompanied by several associations supported with synoptic tables (ICPN Art. 7), the analyses of our complete dataset did not confirm their specificity. Thus out of six taxa singled out by RITTER-STUDNIČKA (1970) as diagnostic for the alliance *Polygonion albanicae*, three can be considered as diagnostic for the class *Festuco-Brometea* (*Centaurea biebersteinii* subsp. *biebersteinii*, *Lotus corniculatus*, *Dorycnium pentaphyllum* subsp. *germanicum*). *Sesleria latifolia* is a common species of rocky grassland occurring on limestone bedrock (*Festuco-Brometea*, JOVANOVIĆ-DUNJIĆ 1955, 1956, PEDASHENKO et al. 2013, VASSILEV et al. 2014) and subalpine grasslands (*Elyno-Seslerietea*, JOVANOVIĆ et al. 1992, RANĐELOVIĆ et al. 1979, RANĐELOVIĆ & REXHEPI 1984). Therefore, only *Euphorbia montenegrina* and *Polygonum albanicum* exhibit higher affinity to serpentine rocky grasslands of Central Bosnia and Herzegovina. It should be noted that part of the populations of *Euphorbia montenegrina* are inhabiting subalpine grasslands on silicates (*Juncetea trifidi*) and carbonates (*Elyno-Seslerietea*) in Montenegro and Bosnia and Herzegovina (ŠILIC 1984) and that the obligate serpentine species *Polygonum albanicum* was also recorded on the serpentine outcrops of northern Albania and Greece (AKERROYD 1987, STEVANOVIĆ et al. 2003). Similarly, out of twelve taxa defined by RITTER-STUDNIČKA (1970) as diagnostic for the alliance *Potentillion visianii*, only *Linaria rubioides*, *Potentilla mollis* and *Verbascum glabratum* subsp. *bosnense* can be considered as characteristic for the serpentine grasslands of Eastern Bosnia and Herzegovina, provided that the significant part of their areas are also on serpentinites of Western Serbia. Moreover, with the exception of *Erysimum linariifolium* and *Silene vulgaris*, which occur also in non-serpentine habitats, other taxa determined as diagnostic for the alliance *Potentillion visianii* by RITTER-STUDNIČKA (1970) occur exclusively on serpentinites of Kosovo and Southern Serbia as well and should therefore be considered as diagnostic for the order.

Furthermore, infraspecific taxa defined as diagnostic for the alliances *Polygonion albanicae* and *Potentillion visianii* by RITTER-STUDNIČKA (1970) – *Sesleria latifolia* (Adam.) Degen var. *serpentinica* Deyl, *Dorycnium germanicum* (Gremli) Rouy var. *serpentinicola* Rt., *Lotus corniculatus* L. f. *serpentina* Novák, *Armeria canescens* Host var. *serpentina* Novák and *Silene cucubalus* Wibel var. *zlatiborensis* Novák – are, according to the most recent taxonomic treatments (e.g. EURO+MED 2006), neglected or considered conspecific with broadly defined species (*Sesleria latifolia*, *Dorycnium pentaphyllum*, *Lotus corniculatus*, *Armeria canescens* and *Silene vulgaris* agg.). Considering the fact that syntaxa belonging to the two mentioned alliances share a significant number of taxa and that almost all the

identified diagnostic taxa are also present on the territory of Serbia, we included in the *Potentillion visianii* all syntaxa occurring either on the serpentine outcrops in Central and Eastern Bosnia and Herzegovina or on the serpentinites in C & W Serbia and N Kosovo. For the moment, we also included the associations published by PAVLOVIĆ (1955, 1962) – *Halacsyo sendtneri-Potentilletum mollis* and *Brometum fibrosi* – in this alliance, on the basis of their floristic composition.

The following associations are currently included in this alliance:

