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New associations of serpentine chasmophitic vegetation (*Asplenietea trichomanis* Br.-Bl. 1934 corr. oberd. 1977) on Kopaonik Mt in Serbia

Dmitar Lakušić[1]* and Branko Karadžić[2]

1 Institute of Botany and Botanical Garden, Faculty of Biology, University of Belgrade, Takovska 43, 11000 Belgrade, Serbia

2 Institute for Biological Research "Siniša Stanković", Bulevar despota Stefana 142, 11000 Belgrade, Serbia

ABSTRACT: Phytosociological characteristics of chasmophitic communities on subalpine serpentine cliffs of Kopaonik Mountain were analysed according to Braun-Blanquet methodology. In order to detect purely floristic differentiation of analysed communities we applied ordinary Correspondence Analysis (CA). Relationship between vegetation and environment was assessed using the Canonical Correspondence Analysis (CCA), while classification of sites was performed using UPGMA method and chord distance. All analyses were performed using the latest version of the "FLORA" package.

According to floristic and ecological characteristics, analysed chasmophitic communities on serpentine cliffs of Kopaonik Mountain is divided in three new associations: *Edraiantho jugoslavici-Festucetum pancicianae* ass. nova, *Silenetum serbicae* ass. nova and *Musco-Jovibarbetum kopaonikense* ass. nova.

Key words: chasmophitic communities, serpentine, ordination, classification, Serbia

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INTRODUCTION

The chasmophitic vegetation (class *Asplenietea trichomanis*) is very complex, since it involves communities on calcareous, serpentine and silicate rocks, at different altitudes, from lowland (usually canyon) habitats to nival regions. For the territory of Serbia different authors described 53 associations and 7 sub-associations, which belong to 13 alliances and 9 orders, so far (Lakušić & Sabovljević 2005).

The real diversity of chasmophitic syntaxa in Serbia is much greater, since some types of chasmophitic vegetation are not investigated. The least investigated communities belong to alliances *Moechringion muscosae*, *Asplenion lepidi*, *Asplenion septentrionalis*, *Potentillion visianii* and *Adiantion*. Although some authors noted that these alliances exist in Serbia, the data of communities that belong to the alliances are missing.

More investigated communities belong to alliances *Amphoricarpion bertiscei* (vegetation on calcareous rocks), *Parietarion judaicae* (anthropogenic communities on calcareous walls) and two siliceous alliances (*Silenion lerhenfeldianae* and *Saxifragion cymosae*). Despite the fact that only a few phytocoenotic tables of these communities are published, available data enable floristic and syntaxonomic characterization of the alliances.

The most investigated chasmophitic communities in Serbia belong to calcareous alliances *Edraiantho graminifolii-Erysimion comatae, Ramondion nathaliae* and *Edraianthion jugoslavici*. Some associations within these alliances are quite subjectively extracted (without detailed analyses of their floristic and syntaxonomic characteristics) and provisory named. Such situation requires a more objective revision of extracted syntaxa.

*correspondence: dlakusic@bio.bg.ac.rs

The least investigated chasmophitic communities in Serbia belong to sub-alpine vegetation on serpentine rocks. They are distributed in sub-alpine regions (from 1300 to 1900 m asl) of the Kopaonik Mt., on localities Treska and Nebeske stolice. These communities were provisory named as *Silenetum serbicae* D. Lakušić 1987 and *Edraiantho-Festucetum pancicianae* D. Lakušić 1989 (Lakušić, D. 1993; Lakušić & Ranđelović 1996; Lakušić *et al*. 2005). The aim of this article is to give an insight into floristic and ecological characteristics of these communities, and to detect their syntaxonomic status.

METHODS

We collected data from 38 stands (relevés) on the mt Kopaonik in two suabalpine serpentine peaks (Treska and Nebeske stolice), according to Braun-Blanquet (1964) methodology. Nomenclature and taxonomy, with a few exceptions, followed the Flora Europaea (Flora Europaea Database). All taxa in the paper and their authors are given in Table 5, while the list of all syntaxa in the paper and their authors are given in Appendix.

The Braun-Blanquet's combined abundance-cover scale is alpha-numeric, and this prevents numeric data processing. Therefore we transformed the combined abundance-cover values into completely numeric scale as proposed by Westhoff & van der Maarel (1973).

In order to detect purely floristic differentiation of analysed communities we applied ordinary Correspondence Analysis (CA). Relationship between vegetation and environment was assessed using the Canonical Correspondence Analysis (CCA) (ter Braak, 1986). We analysed differentiation of communities with respect to orography. Orographic variables involved altitude, measured in meters; slope, measured in angles and exposure. Using angular degrees, we assigned 0 to north exposition, 180 to south exposition and 90 for both east and west expositions.

Classification of sites was performed using UPGMA method (Sneath and Sokal, 1974) and chord distance (Orloci, 1967) as a dissimilarity measure. Compared to other possible combinations of agglomerative methods with dissimilarity measures, this combination has several benefits (Karadžić & Marinković, 2009).

All analyses were performed using the newest version of the "FLORA" package (Karadžić *et al.,* 1998). The package offers application of a wide spectrum of classification and ordination methods (Karadžić *et al.,* 1999, 2003).

Synoptic tables were formed by calculating the covarage index (Ic) according to Lausi *et al.* (1982).

Vegetation studies were done on the Kopaonik Mt in two suabalpine serpentine peaks: Treska (1550-1620 mnv) and Nebeske stolice (1800-1913 mnv).

In order to detect syntaxonomy of analysed communities on ultrabasic serpentine rocks, we compared these communities with chasmophytic vegetation on basic rocks (orders *Potentilletalia caulescentis* and *Amphoricarpetalia*), which are distributed in central and western Serbia (Table 1).