- Ass. 1.1.1 – *Halacsyo sendtneri-Caricetum humilis* Krause & Ludwig 1956 *nomen inversum propositum* (incl. *Euphorbio montenegrinae-Brometum erecti* Krause & Ludwig 1956)
- Ass. 1.1.2 – *Violo beckiana-Seslerietum serbicae* Krause & Ludwig 1957 *nomen inversum propositum*
- Ass. 1.1.3 – *Halacsyo sendtnerii-Seselietum rigidae* Ritter-Studnička 1970 *nomen inversum propositum*
- Ass. 1.1.4 – *Dorycnio germanicae-Scabietosum cinerea* Ritter-Studnička 1970 *nomen mutatum propositum*
- Ass. 1.1.5 – *Alyssu muralis-Silenetum vulgaris* (Ritter-Studnička 1970) Kuzmanović *et al. nom. nov. hoc loco*
- Ass. 1.1.6 – *Erysimo linariifoliae-Jovibarbetum heuffelii* Ritter-Studnička 1970 *nomen mutatum propositum*
- Ass. 1.1.7 – *Fumano bonapartei-Euphorbietum glabriflorae* Ritter-Studnička 1970 *nomen inversum propositum*
- Ass. 1.1.8 – *Scrophulario tristis-Linarietum rubioides* Ritter-Studnička 1970 *nomen mutatum propositum*
- Ass. 1.1.9 – *Stipetum novakii* Kabaš et D. Lakušić in Kabaš et al. 2013
- Ass. 1.1.10 – *Potentillo tommasiniana-Stipetum novakii* A. Marković ex Aćić et al. 2014 *nomen mutatum propositum*
- Ass. 1.1.11 – *Bromo fibrosi-Chrysopogonetum grylli* Tatić 1969
- Ass. 1.1.12 – *Bromo fibrosi-Artemisietum albae* A. Marković ex Aćić et al. 2014
- Ass. 1.1.13 – *Alyssu markgrafii-Artemisietum albae* Aćić et al. 2014
- Ass. 1.1.14 – *Artemisio albae-Achnatheretum calamagrostis* Jovanović-Dunjić et S. Jovanović ex Aćić et al. 2014
- Ass. 1.1.15 – *Festuco ovinae-Euphorbietum glabriflorae* S. Jovanović et R. Jovanović-Dunjić in S. Jovanović et al. ex Aćić et al. 2014
- Ass. 1.1.16 – *Potentillo tommasiniana-Festucetum panciciana* D. Lakušić et Kabaš in Aćić et al. 2014
- Ass. 1.1.17 – *Festuco panciciana-Caricetum humilis* Jovanović-Dunjić et S. Jovanović ex Aćić et al. 2014
- Ass. 1.1.18 – *Seslerio serbicae-Caricetum humilis* D. Lakušić et Kabaš in Aćić et al. 2014
- Ass. 1.1.19 – *Potentillo tommasiniana-Fumanetum bonapartei* Rexhepi ex Aćić et al. 2014
- Ass. 1.1.20 – *Sedo serpentini-Dianthetum serbici* Pavlović 1967
- Ass. 1.1.21 – *Carici kitaibeliana-Euphorbietum glabriflorae nom. prov.*
- Ass. 1.1.22 – *Brometum fibrosi* Pavlović 1962
- Ass. 1.1.23 – *Halacsyo sendtneri-Potentilletum mollis* Pavlović 1955



***Centaureo kosaninii-Bromion fibrosi* Blečić et al. 1969 (*Halacsyetalia sendtneri*, *Festuco-Brometea*)**

Orig. *Centaureo-Bromion fibrosi* Blečić et al. 1969

Name-giving species: *Centaurea kosaninii* Hayek, *Bromus fibrosus* Hack.

Nomenclature type: *Polygala doerfleri-Genistetum hassertianae* Blečić et al. 1969 (*lectotypus hoc loco*)

Diagnostic taxa: *Aster albanicus*, *Centaurea kosaninii*, *Convolvulus boissieri* subsp. *compactus*, *Genista hassertiana*, *Polygala doerfleri*, *Sanguisorba albanica*, *Saponaria sicula* subsp. *intermedia*, *Stipa mayeri*.

Constant taxa: *Achillea coarctata*, *Acinos alpinus*, *Agropyron cristatum*, *Allium flavum*, *Alyssum markgrafii*, *A. montanum* subsp. *serbicum*, *Anthyllis vulneraria*, *Artemisia alba*, *Astragalus onobrychis*, *Bromus fibrosus*, *Carex caryophylla*, *C. praecox*, *Centaurea kosaninii*, *C. stereophylla*, *Convolvulus cantabrica*, *Dorycnium pentaphyllum* subsp. *germanicum*, *Erysimum diffusum*, *Euphorbia cyparissias*, *E. glabriflora*, *Festuca panciciana*, *Filipendula vulgaris*, *Galium lucidum*, *Halacsysa sendtneri*, *Hieracium bauhini*, *H. cymosum*, *Hippocrepis comosa*, *Hypericum barbatum*, *H. perforatum*, *Iris reichenbachii*, *Juniperus oxycedrus*, *Koeleria macrantha*, *Leontodon crispus*, *Linum perenne*, *Lotus corniculatus*, *Melica ciliata*, *Minuartia verna*, *Orobanche gracilis*, *Petrorhagia saxifraga*, *Plantago argentea*, *P. holosteam*, *P. lanceolata*, *Poa badensis*, *Polygala doerfleri*, *Potentilla argentea*, *P. pedata*, *Rumex acetosella*, *Sanguisorba minor*, *Scabiosa columbaria*, *Scorzonera laciniata*, *Sedum ochroleucum*, *S. serpentini*, *Silene bupleuroides* subsp. *staticifolia*, *S. paradoxa*, *S. vulgaris*, *Stachys recta* subsp. *baldaccii*, *S. scardica*, *Stipa pulcherrima*, *Teucrium montanum*, *Thesium arvense*, *Thymus longicaulis*, *Vincetoxicum fuscum*.

Distribution: Central part of the Balkan peninsula, in the territories of S Serbia, Kosovo and N Albania. From a synchorological viewpoint, the *Centaureo kosaninii-Bromion fibrosi* vegetation is typical for the northern part of the Scardo-Pindian biogeographical province (Scardian Mts.) (sensu HORVAT et al. 1974).

Diagnosis: Rocky steppic grasslands over ultramafic bedrocks in S Serbia, Kosovo and N Albania.

Syntaxonomy and nomenclature: The alliance *Centaureo kosaninii-Bromion fibrosi* was described by BLEČIĆ et al. (1969). Following the original diagnosis, RODWELL et al. (2002) defined this alliance as “rocky steppic grasslands over ultramafic bedrocks in Serbia and Albania”. The analyses of our complete dataset verified *Centaureo kosaninii-Bromion fibrosi* as well-defined alliance. However, it turned out that the broadly defined concept of the *Centaureo kosaninii-Bromion fibrosi* proposed by ZUPANČIĆ (1986) and RODWELL et al. (2002), which included all rocky steppic grasslands over ultramafic bedrock in Serbia and Albania, is not adequate. The results of our analyses suggest that this alliance should be restricted to the rocky grasslands occurring on the territories of South Serbia (personal field observation in surrounding of Preševo), Kosovo and North Albania (personal field observation in surrounding of Shkoder). This distinction is not merely geographic, but also based on different climatic conditions, with the prevailing influence of the Mediterranean climate from the south. Additionally, the main part of the area of this alliance is situated in the northern part of the Scardo-Pindic phytogeographic province (sensu HORVAT et al. 1974).

In the original description, BLEČIĆ et al. (1969) proposed 10 taxa as diagnostic for the alliance. According to the results of our analyses, only *Centaurea kosaninii* can maintain the status “diagnostic for the alliance”, while *Bromus fibrosus* can be considered as diagnostic for the order *Halacsyetalia sendtneri*. All other taxa originally defined as “diagnostic for the

alliance” are in fact typical *Festuco-Brometea* (*Astragalus onobrychis*, *Galium lucidum*, *Potentilla pedata*, *Scabiosa columbaria*, *Teucrium montanum*, *Thymus longicaulis*) or *Koelerio-Corynephoretea* species (*Plantago holosteum*, *Poa badensis*). Moreover, we identified seven new taxa that can be considered as diagnostic for the alliance. This alliance was characterised by many endemic taxa, suggesting that historical biogeographic events have had a significant influence on the differentiation of the flora within this region. Thus, local endemic taxa were found within this group (obligate serpentine endemics sensu STEVANOVIĆ et al. 2003), such as *Aster albanicus*, *Centaurea kosaninii*, *Genista hassertiana*, *Polygala doerfleri*, *Sanguisorba albanica*, *Saponaria sicula* subsp. *intermedia* and *Stipa mayeri*.

The following associations are currently included in it:

- Ass. 1.2.1 – *Cynancho fuscata*-*Saponarietum intermediae* Blečić et al. 1969 *nomen mutatum propositum*
- Ass. 1.2.2 – *Centaureo kosaninii-Euphorbietum glabriflorae* S. Jovanović et V. Stevanović in Ačić et al. 2014
- Ass. 1.2.3 – *Polygalo doerfleri-Genistetum hassertianae* Blečić et al. 1969
- Ass. 1.2.4 – *Hyperico barbati-Euphorbietum glabriflorae* Rexhepi ex Ačić et al. 2014
- Ass. 1.2.5 – *Onosmo echiodis-Scabiosetum fumarioidis* Rexhepi ex Ačić et al. 2014
- Ass. 1.2.6 – *Stipo mayeri-Convolvuletum compacti* Milaku et al. 2011

#### **“*Thymion jankae*”**

The peculiarity of the associations of the type “*Poo-Plantaginetum holostei*” was noticed by KOJIĆ et al. (1992). They proposed a new alliance *Thymion jankae* citing the following characteristic taxa: *Rumex acetosella*, *Carex verna*, *Cerastium glutinosum*, *Potentilla inclinata* and *Thymus jankae*. However, this name was not validly published since the nomenclatural type for the association that was determined as typical for this alliance was not indicated as required by Art. 5. These associations dominated by *Plantago holosteum* (incl. *P. carinata*, *P. subulata*) and small grasses from the *Poa badensis* group (*Poa badensis*, *P. concinna*, *P. molinieri*, *P. perconcinna*) were classified in the order *Halascyetalia sendtneri* by AČIĆ et al. (2014).