Table 1. Communities that are used to compare

Associations	Localities	Reference
Edraiantho jugoslavicii-Hieracietum humile S. Stanić et D. Lakušić	Veliki Mučanj, 1400-1500 m	Stanić & Lakušić D. 1993
Carici laevis-Leontopodietum alpinii S. Stanić et D. Lakušić	Veliki Mučanj, 1400-1500 m	Stanić & Lakušić D. 1993
Edraiantho-Saxifragetum porophyllae Tatić et Veljović 1982	Kopaonik (Srebrnac, Bele stene, Gobelja, Oštri krš), 1720-1750 m	Tatić & Veljović 1982), Lakušić, D. 1993, Lakušić, D. & Ranđelović 1996
Musco-Seslerio-Edraianthetum jugoslavici Petković et al. 1999	Okolina Tutina: Gorge of river Godulja, Canyon of river Crne reke and Canyon of river Bukovice, 800 i 1350 m	Petković et al. 1991
Centaureo derventanae-Seslerietum tenuifoliae R. Jovanović et S. Jovanović 1986	Canyon of river Dervente, 240 i 350 m	Jovanović & Jovanović-Dunjić 1986, Lakušić, R. & Redžić 1989
Edraiantho-Saxifragetum aizooni B.Petković et al. 1990	Mokra Gora (Crvene Vode), 1800 m	Petković et al. 1990
Edraiantho-Centauretum derventanae R.Lakušić et Redžić 1988	Canyon of river Dervente 230 - 345 m	Lakušić, R. & Redžić 1989

Geography, geomorphology and climate of investigated habitats. Analysed chasmophitic vegetation covers serpentine clifs on Kopaonik Mt, on three localities: Kozje stene (1300-1550m), Treska (1550-1620m) and Nebeske stolice (1800-1913m). The most compact and continuous vertical cliffs are located on Kozje stene locality. Height of these cliffs exceeds 100 meters. Significantly smaller vertical surfaces are present on localities Treska and Nebeske stolice. Vertical cliffs on Kozje stene locality are continuously spread over 1.5 km. On two other localities, the cliffs are discontinuous and form cone-like structures or sloping rocks.

Considering the vertical profile of Kopaonik Mt, the investigated communities are distributed within the altitude belts IV and V (Lakušić D. 1993). Each belt corresponds to specific climate-vegetation zone. The belt IV corresponds to the zone of severe mountainous climate, where pure spruce forests (all. *Vaccinio-Piceion*) dominate. The belt covers area between 1550 and 1750m (on the south slopes) and between 1500 and 1700m (on the north slopes). Average annual temperature within this belt is approximately 4°C, and avarage annual precipitation amounts 857mm. December, January, February and March are months with average temperature below zero.

The altitude belt V corresponds to the zone of severe sub-alpine climate, where sub-alpine shrub communities (alliances *Juniperion sibiricae* and *Vaccinion myrtilli*) dominate. The belt covers area from 1750 to 1950m on the southern slopes and from 1700 to 1950m on the northern slopes. Average annual temperature within this belt is approximately 3°C, and avarage annual precipitation amounts 870mm. November, December, January, February and March are months with average temperature below zero. (Mišić 1954; Mišić *et al.* 1985; Lakušić D. 1993).

RESULTS

Ordination of investigated communities. Correspondence analysis was performed on different data sets. First set involved 117 relevés (stands) of chasmophitic vegetation on serpentine (ultrabasic) and carbonate (basic) rocks that are distributed in Central and Western Serbia. Out of 247 taxa, that were recorded in these two groups of communities, 27 taxa were present only in serpentine communities, whereas 199 taxa were exclusive for carbonate communities. Only 21 taxa were present in both groups of communities.

The most frequent and the most abundant species that are distributed exclusively in serpentine habitats are: *Poa badensis, Silene parnassica* subsp. *serbica, Jovibarba heuffelii* var *kopanikense, Cardamine plumieri* and *Sedum annuum.* Other, less frequent, species of this group are: *Trinia glauca, Sedum micranthum, Saxifraga adscendens, Sesleria serbica, Bellardiochloa violacea, Koeleria eriostachya, Carex digitata, Dianthus sylvestris* subsp. *sylvestris, Potentilla heptaphylla, Medicago sativa* subsp. *falcata, Festuca dalmatica, Armeria rumelica, Armeria maritima* subsp. *maritima, Lamium garganicum* subsp. *laevigatum, Genista subcapitata, Vaccinium myrtillus, Dianthus cruentus, Centaurea rhenana, Allium carinatum* subsp. *pulchellum, Agrostis capillaris* and *Ornithogalum* sp.

The most frequent species that occur in both serpentine and carbonate habitats are: *Edraianthus jugoslavicus, Festuca panciciana* and *Asplenium trichomanes-ramosum*. Less frequent species of this group are: *Saxifraga tridactylites, Carex humilis, Asplenium ruta-muraria, Sesleria latifolia, Minuartia verna* subsp. *collina, Bromus erectus* and *Thymus praecox* subsp. *skorpilii.*

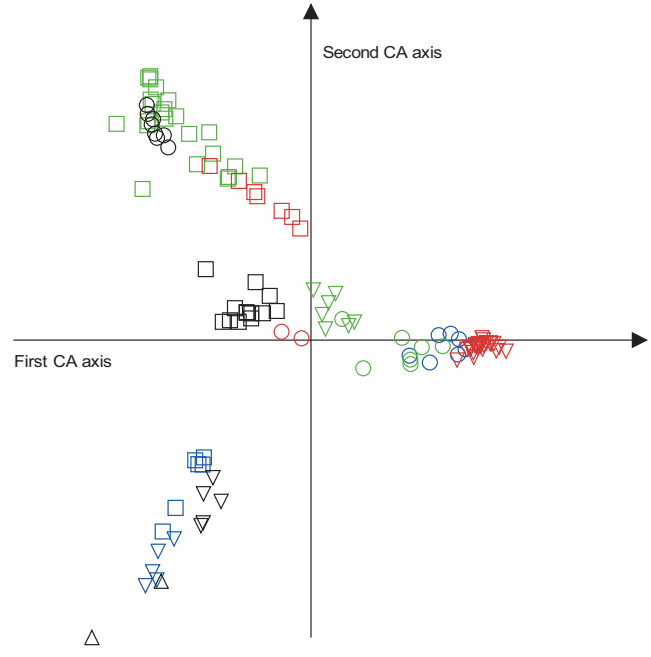

Fig 1. Correspondence analysis (CA) of all chasmophitic communities on serpentine and carbonate rocks in Central and Western Serbia

Legend: serpentine (ultrabasic) rocks – □ *Silenetum serbicae*, □ *Edraiantho-Festucetum pancicianae*, ○ *Musco-Jovibarbetum kopaonikense*; **carbonate (basic) rocks** – □ *Edraiantho jugoslavicii-Hieracietum humile*, □ *Carici laevis-Leontopodietum alpinii*, ○ *Edraiantho-Saxifragetum sempervivi*, ○ *Edraiantho-Saxifragetum sempervivi helianthemosum cani*, ○ *Edraiantho-Saxifragetum sempervivi muscietosum*, ▽ *Musco-Seslerio-Edraianthetum jugoslavici*, ▽ *Centaureo derventanae-Seslerietum tenuifoliae*, ▽ *Edraiantho-Saxifragetum aizooni*, ▽ *Edraiantho-Saxifragetum porophyllae*, △ *Edraiantho-Centauretum derventanae.*