The thermophilous pioneer grasslands and therophyte sward communities of ultramafic fine-grained and shallow soils and rocky outcrops in the Central Balkans, named here as associations of the type “*Poo-Plantaginetum holostei*” and segregated by KOJIĆ et al. (1992) in the alliance *Thymion jankae* are physiognomically and floristically easily identifiable. All the associations included in this group are floristically rather poor. Given the absence of typical species of the order *Halascyetalia sendtneri* and the presence of taxa diagnostic for the class *Koelerio-Corynephoretea* (*Plantago holosteum*, *Scleranthus perennis* subsp. *perennis*, *S. perennis* subsp. *dichotomus*, *S. annuus*, *Rumex acetosella*), these associations could even be classified within the latter class and not *Festuco-Brometea*. Given that, as mentioned before, our data suffer from serious methodological problems with respect to plot sizes and gaps in data on cryptogams, a more accurate judgement regarding the syntaxonomic position of these syntaxa can only be made after additional detailed field surveys.

As pointed out in the paper of PEDASHENKO et al. (2013), little attention has been paid to studying this type of vegetation in the Balkans. The main problem is that there are no records of bryophytes and lichens in published associations for the territories of Serbia and Kosovo, which was already discussed in a wider context of phytocenoses of SE European grasslands by PEDASHENKO et al. (2013) and APOSTOLOVA et al. (2014). Additional issues that have



**Fig. 2.** Steppe-like vegetation on shallow ultramafic soils in the Balkans included in the order *Halacsyetalia sendtneri*. **a)** Stand of a *Festuco ovinae-Euphorbietum glabriflorae* (*Potentillion visianii*) in the Mt Zlatibor Mountain, Serbia. Visible are *Artemisia alba*, *Euphorbia glabriflora*, *Halacsya sendtneri* and *Stipa* gr. *pulcherrima* (Photo: N. Kuzmanović, 12.06.2015). **b)** Stand of a *Cynancho vincetoxici-Saponarietum intermediae* (*Centaureo kosaninii-Bromion fibrosi*) in the Mt Šarplanina Mountain, Brezovica, Gradište, Kosovo. Visible are *Festuca* gr. *valesiaca* and *Saponaria sicula* subsp. *intermedia* (Photo: M. Lazarević, 11.08.2014). **c)** Stand of a *Poo alpinae-Plantaginetum holostei* (“*Thymion jankae*”) in the Mt Tara Mountain, Kremna, Serbia. Visible are *Plantago holostium*, *Poa badensis* gr. and *Thymus jankae* (Photo: N. Kuzmanović, 10.06.2015). **d)** Stand of a *Stipetum novakii* (*Potentillion visianii*) in the Brđani-Schlucht, Serbia. Visible are *Halacsya sendtneri*, *Stipa novakii* und *Artemisia alba* sowie Gebüsche aus *Quercus cerris* und *Fraxinus ornus*. (Foto: D. Lakušić, 10.05.2011).

**Abb. 2.** Steppenrasen der Ordnung *Halacsyetalia sendtneri* auf flachgründig-ultramafischen Böden auf dem Balkan. **a)** Bestand eines *Festuco ovinae-Euphorbietum glabriflorae* (*Potentillion visianii*) am Mt Zlatibor, Serbien mit *Artemisia alba*, *Euphorbia glabriflora*, *Halacsya sendtneri* und *Stipa* gr. *pulcherrima* (Foto: N. Kuzmanović, 12.06.2015). **b)** Bestand eines *Cynancho vincetoxici-Saponarietum intermediae* (*Centaureo kosaninii-Bromion fibrosi*) am Mt Šarplanina, Brezovica, Gradište, Kosovo, mit *Festuca* gr. *valesiaca*, *Saponaria sicula* subsp. *intermedia* (Foto: M. Lazarević, 11. 08.2014). **c)** Bestand eines *Poo alpinae-Plantaginetum holostei* (“*Thymion jankae*”) am Mt Tara, Kremna, Serbien, mit *Plantago holostium*, *Poa badensis* gr. und *Thymus jankae* (Foto: N. Kuzmanović, 10.06.2015). **d)** Bestand eines *Stipetum novakii* (*Potentillion visianii*) in der Brđani-Schlucht in Serbien mit blühende *Halacsya sendtneri* (nach den österreichischen bzw. deutschen Botanikern Eugen von Halácsy und Otto Sendtner), *Stipa novakii* und *Artemisia alba* sowie Gebüsche aus *Quercus cerris* und *Fraxinus ornus*. (Foto: D. Lakušić, 10.05.2011).

already been pointed out by SOPOTLIEVA & APOSOTOLOVA (2014) were noticed in our study as well: Some associations exhibited transitional character, having almost equal shares of diagnostic taxa of both mentioned classes. The reason for this might be that this transitional association is in a more advanced successional stage. Or it has not been degraded by over-grazing to the same extent as the other associations belonging to this group.

The following associations are currently included in it:

Ass. 1.3.1 – *Sedo serpentini-Bornmuellerietum dieckii* Blečić et al. 1969

Ass. 1.3.2 – *Poo molinerii-Plantaginetum holostei* Pavlović 1951

Ass. 1.3.3 – *Poo alpinae-Plantaginetum holostei* Kojić et Ivanović 1953 nomen mutatum propositum

Finally, it was rather difficult to determine the final position of the association *Artemisia albae-Silenetum armeriae*. It exhibited high specificity in the cluster analysis, being characterised by a significant number of *Festuco-Brometea* species, but only one character species of the order *Halacsyetalia sendtneri* and one of the alliance “*Thymion jankae*”. For the moment we left it classified in the class *Festuco-Brometea*, although it could be placed even in another class after more comprehensive studies of similar syntaxa.

#### 4.2.2.3 Nomenclatural adjustments at association level

Most of the syntaxa published by RITTER-STUDNIČKA (1970) and KRAUSE & LUDWIG (1957) in the form of synoptic tables listed below were validly published (Art. 5 & 7, ICPN, WEBER et al. 2000). Only the name *Silenetum willdenowii serpentinae* of RITTER-STUDNIČKA (1970) is illegitimate according to Art. 34a. The provided corrections are related to their orthographically correct form according to Art. 41 and in some cases adaptations of syntaxa names to taxonomic nomenclature (Art. 45). However, no data were available for designating neotypes (Art. 21) for these associations, and they remained without nomenclatural type. For the two associations published by KRAUSE & LUDWIG (1956), lectotypes have been designated. Another lectotype has been designated for the association *Poo alpinae-Plantaginetum holostei* incorrectly synonymised in AČIĆ et al. (2014). For the two associations 1.1.10 and 1.2.1, the corrections are related to adaptations of syntaxa names to taxonomic nomenclature (Art. 45). Lectotypes were defined for the determination of the correct names for syntaxa not yet typified.

- *Erysimo linariifoliae-Jovibarbetum heuffelii* Ritter-Studnička 1970 nomen mutatum propositum. Orig. (RITTER-STUDNIČKA 1970): *Erysimo-Semperviretum heuffelii* (Art. 41, 45)
- *Fumano bonapartei-Euphorbietum glabriflorae* Ritter-Studnička 1970 nomen inversum propositum. Orig. (RITTER-STUDNIČKA 1970): *Euphorbio-Fumanetum bonapartei* (Art. 10b, 41, 42)
- *Scrophulario tristis-Linarietum rubioides* Ritter-Studnička 1970 nomen mutatum propositum. Orig. (RITTER-STUDNIČKA 1970): *Linarietum concoloris* (Art. 41, 45)
- *Alyso muralis-Silenetum vulgaris* (Ritter-Studnička 1970) Kuzmanović et al. *nom. nov. hoc loco*. Orig. (RITTER-STUDNIČKA 1970): *Silenetum willdenowii serpentinae nomen illeg.* (Art. 34a, 39)
- *Dorycnio germanicae-Scabietosum cineraeae* Ritter-Studnička 1970 nomen mutatum propositum. Orig. (RITTER-STUDNIČKA 1970): *Dorycnio-Scabioetum leucophyllae* (Art. 41, 45)