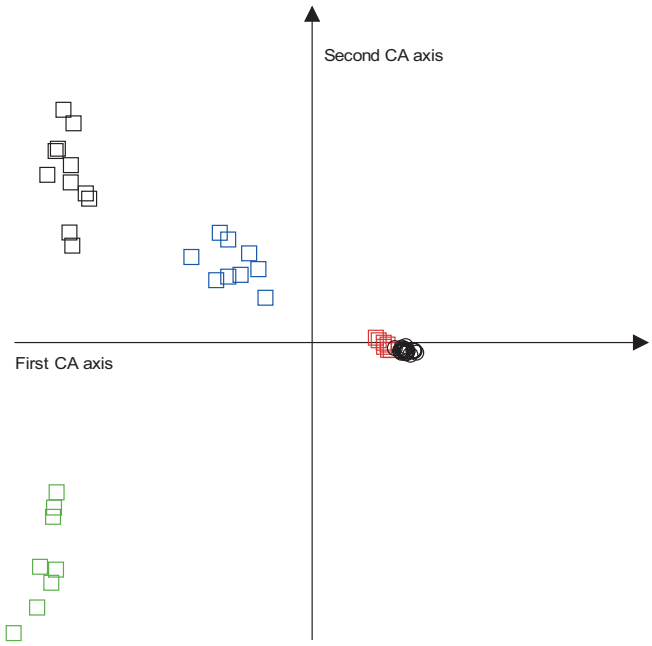

Fig. 2. Correspondence analysis (CA) of all chasmophitic communities on Kopaonik Mountain.
Legend: serpentine (ultrabasic) rocks – ☐ *Silenetum serbicae,* ☐ *Edraiantho jugoslavici-Festucetum pancicianae,* ☐ *Musco-Jovibarbetum kopaonikense;* **carbonate (basic) rocks** – ☐ *Edraiantho-Saxifragetum sempervivi*, ○ *Edraiantho-Saxifragetum porophyllae*

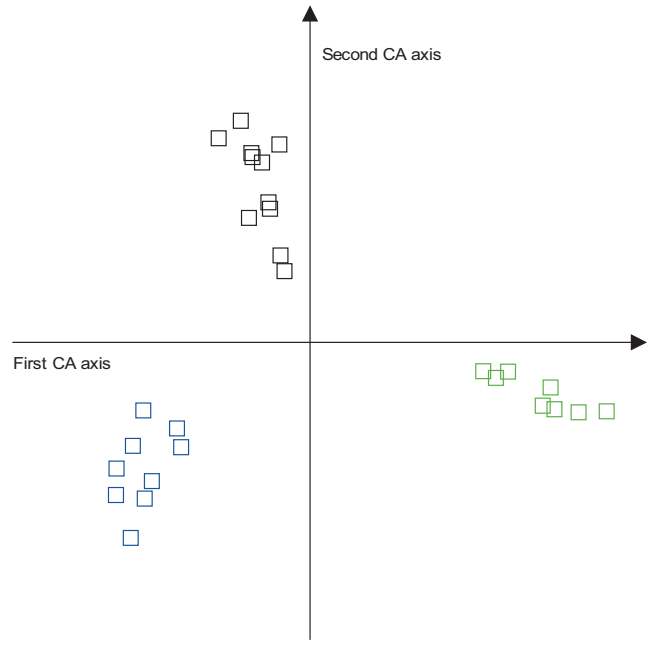

Fig. 3. Correspondence analysis (CA) of serpentine chasmophitic communities that are distributed in sub-alpine region of Kopaonik Mountain
Legend: ☐ *Silenetum serbicae,* ☐ *Edraiantho jugoslavici-Festucetum pancicianae* , ☐ *Musco-Jovibarbetum kopaonikense*

The relevés of serpentine communities are well separated from all other relevés, along the second principal axis (Fig 1).

The second data set involved 60 relevés of all chasmophitic communities on Kopaonik Mt. Correspondence analysis extracted three groups of communities on serpentine rocks, and one communities on calcareous rocks. Calcareous communities are represented by a cluster of overlaping points. (Fig 2). This may indicate that the variability of floristic composition is much greater in serpentine than in calcareous communities. However, such conclusion is missleading, since calcareous communities are more diverse than communities on serpentine rocks. Overlapped cluster of calcareous phytocoenoses may be explained by well known drawback of correspondence analysis, that is its hypersensitivity to rare categories. If a data set is represented by rare species that occur in low-biodiversity sites, than the correspondence analysis usually separates the rare categories from all other species (sites), which are represented as a cluster of overlapping points.

Finally, for third data set we selected only the serpentine chasmophitic communities (29 relevés) that are distributed in sub-alpine region of Kopaonik Mt. Correspondence analysis revealed three groups of communities that are well separated along principal axes (Fig 3).

In order to detect the differentiation of extracted groups with respect to environmental factors, we performed canonical correspondence analysis (CCA). For this analysis, we used main orographic parameters (altitude, exposure and slope). Altitude is the main environmental factor that separates analysed communities. Moreover, lengths of environmental vectors indicate that both exposure and slope are also important in floristic differentiation of the communities (Fig 4). First group of communities is located on north-exposed and very steep rocks. The second group of communities is also located on north-exposed sites and steep rocks, but on lower altitudes. Finally, the third group of relevés is located on south-exposed and gently sloped rocks.

According to floristic and ecological characteristics, analysed chasmophitic communities on serpentine cliffs of Kopaonik Mt may be divided in three new associations: *Edraiantho jugoslavici-Festucetum pancicianae* ass. nova, *Silenetum serbicae* ass. nova and *Musco-Jovibarbetum kopaonikense* ass. nova

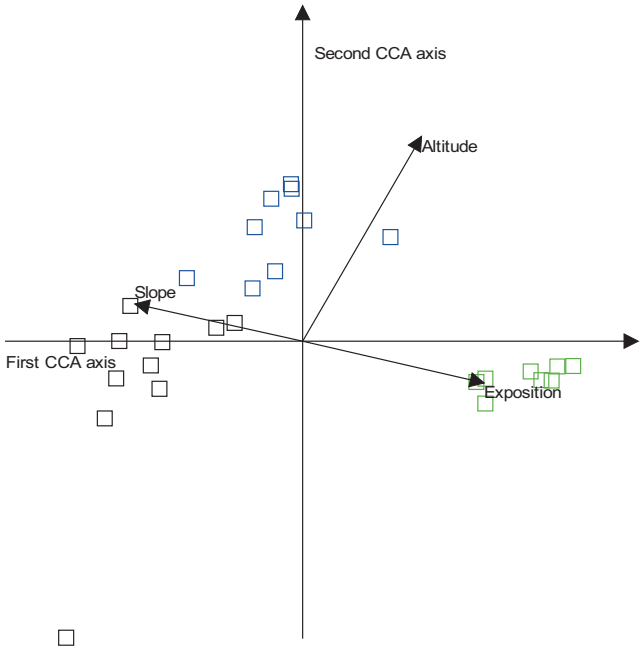

Fig. 4. Canonical correspondence analysis (CCA) of serpentine chasmophitic communities that are distributed in sub-alpine region of Kopaonik Mountain
Legend: ☐ *Silenetum serbicae,* ☐ *Edraiantho jugoslavici-Festucetum pancicianae ,* ☐ *Musco-Jovibarbetum kopaonikense*

Classification of relevés suggests that four types of analysed chasmophytic vegetation can be extracted (Fig 5). However, the internal homogeneity of the fourth group, which is represented by relevés 10-14, is very low. Therefore this group is artificial, and it represents a set of intermediate relevés, connected to the other three more homogeneous groups of relevés.