- *Halacsyo sendtnerii-Seselietum rigidae* Ritter-Studnička 1970 Orig. (RITTER-STUDNIČKA 1970): *Halacsyo-Seselietum rigidae* (Art. 41)
- *Viola beckiana-Seslerietum serbicae* Krause et Ludwig 1957 nomen inversum propositum. Orig. (KRAUSE & LUDWIG 1957): *Sesleria rigida-Viola beckiana* (Art. 10b, 41, 42, 45)
- *Euphorbio montenegrinae-Brometum erecti* Krause & Ludwig 1956 1956 nomen inversum propositum. Orig. (KRAUSE & LUDWIG 1956): *Bromus erectus-Euphorbia montenegrina* (Art. 10b, 41, 42). Typus: Krause & Ludwig 1956, Tab. 1, rel. 68 [Lectotypus hoc loco]
- *Halacsyo sendtneri-Caricetum humilis* Krause & Ludwig 1956 nomen inversum propositum. Orig. (KRAUSE & LUDWIG 1956): *Carex humilis-Halacsysa sendtneri* (Art. 10b, 41, 42). Typus: Krause & Ludwig 1956, Tab. 1, rel. 82 [Lectotypus hoc loco]
- *Poo alpinae-Plantaginetum holostei* Kojić et Ivanović 1953 nomen mutatum propositum. Orig. (KOJIĆ & IVANOVIĆ 1953): *Poeta alpinae-Plantaginetum carinatae* (Art. 45). Typus: Kojić et Ivanović 1953, Tab. 3, rel. 1 [Lectotypus hoc loco]  
Note: This association was wrongly listed as homonym of *Poo molinerii-Plantaginetum holostei* Pavlović 1951 in AČIĆ et al. (2014).
- *Cynancho fuscata-Saponarietum intermediae* Blečić et al. 1969 nomen mutatum propositum. Orig. (BLEČIĆ et al. 1969): *Cynancho vincetoxici-Saponarietum intermediae* (Art. 45)
- *Potentillo tommasiniana-Stipetum novakii* A. Marković ex Ačić et al. 2014 nomen mutatum propositum. Orig. (AČIĆ et al. 2014): *Potentillo tommasiniana-Stipetum pennatae* (Art. 45)

## 5. Conclusion and outlook

The results of our study, in which we included all available data on the order *Halascyetalia sendtneri*, are partly in accordance with previous syntaxonomic views. The confirmation of the position of the order *Halascyetalia sendtneri* within the class *Festuco-Brometea* as well as the fact that the order is characterised by a significant number of obligate endemic serpentinophytes confined to the Central Balkan Peninsula allowed us to re-evaluate the alliances traditionally classified in it. We distinguished two alliances (*Centaureo kosaninii-Bromion fibrosi* and *Potentillion visianii*), for which the diagnoses, diagnostic and constant taxa are given. The alliance *Centaureo kosaninii-Bromion fibrosi* is restricted to the rocky grasslands occurring on the territories of South Serbia, Kosovo and North Albania. The area of this alliance is situated in the Scardo-Pindic phytogeographic province influenced by arid Mediterranean climate. The alliance *Potentillion visianii*, in which we also included all syntaxa previously considered as being part of the *Polygonion albanicae*, is restricted to rocky grasslands occurring on the serpentine outcrops in Central and Eastern Bosnia and Herzegovina, Central and West Serbia and North Kosovo. In contrast to the alliance *Centaureo kosaninii-Bromion fibrosi*, the area of the alliance *Potentillion visianii* is situated in the Illyrian biogeographical province, influenced by humid Atlantic climate. Finally, the thermophytic pioneer grasslands and therophyte sward communities included in the alliance *Thymion jankae* (nomen. inval.), characterised by the absence of typical species of the order *Halascyetalia sendtneri* and the presence of taxa diagnostic for the class *Koelerio-*

*Corynephoretea*, are temporarily left within the order *Halacsyetalia sendtnerii* (class *Festuco-Brometea*), although more detailed field surveys, in which data on cryptogams will be included, are needed for the formal validation of this syntaxon.

Nevertheless, a more detailed syntaxonomic revision of the analysed order *Halacsyetalia sendtnerii* as well as a conclusive judgement regarding all the associations currently included in it can only be given after additional detailed field surveys on the territories of Bosnia and Herzegovina, Albania, Montenegro and northern Macedonia and more comprehensive analyses, in which all floristically and ecologically similar syntaxa (e.g. *Astragalo-Potentilletalia*, *Brachypodietalia pinnati*, *Festucetalia valesiaca*, *Stipo pulcherrimae-Festucetalia pallentis*) will be included.

### Erweiterte Deutsche Zusammenfassung

**Einleitung** – Extensive Landnutzung spielte auf dem Balkan lange Zeit eine große Rolle und in Folge davon degradierten die natürlichen Wälder und sekundäres Grasland breitete sich stark aus. Auf flachgründigen Serpentinböden mit hohen Magnesium-Gehalten konnten sich dabei in der Zone der thermophilen Laubmisch- und Kiefernwälder sog. Serpentin-Steppenrasen entwickeln, die in der Ordnung *Halacsyetalia sendtnerii* zusammengefasst sind. Diese Ordnung mit zahlreichen endemischen Serpentinophyten wurde von Ritter-Studnička nach Untersuchungen der Bestände des zentralen und östlichen Bosniens und Herzegowinas aufgestellt und in die beiden Verbände *Polygonion albanicae* und *Potentillion visianii* untergliedert (RITTER-STUDNIČKA 1970). Aufgrund des zahlreichen Vorkommens von Charakterarten der *Festucetalia valesiaca* wurde die Ordnung in die Klasse *Festuco-Brometea* eingegliedert. Diese Stellung war bislang jedoch umstritten. Einigkeit bestand lediglich darin, dass die Serpentin-Steppenrasen des Balkans eine eigene Ordnung *Halacsyetalia* bildeten. Eine konsistente Gliederung der *Halacsyetalia* fehlte bislang ebenfalls. Daher revidieren wir hier das Syntaxon der *Halacsyetalia* kritisch.