***Edraiantho jugoslavici-Festucetum pancicianae* ass. nova.** In nine relevés representing this community only 22 species were found. The median number of species per relevé area was 8. The community was poorly developed and covered 5-40 % (average 16.7 %) of the relevé area (Table 2).

Characteristic species of the association were: *Festuca panciciana*(1) (Ic = 33) and *Edraianthus jugoslavicus*(+-1) (Ic = 32). Differential species of the association compared to other communities in the vegetation of rocky crevices in Kopaonik Mt were: *Saxifraga adscendens*(1) (Ic = 11), *Dianthus sylvestris*(1) (Ic = 4), *Armeria rumelica* (1) (Ic = 4), *Bromus erectus*(1) (Ic = 4), *Carex digitata*(1) (Ic = 7), *Armeria maritima*(1) (Ic = 7), *Thymus praecox* subsp. *skorpilii*(1) (Ic = 7), *Potentilla heptaphylla*(1) (Ic = 4), *Agrostis capillaris*(1) (Ic = 4) and *Asplenium ruta-muraria*(+) (Ic = 2). Other species with the indices of significant coverage were: *Poa badensis*(1) (Ic = 33), *Carex humilis*(1) (Ic = 26), *Cardamine plumieri*(+-1) (Ic = 21) and *Minuartia verna* subsp. *collina*(1) (Ic = 19). The number of species and coverage indices are presented in Table 2.

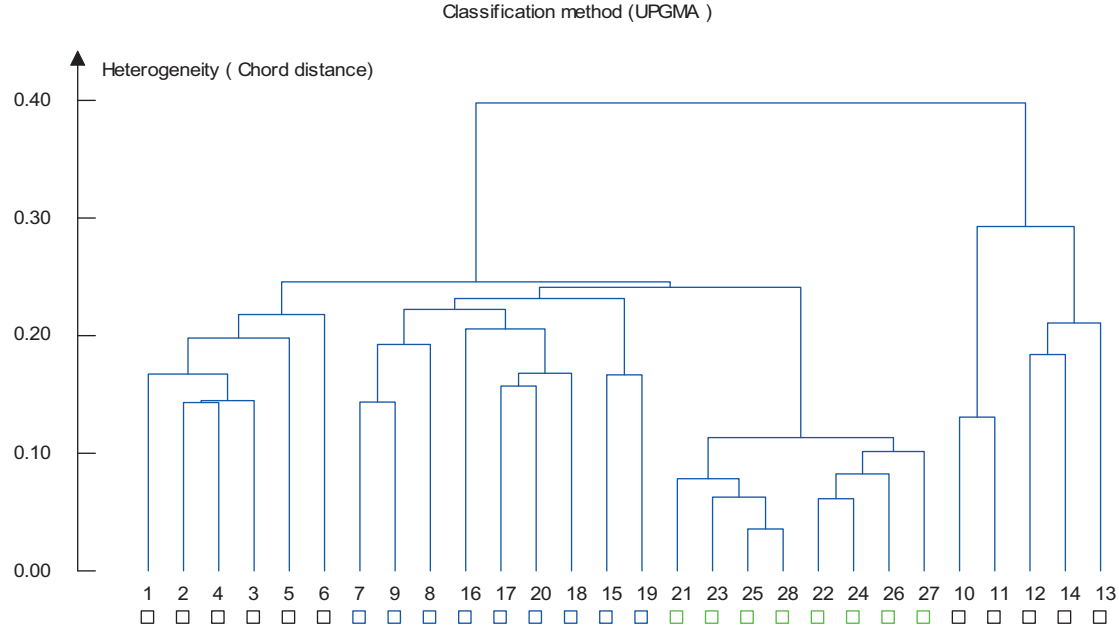

Fig. 5. Classification of serpentine chasmophitic communities that are distributed in sub-alpine region of Kopaonik Mountain
Legend: ☐ *Silenetum serbicae,* ☐ *Edraiantho jugoslavici-Festucetum pancicianae ,* ☐ *Musco-Jovibarbetum kopaonikense*

Table 2. Phytosociological table of the association *Edraiantho jugoslavici-Festucetum pancicii* ass. nova from the mt. Kopaonik

No. Relevé	1	2	3	4	5	6	7	8*	9		
Altitude (m)	1900	1900	1900	1900	1900	1900	1900	1900	1900		
Aspect	SE	SE	S	W	W	N	N	N	N		
Inclination (°)	70	80	80-90	80	0	80	90	80	45		
Stoniness (%)	40	5	15	20	20	20	10	10	10		
Relevé area (m^2)	12	9	15	4	4	9	7	9	16		
Number of species/relevé	12	6	10	8	7	9	7	8	6	%	Ic
Characteristic species of the asociation											
Festuca panciciana	1	1	1	1	1	1	1	1	1	100	33
Edraianthus jugoslavicus	1	+	1	1	1	1	1	1	1	100	32
Differential species of the asociation											
Saxifraga adscendens	1	1	1							33.3	11
Dianthus sylvestris	1									11.1	4
Armeria rumelica	1									11.1	4
Bromus erectus	1									11.1	4
Carex digitata						1	1			22.2	7
Armeria maritima				1				1		22.2	7
Thymus praecox subsp. *skorpilii*				1				1		22.2	7
Potentilla heptaphylla					1					11.1	4
Agrostis capillaris					1					11.1	4
Asplenium ruta-muraria			+							11.1	2
Other species											
Poa badensis	1	1	1	1	1	1	1	1	1	100	33
Carex humilis	1	1		1	1	1	1		1	77.8	26
Cardamine plumieri	+		1		1	1		1	1	66.7	21
Minuartia verna subsp. *collina*	1		1			1		1	1	55.6	19
Silene parnassica subsp. *serbica*	2	1	1							33.3	14
Ranunculus montanus				1			1	1		33.3	11
Trinia glauca						1	1			22.2	7
Koeleria eriostachya	1		1							22.2	7
Asplenium trichomanes-ramosum			+	1						22.2	6
Saxifraga tridactylites						1				11.1	4

Relevés 1-9: Serbia, Kopaonik, Nebeske Stolice, , 43° 15.745 N, 20° 49.898 E

Table 3. Phytosociological table of the association *Silenetum serbicae* ass. nova from the mt. Kopaonik

No. Relevé	1	2	3	4	5*	6	7	8	9	10	11		
Altitude (m)	1600	1600	1600	1600	1600	1600	1900	1900	1900	1900	1900		
Aspect	N	N-NE	NE	NE-E	N	N-NE	NE	SW	NE	NE	E		
Inclination (°)	85	80	70	80	60	80	75	70-90	90	90	80		
Stoniness (%)	15	60	40	30	40	50	10	10	40	10	10		
Relevé area (m^2)	8	9	6	12	24	12	20	12	24	20	24		
Number of species/relevé	14	9	12	8	10	7	2	2	3	5	5	%	Ic
Characteristic species of the asociation													
Silene parnassica subsp. *serbica*	1	1	1	1	2	2	1	1	1	1	1	100	37
Sedum micranthum		1	1	1	1							36	12
Differential species of the asociation													
Galium lucidum	1		1								+	27	8
Sesleria serbica	1			1	1							27	9
Medicago sativa subsp. *falcata*					1					+		18	5
Leontodon crispus			+									9	2
Festuca dalmatica						2						9	5
Erysimum linariifolium						+						9	2
Lamium garganicum subsp. *laevigatum*	1											9	3
Galium mollugo					1							9	3
Vaccinium myrtillus	+											9	2
Dianthus cruentus	+											9	2
Allium carinatum subsp. *pulchellum*			+									9	2
Other species													
Poa badensis	1	+	1	1		1	1	+	1	1	1	91	28
Asplenium trichomanes-ramosum	1	1	+		1				1	+	1	64	19
Jovibarba heuffelii var .*kopaonikense*	+	1	1	1	1	1						55	17
Cardamine plumieri	+	1	1	1	1							45	14
Saxifraga tridactylites	1	1		1	+	+						45	13
Sedum annuum	1	1	1							+	+	45	13
Festuca panciciana	1	1	+	1								36	11
Trinia glauca	+		+			1						27	7
Ranunculus montanus					1							9	3

Relevés 1-6: Serbia, Kopaonik, Treska (43° 15.605 N, 20° 47.138 E); Relevés 7-11: Serbia, Kopaonik, Nebeske Stolice, 43° 15.745 N, 20° 49.898 E

Table 4. Phytosociological table of the association *Musco-Jovibarbetum kopaonikense* ass. nova from the mt. Kopaonik

No. Relevé	1	2	3	4	5	6	7*	8		
Altitude (m)	1835	1835	1835	1855	1855	1855	1855	1840		
Aspect	SW	SW	SW	S	S	S	S	SW		
Inclination (°)	10	10-30	10-30	20	40	30-40	40	80		
Stoniness (%)	20	10	10	10	30	30	40	30		
Relevé area (m^2)	0.5	4	1	1	6	4	1	4		
Number of species/relevé	5	9	6	6	5	8	8	5	%	Ic
Characteristic species of the association										
Jovibarba heuffelii var *kopaonikense*	1	2	1	2	1	2	2	1	100	44
Lichenes sp. div.	2	3	3	3	3	3	3	3	100	75
Musci sp. div.	3	2	2	2	2	2	2	3	100	61
Differential species of the asociation										
Genista subcapitata							1		12.5	4
Rubus idaeus						1			12.5	4
Ornithogalum sp.		+							12.5	3
Centaurea triumfetti		+							12.5	3
Other species										
Poa badensis	1	1	1	1	1	1	1	1	100	33
Festuca panciciana		1	+	1	1	1	1	1	87.5	28
Silene parnassica subsp. *serbica*		1		1		1			37.5	13
Thymus praecox subsp. *polytrichus*	1	1	1						37.5	13
Cardamine plumieri						1			12.5	4
Sedum annuum							1		12.5	4
Koeleria eriostachya							1		12.5	4

Relevés 1-8: Serbia, Kopaonik, Nebeske Stolice (43° 15.745 N, 20° 49.898 E)

Stands was developed in N, W and SE (rarely S) exposed cliffs, with inclination between 40° and 90° (rarely inclination was 0°). All stands was recorded at altitude of 1900m.

Typification of assocation *Edraiantho jugoslavici-Festucetum pancicii* ass. nova: rel. No. 8 in the Table 2, holotypus hoc loco.

***Silenetum serbicae* ass. nova.** In eleven relevés only 22 species were found. The median number of species per relevé area was 7. The community was poorly developed and covered 10-40 (-60) % (average 26.67 %) of the relevé area (Table 3).

Characteristic species of the asociation were *Silene parnassica* subsp. *serbica*(1-2) (Ic = 37) and *Sedum micranthum*(1) (Ic = 12). Differential species of the association were: *Galium lucidum*(+-1) (Ic = 8), *Sesleria serbica*(1) (Ic = 9), *Medicago sativa* subsp. *falcata*(+-1) (Ic = 5), *Leontodon crispus*(+) (Ic = 2), *Festuca dalmatica*(2) (Ic = 5), *Erysimum linariifolium*(+) (Ic = 2), *Lamium garganicum* subsp. *laevigatum*(1) (Ic = 3), *Galium mollugo*(1) (Ic = 3), *Vaccinium myrtillus*(+) (Ic = 2), *Dianthus cruentus*(+) (Ic

= 2) and *Allium carinatum* subsp. *pulchellum*$^{(+)}$ (Ic = 2). Other species with important coverage indices were: *Poa badensis*$^{(+-1)}$ (Ic = 28), *Asplenium trichomanes-ramosum*$^{(+-1)}$ (Ic = 19), *Jovibarba heuffelii* var. *kopaonikense*$^{(+-1)}$ (Ic = 17) and *Cardamine plumieri*$^{(+-1)}$ (Ic = 14), *Saxifraga tridactylites*$^{(+-1)}$ (Ic = 13) and *Sedum annuum*$^{(+-1)}$ (Ic = 13). The number of species and coverage indices are presented in Table 3.

Stands was developed in N and NE (rarely SW and E) exposed cliffs, with inclination between 70° and 90°. All stands was recorded at altitude between 1600 and 1900m.

Typification of assocation *Silenetum serbicae* ass. nova: rel. No. 5 in the Table 3, holotypus hoc loco.