**Untersuchungsgebiet** – Das Untersuchungsgebiet umfasst die Serpentin-Ausstriche von Bosnien und Herzegowina sowie von West-Serbien und Kosovo; somit liegt das Untersuchungsgebiet auf dem zentralen Balkan (Abb. 1). Aus biogeographischer Sicht gehört das Gebiet zum östlichen Teil der Dinarischen Alpen (Illyrien) und mit dem Šar-Gebirge auch zum nördlichen Teil der skardo-pindischen Region der mitteleuropäischen Florenregion (HORVAT et al. 1974).

**Material und Methoden** – Zunächst wurde die pflanzensoziologische Literatur aus den Serpentinegebieten des westlichen und zentralen Balkans zusammengetragen und die darin vorhandenen Aufnahmen in die Datenbank „Grassland Vegetation of Serbia“ eingegeben (GIVD Nummer: EU-RS-002, AČIĆ et al. 2012). Die Nomenklatur der Taxa folgt dabei außer für einige wenige Arten der Flora Europaea. Wegen der heterogenen Datengrundlage von 277 Einzelaufnahmen aus 26 Assoziationen sowie 7 Assoziationen, die lediglich durch Stetigkeitstabellen vertreten waren, wurde die Datenanalyse in mehreren Schritten durchgeführt. Im ersten Schritt wurden mehrere Cluster-Analysen mit verschiedenen Kombinationen aus Distanzmaßen und Methoden der Gruppenverknüpfung durchgeführt. Dadurch sollte geklärt werden, ob alle Aufnahmen, die in der Originalliteratur einem bestimmten Syntaxon zugeordnet waren, floristisch klar abgegrenzte Gruppen bildeten. Für die Cluster-Analyse der verwendeten 273 Aufnahmen (455 Taxa, 24 Assoziationen) wurden die ursprünglichen Deckungswerte der einzelnen Arten ordinal-transformiert (VAN DER MAAREL 1979). Die Cluster-Analysen (Bray-Curtis und gepaarte Gruppenmittel, euklidische Distanzen und Ward-Methode, relative euklidische Distanzen und flexibles Beta,  $\beta = -0,25$ ) wurden mit den Programmen PAST (HAMMER et al. 2001) und JUICE (TICHÝ 2002) durchgeführt. Im zweiten Schritt wurden dann 26 synoptische Stetigkeitsspalten für diejenigen Assoziationen vorbereitet, die als analytische Tabellen publiziert waren. Schließlich wurden die synoptischen Spalten mit den synoptischen Tabellen von sieben Assoziationen von RITTER-STUDNIČKA (1970) und KRAUSSE & LUDWIG (1957) zusammengeführt. Am Ende wurde die Klassifikation der gesamten Tabelle (499 Taxa und 33 Gruppen) gemäß klassischer

pflanzensoziologischer Tabellensortierung anhand von berechneten Frequenzen (TICHÝ et al. 2012) durchgeführt. Für jedes Taxon wurde die prozentuale Stetigkeit und relative Treue (s. hochgestellte *phi*-Werte über den Stetigkeiten, mit „\*\*“ wenn  $phi \geq 0,5$  war und „\*“ wenn  $phi \geq 0,25$  war) berechnet und in einer synoptischen Tabelle festgehalten. *Phi*-Werte wurden nur für diejenigen synoptischen Spalten, die auf analytischen Tabellen beruhten, angegeben. Basierend auf dem Konzept der relativen Treue wurde das Optimum jeder Art in einer Gruppe floristisch-ähnlicher Gesellschaften bestimmt (WILLNER 2006, WILLNER et al. 2009).