***Musco-Jovibarbetum kopaonikense* ass. nova.** In eight relevés only 14 species were found. The median number of species per relevé area was 6. The community was poorly developed and covered 10-30 (-40) % (average 22.5 %) of the relevé area (Table 4).

Characteristic species of the asociation were: *Jovibarba heuffelii* var *kopaonikense*$^{(1-2)}$ (Ic = 44) and few nonidentified species of *Musci sp. div.*$^{(2-3)}$ (Ic = 61) and *Lichenes sp. div.*$^{(2-3)}$ (Ic = 75). Differential species of the asociation were: *Genista subcapitata*$^{(1)}$ (Ic = 4), *Rubus idaeus*$^{(1)}$ (Ic = 4), *Ornithogalum sp.*$^{(+)}$ (Ic = 3) and *Centaurea triumfetti*$^{(+)}$ (Ic = 3). Other important species were: *Poa badensis*$^{(1)}$ (Ic = 33), *Festuca panciciana*$^{(+-1)}$ (Ic = 28), *Silene parnassica* subsp. *serbica*$^{(1)}$ (Ic = 13) and *Thymus praecox* subsp. *polytrichus*$^{(1)}$ (Ic = 13).. The number of species and coverage indices are presented in Table 4.

Stands was developed in S and SW exposed rocks, with inclination between 10° and 40° (rarely inclination was 80°). All stands was recorded at altitude of 1900m.

Typification of assocation *Musco-Jovibarbetum kopaonikense* ass. nova: rel. No. 7 in the Table 4, holotypus hoc loco.

DISCUSSION

The serpentine (ophiolithic, ultramafic) rock belongs to the group of siliceous rocks characterized by calcium deficiency, high concentrations of aluminium, iron, magnesium, nickel, cobalt and chromium, and few plant nutrients. In contrast to other acid siliceous rocks, the pH values of serpentine substrate vary from basic to ultra-basic (pH 5.5–8). Many interesting basiphilous-calcifugal plants flourish on serpentine owing to this factor. It is one of the most important reasons why the serpentine flora and vegetation differ from that occurring on limestone or other siliceous substrates. Serpentine flora and vegetation present taxonomical, phyto-geographical and ecological phenomena of great interest wherever they occur. The significance of serpentine geological substratum for the plant speciation and total genesis of the flora in wider geographical regions, were registered long time ago and studied in detail. General overviews of rich and interesting endemic serpentine flora in the Balkans are reported in Tatić and Veljović (1990) and Stevanović *et al.* (2003).

In aanalyzed chasmophitic vegetation on serpentine cliffs of Kopaonik Mt, we detected only 41 species of vascular plants and considerable number of unidentified mosses and lichens. Most important among vascular plants are endemic taxa: *Silene parnassica* subsp. *serbica*, *Festuca panciciana, Edraianthus jugoslavicus, Jovibarba heuffelii* var. *kopaonikense*, *Sesleria serbica, Saxifraga adscendens* subsp. *adscendens* and *Genista subcapitata.* A few (eu)serpentinophytes (the plants that exist exclussively, or mostly, on serpentine soils), such as *Sesleria serbica, Cardamine plumieri, Sedum micranthum, Sedum annuum, Poa badensis, Koeleria eriostachya* are also important constituents of these communities.

Serpentine area of Central and Western Serbia are represented by presence of many euserpentinophytes. This group of plants involves many endemic chasmophytic species (Stevanović *et al.* 2003). Considering these facts, we expected to find numerous serpentinophytes in investigated area. Relatively small percent of serpentinophytes, compared to other chasmophytic species, may be explained by the fact that frigoriphilous sub-alpine and thermophilous (lowland) serpentine habitats have different biogeographic characteristics. Namely, serpentine and calcareous flora is much more similar in sub-alpine than in lowland area. This regularity can be explained by the fact that low temperatures and high humidity in subalpine regions attenuate extreme climate conditions that are characteristic for lower altitudes. Therefore, compared to euserpentinophytes, the presence of calciphytes at sub-alpine area is much greater (Lakušić D. 2002)

Results of canonical correspondence analysis indicate that three chasmophitic associations on serpentine cfills are well differentiated with respect to altitude, slope and exposure. Ass. *Edraiantho jugoslavici-Festucetum pancicianae* is distributed on the highest, north exposed and very steep cliffs. Ass. *Silenetum serbicae* is distributed on steep, northern slopes, but on lower altitudes. Finally, Ass. *Musco-Jovibarbetum kopaonikense* is developed on southern and gently sloped rocks. As classification results suggest (Fig 5), both associations *Silenetum serbicae* and *Musco-Jovibarbetum kopaonikense* can be devided into two groups of relevés. In both cases, these associations may be divided into low-biodiversity relevés and relevés with much greater species richness.

In a series of articles, the sub-alpine chasmophitic vegetation on serpentine cliffs of Kopaonik Mt were

Table 5. Synoptic table of analysed associations (Legend: **%** – frequency, **Ic** – coverage index according to Lausi et al. (1982), **Br.-Bl.** – range of coverage values according to Braun-Blanquet (1964).

	Edraiantho jugoslavici-Festucetum pancicii			**Silenetum serbicae**			**Musco-Jovibarbetum kopaonikense**		
	%	Ic	Br-Bl.	%	Ic	Br-Bl.	%	Ic	Br-Bl.
Characteristic species									
Festuca panciciana (Hackel) K. Richter	**100**	**33**	**1**	36	11	+-1	88	28	+-1
Edraianthus jugoslavicus Lakušić	**100**	**32**	**+-1**						
Silene parnassica Boiss. & Spruner subsp. serbica (Adamović) Greuter	33	14	1-2	**100**	**37**	**1-2**	38	13	1
Sedum micranthum DC.				**36**	**12**	**1**			
Jovibarba heuffelii (Schott) Á. & D. Löve				55	17	+-1	**100**	**44**	**1-2**
Lichenes sp. div.							**100**	**75**	**2-3**
Musci sp. div.							**100**	**61**	**2-3**
Differential species									
Saxifraga adscendens L. subsp. adscendens	**33**	**11**	**1**						
Dianthus sylvestris Wulfen subsp. sylvestris	**11**	**4**	**1**						
Armeria rumelica Boiss.	**11**	**4**	**1**						
Bromus erectus Hudson subsp. erectus	**11**	**4**	**1**						
Carex digitata L.	**22**	**7**	**1**						
Armeria maritima (Miller) Willd. subsp. maritima	**22**	**7**	**1**						
Thymus praecox Opiz subsp. skorpilii (Velen.) Jalas	**22**	**7**	**1**						
Potentilla heptaphylla L.	**11**	**4**	**1**						
Agrostis capillaris L.	**11**	**4**	**1**						
Asplenium ruta-muraria L. subsp. ruta-muraria	**11**	**2**	**+**						
Galium lucidum All.				**27**	**8**	**+-1**			
Sesleria serbica (Adamović) Ujheli				**27**	**9**	**1**			
Medicago sativa L. subsp. falcata (L.) Arcangeli				**18**	**5**	**+-1**			
Leontodon crispus Vill. subsp. crispus				**9**	**2**	**+**			
Festuca dalmatica (Hackel) K. Richter				**9**	**5**	**2**			
Erysimum linariifolium Tausch				**9**	**2**	**+**			
Lamium garganicum L. subsp. laevigatum Arcangeli				**9**	**3**	**1**			
Galium mollugo L.				**9**	**3**	**1**			
Vaccinium myrtillus L.				**9**	**2**	**+**			
Dianthus cruentus Griseb.				**9**	**2**	**+**			
Allium carinatum L. ssp. pulchellum Bonnier & Layens				**9**	**2**	**+**			
Genista subcapitata Pančić							**13**	**4**	**1**
Rubus idaeus L.							**13**	**4**	**1**
Ornithogalum sp.							**13**	**3**	**+**
Centaurea triumfetti All.							**13**	**3**	**+**

	Edraiantho jugoslavici-Festucetum pancicii			Silenetum serbicae			Musco-Jovibarbetum kopaonikense		
	%	Ic	Br-Bl.	%	Ic	Br-Bl.	%	Ic	Br-Bl.
Other species									
Poa badensis Haenke ex Willd.	100	33	1	91	28	+-1	100	33	1
Cardamine plumieri Vill.	67	21	+-1	45	14	+-1	13	4	1
Asplenium trichomanes-ramosum L.	22	6	+-1	64	19	+-1			
Saxifraga tridactylites L.	11	4	1	45	13	+-1			
Trinia glauca (L.) Dumort. subsp. glauca	22	7	1	27	7	+-1			
Ranunculus montanus Willd.	33	11	1	9	3	1			
Carex humilis Leysser	78	26	1						
Minuartia verna (L.) Hiern subsp. collina (Neilr.) Domin	56	19	1						
Koeleria eriostachya Pančić	22	7	1				13	4	1
Sedum annuum L.				45	13	+-1	13	4	1
Thymus praecox Opiz subsp. polytrichus (A. Kerner ex Borbás) Jalas							38	13	1

provisory included into, also provisory defined, sub-alliance *Edraianthion jugoslavici subalpinae serpentinicum* (Lakušić 1993; Lakušić & Ranđelović 1996, Lakušić *et al.* 2005). All chasmophytic communities (*Asplenietea trichomanes*) in Serbia have been, inconsistently, involved into alliances *Ramondion nathaliae, Edraiantho graminifolii-Erysimion comatae* and *Edraianthion jugoslavici*, within the orders *Potentilletalia caulescentis* and *Amphoricarpetalia* (Horvat *et al.* 1974; Ranđelović & Rexhepi 1980; Zupančić *et al.* 1986; Mucina *et al.* 1990; Lakušić & Ranđelović 1996; Kojić *et al.* 1998; Lakušić & Sabovljević 2005). The accurate syntaxonomy of new associations, requires previous revision of higher syntaxa, and therefore, it is not possible at this moment.

REFERENCES

Braun-Blanquet J. 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde. 3. Auflage. Springer, Wien – New York, 865. pp.

Flora Europaea Database - http://rbg-web2.rbge.org.uk/FE/fe.html, Royal Botanic Garden Edinburgh.

Horvat I, Glavač V & Ellenberg H. 1974. Vegetation Südosteuropas. In: Tüxen R. (ed.), Geobotanica selecta 4: (I-XXXII), 1-768, Gustav Fischer, Jena/Stuttgart.

Jovanović S & Jovanović-Dunjić R. 1986. Prilog poznavanju hazmofitske vegetacije kanjona Dervente (Nacionalni park Tara). *Glasnik Instituta za Botaniku i Botaničke bašte Univerziteta u Beogradu* **20**: 33-43.

Kojić M, Popović R & Karadžić B. 1998. Sintaksonomski pregled vegetacije Srbije. Institut za biološka istraživanja "Siniša Stanković", Beograd.

Karadžić B, Šašo-Jovanović V, Jovanović Z & Popović R. 1998. "FLORA" a database and software for floristic and vegetation analyzes. In: Tsekos I. & Moustakas M. (eds.) *Progress in Botanical Research*. pp. 69-72, Kluwer Academic Publishers, Dodrecht.

Karadžić B, Šašo-Jovanović V, Jovanović Z & Karadžić D. 1999. On detrending in correspondence Analysis and Principal Components Analysis. *Ecoscience* **6**(1): 110-116

Karadžić B, Marinković S & Kataranovski D. 2003. Use of the β-function to estimate the skewness of species responses. *J. Veg. Sci.* **14**: 799-805.

Lakušić D. 1993. Visokoplaninska flora Kopaonika - ekološko fitogeografska studija. Magistarski rad. Biološki fakultet, Beograd.

Lakušić D. 2002. Prostorna i ekološka diferencijacija flore Kopaonika. I Konferencija "S planinom u novi vek", Kopaonik, Zbornik radova, 111-120.

Lakušić D & Ranđelović V. 1996. Pregled biljnih zajednica Kopaonika. *Ekologija* **31**: 1-17.

Lakušić D & Sabovljević M. 2005. Fitocenološka klasifikacija vegetacije. In: Lakušić D. (ed.): Staništa Srbije, Rezultati projekta "Harmonizacija nacionalne nomenklature u klasifikaciji staništa sa standardima međunarodne zajednice", Institut za Botaniku i Botanička Bašta "Jevremovac", Biološki fakultet, Univerzitet u Beogradu, Ministarstvo za nauku i zaštitu životne sredine Republike Srbije, http://habitat.bio.bg.ac.rs/nacionalne_klasifikacije_stanista.htm

Lakušić R & Redžić S. 1989. Flora i vegetacija vaskularnih biljka u refugijalno-reliktnim ekosistemima kanjona rijeke Drine i njenih pritoka. *Glasnik odeljenja prirodnih nauka, Crnogorska akademija nauka i umjetnosti* **7**: 107-205.

Lausi D, Gerdol R & Piccoli F. 1982. Syntaxonomy of the *Ostrya carpinifolia* wods in the southern Alps (N Italy) based on numerical methods. *Studia Geobotanica* **2**: 41-58.

Mišić V. 1954. Prilog poznavanju strukture i sezonske dinamike bukovih fitocenoza Kopaonika.- *Archives of Biological Sciences* **6**: 81-99.