Bei der Berechnung der *phi*-Werte wurde das Vorkommen einer Art innerhalb eines höherangigen Syntaxons berücksichtigt. Die Ordnung *Halacsyetalia sendtneri* wurde dabei als abstrakte Einheit genutzt um die *phi*-Werte der diagnostischen Arten innerhalb ihrer Verbände zu bestimmen. Arten mit  $phi \geq 0,25$  wurden als diagnostisch und stet und Arten mit  $phi \geq 0,50$  als hoch-diagnostisch betrachtet (CHYTRÝ 2007). Konstante Arten mussten dagegen einen Frequenzwert von mindestens 30 % (Ordnung) und 40 % (Verband) aufweisen. Die diagnostischen Arten der Klassen wurden anhand des EuroVegChecklist Expert-Systems und mit Hilfe der ESL1-Artenliste (MUCINA et al. in press) mit dem Programm JUICE (TICHÝ et al. 2012) bestimmt. Eine Ausnahme bildeten Arten, die noch nicht in der ESL1-Artenliste klassifiziert waren (z. B. *Genista hassertiana* und *Polygala doerfleri*).

Weiterhin wurde das Auftreten diagnostischer Arten der *Halacsyetalia sendtneri* sowie weiterer potentiell diagnostischer, hoch-frequenter und dominanter Serpentinophyten aus unserem Datensatz in den fünf wichtigsten Grasslandtypen Serbiens (*Molinio-Arrhenatheretea*, *Festucetalia valesiaca*, *Festucetalia vaginata*, *Astragalo-Potentilletalia*, *Halacsyetalia sendtneri*) untersucht. Diese Analyse basierte auf der Datenbank Grassland Vegetation of Serbia (GIVD number: EU-RS-002, AČIĆ et al. 2012, 2015). Dabei wurden insgesamt 33 obligate oder fakultative Serpentinophyten bzw. 3.346 Aufnahmen berücksichtigt.

**Ergebnisse und Diskussion** – Trotz zahlreichen Auftretens von diagnostischen Arten der Klasse *Koelerio-Coryneporetea* wurden auf der Basis des *EuroVegChecklist Expert-Systems* lediglich 1 % der Aufnahmen in diese Klasse gestellt; die anderen 98 % Aufnahmen wurden den *Festuco-Brometea* zugeordnet. Dieses Ergebnis wurde von der Tatsache unterstützt, dass in den analysierten Assoziationen, diagnostische Taxa der *Festuco-Brometea* die höchste Frequenz und Abundanz aufwiesen. Insgesamt enthielt unser Datensatz 499 Taxa, darunter 49 obligate oder fakultative Serpentinophyten, von denen wiederum 40 für die Balkan Halbinsel endemisch sind. Die Analyse der Verbreitung von 33 obligaten oder fakultativen Serpentinophyten zeigte, dass sowohl endemische als auch nicht-endemische Sippen fast ausschließlich in den Fels-Steppenrasen auf ultramafischen Böden vorkommen. Sie können daher zwanglos als diagnostische Arten der *Halacsyetalia sendtneri* und deren Verbände betrachtet werden (Tab. 4).

Die Wiedereinordnung der Ordnung *Halacsyetalia sendtneri* in die *Festuco-Brometea* sowie die signifikante Zahl von endemischen obligaten Serpentinophyten ermöglichten auch eine Evaluation der Verbände. Zwei Verbände konnten bestätigt und durch diagnostische und stete Arten charakterisiert werden: Das *Centaureo kosaninii-Bromion fibrosi* umfasst Fels-Steppenrasen in Süd-Serbien, im Kosovo und in der vom Mittelmeerklima beeinflussten skardisch-pindischen Florenprovinz Nord-Albaniens. Das *Potentillion visianii* (dem hier auch Syntaxa zugeordnet werden, die früher im *Polygonion albanicae* standen), umfasst dagegen Fels-Steppenrasen auf Serpentin-Ausstrichen des zentralen und östlichen Bosnien und Herzegowinas, des zentralen und westlichen Serbiens und des nördlichen Kosovo. Dieser Verband siedelt in der illyrischen Region, die vom niederschlagsreichen Atlantikklima beeinflusst wird.

Das thermophytische Pionier-Grasland und die therophytischen Rasengesellschaften des Verbandes *Thymion jankae* (nomen. inval.) wurden provisorisch in der Ordnung *Halacsyetalia sendtnerii* belassen. Diese Vegetationstypen sind durch das Fehlen der typischen Arten der *Halacsyetalia sendtneri* gekennzeichnet und weisen stattdessen mehr diagnostische Taxa der *Koelerio-Coryneporetea* auf.

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## Supplements

**Supplement S1.** Synoptic table for associations, alliances, order and classes.

**Beilage S1.** Übersichtstabelle der Assoziationen, Verbände, Ordnungen und Klassen.

**Additional supporting information may be found in the online version of this article.**

**Zusätzliche unterstützende Information ist in der Online-Version dieses Artikels zu finden.**

**Supplement E1.** Localities of analysed syntaxa.

**Anhang E1.** Lokalisationen der untersuchten Syntaxa.

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