Mišić V, Jovanović B & Popović M. 1985. Vegetacija Kopaonika. Studija sa vegetacijskim kartama 1:50 000 za šire područje. Prostorni plan NP Kopaonik. Zavod za urbanizam i prostorno planiranje, 1-169, Beograd.

Mišić V, Popović M & Dinić A. 1985 Šume jele i smrče (*Abieti - Picetum serbicum typicum*) na Kopaoniku i Zlataru. *Glasnik Prirodnjačkog muzeja u Beogradu* B, **40**: 67-73.

Mucina L, Valachović M, Jarolímek I, Šeffer J, Kubinská A & Pišut I. 1990. The vegetation of rock fissures, screes, and snow-beds in the Pirin Planina mountains (Bulgaria). *Studia Geobotanica* **10**: 15-58.

Orloci L. 1967. An agglomerative method for classification of plant communities. *Journal of Ecology* **55**: 193-205.

Petković B, Tatić B, Marin P & Dujmić J. 1990. Prilog poznavanju zajednica sa Edraianthus jugoslavicus Lakušić sa Mokre Gore (jugozapadna Srbija). *Bilten Društva ekologa Bosne i Hercegovine* **5B**:131-135.

Petković B, Tatić B, Marin P & Ilijin-Jug M. 1991. *Musco-Seslerio-Edraianthetum jugoslavici*, ass. nov., nova zajednica klisura i kanjona Tutinskog područja. Drugi simpozijum o flori jugoistočne Srbije i mogućnostima njenog racionalnog korišćenja (Proceedings):133-139.

Randjelović N. & Rexhepi F. 1980 Prodromusi i fitocenozave te Kosoves/Prodromus biljnih zajednica Kosova. *Biotehnika* **8**: 213-222.

Sneath PHA & Sokal RR. 1973. *Numerical taxonomy.* W. H. Freeman, San Francisco.

Stanić S. & Lakušić D. (1990-1991): *Edraiantho jugoslavicii-Hieracietum humile* i *Carici laevis-Leontopodietum alpinii*, nove hazmofitske zajednice na krečnjacima planine Mučanj (JZ Srbija). *Glasnik Instituta za botaniku i Botaničke bašte u Beogradu* **24-25**: 21-32. (1993).

Stevanović V, Kit Tan & Iatrou G. 2003. Distribution of the endemic Balkan flora on serpentine I. – obligate serpentine endemics. *Plant Syst. Evol.* **242**: 149–170

Tatić B & Veljović V. 1982. *Edraiantho-Saxifragetum porophyllae* ass. nova. *Glasnik Instituta za botaniku i Botaničke bašte Univerziteta u Beogradu* **15**: 69-75.

Tatić B & Veljović V. 1990. Distribution of serpentinized massives on the Balkan peninsula and their ecology. In: Roberts BA & Proctor J (eds.). *The ecology of areas with serpentinized rocks*. Kluwer Acad. Publ., Dordrecht, pp. 199–215

ter Braak CJF. 1986. Canonical correspondence analysis: A new eigenvector technique for multivariate direct gradient analysis. *Ecology* **67**: 1167-1179.

Westhoff V & van der Maarel E. 1973. The Braun-Blanquet approach. In: Whittaker RH (ed.) Ordination and classification of communities. Handbook of Vegetation Science 5. The Hague, pp. 619-726.

Zupančić M. (ed.) (1986): Prodromus phytocoenosum Jugoslaviae ad mappam vegetationis m 1:200.000. - Naučno veće vegetacijske karte Jugoslavije, Bribir-Ilok.

REZIME

Nove zajednice u vegetaciji serpentinitskih stena (*Asplenietea trichomanis* Br.-Bl. 1934 corr. oberd. 1977) na Kopaoniku u Srbiji

Dmitar Lakušić, Branko Karadžić

U radu su analizirane fitocenološke karakteristike vegetacije u pukotinama subalpijskih serpentinitskih stena planine Kopaonik u Srbiji. Za prikupljanje osnovnih podataka korišćena je Braun-Blanquet metodologija, dok su u cilju utvrđivanja florističke i cenoekološke diferencijacije analiziranih sastojina korištene koorespodentna analiza (CA) i kanonijska koorespodentna analiza (CCA). Klasifiakcija sastojina je uradjena na osnovu Chord distanci, a na osnovu UPGMA klasifikacionog modela. Sve analize su uradjene u najnovijoj verzije softverskog paketa "Flora"

Na osnovu flotrističkih i ekoloških karakteristika sve analizirane hazmofitske sastojine se jasno diferenciraju na tri grupe koje su opisane kao neve asocijacije: *Edraiantho jugoslavici-Festucetum pancicianae* ass. nova, *Silenetum serbicae* ass. nova i *Musco-Jovibarbetum kopaonikense* ass. nova.

Ključne reči: hazmofitske zajednice, serpentin, ordinacija, klasifikacija, Srbija

APPENDIX

Asplenietea trichomanis Br.-Bl. 1934 corr. Oberd. 1977

Potentilletalia caulescentis Br.-Bl. 1926
Moechringion muscosae Ht. 1930,
Asplenion lepidi Lakušić 1968,
Ramondion nathaliae Ht. 1935
Edraiantho graminifolii-Erysimion comatae Mucina et al 1990

Amphoricarpetalia Lakušić 1968
Edraianthion jugoslavici Lakušić 1968
Edraianthion jugoslavici Lakušić 1968 *subalpinae serpentinicum* prov. D. Lakušić 1996.
Amphoricarpion bertiscei Lakušić 1968

Androsacetalia vandelii Br.-Bl. 1926
Asplenion septentrionalis Lois. 1968,
Saxifragion cymosae Lakušić 1970
Silenion lerhenfeldianae Ht. 1960
Potentillion visianii H. Ritter-Studni~ka 1970

Tortulo-Cymbalarietalia Segal 1969
Parietarion judaicae Segal 1969

Adiantetea capilli-veneris Braun-Blanq. in Braun-Blanq., Roussine & Nègre 1952

Adiantetalia capilli-veneris Braun-Blanq. ex Horvatić 1939
Adiantion capilli-veneris Braun-Blanq. ex Horvatić 1939

Vaccinio-Piceetea Br.-Bl. 1939 emend. Zupančić 1976

Vaccinio-Piceetalia Br.-Bl. 1939 emend. K.-Lund 1967
Vaccinio-Piceion Br.-Bl. (1938) 1939
Juniperion sibiricae Br.-Bl. 1939

Vaccinietalia Lakušić et al. 1979
Vaccinion myrthylli Lakušić 1974