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NOMENCLATURAL-PHYTOCOENOLOGICAL ANALYSIS OF THE ASSOCIATION *POTENTILLO MICRANTHAE-QUERCETUM PETRAEAE* ASS. NOVA IN CROATIA

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Abstract

Phytocoenological traits of forests of sessile oak in the area of Zrinska Gora were investigated in 2009. Phytocoenological research was conducted using a method of the Zürich-Montpellier School. A comparison was made with acido-thermophilic forests of sessile oak from central and north-western Croatia, then from Slovenia and the Mescek Mountains in Hungary.

A statistical comparison was made by entering all the phytocoenological relevés into the Turboveg database. This was followed by a classical synthetic analysis of the phytocoenological relevés and a multivariate analysis using Syntax 2000 software. Average Ellenberg's values were calculated for each relevé with JUICE 6.3 software.

Taking into consideration all the facts, it can be concluded that the newly established association *Potentillo micranthae-Quercetum petraeae* shows a high degree of independence and differentiation from other similar associations described to date. In relation to others, it is poorer in species, both in terms of the systematic categories to which it belongs and the number of elements from the orders of *Fagetalia* and *Quercetalia pubescentis*. Of the species occurring in acidophilic forests of sessile oak, *Genista tinctoria, Chamaecytisus hirsutus* and *Dicranella heteromalla* can be considered characteristic species, whereas *Galium sylvaticum, Cephalanthera longifolia, Dianthus armeria* and *Viola alba* can be termed differentiating species. The species *Potentilla micrantha, Festuca drymeia* and *Luzula forsteri* are very important for the structure, physiognomy and syndynamics of the association.

It is subordinated to the alliance *Quercion robori-petraeae*, the order *Quercetalia robori-petraeae* and the class *Querco-Fagetea*.

Key words: nomenclatural-phytocoenological analysis, acidophilic forests, *Potentillo micranthae-Quercetum petraeae*, Zrinska gora, Croatia.

Izvleček

V letu 2009 smo preučevali fitocenološke značilnosti gozdov gradna na območju Zrinske gore. Raziskavo smo naredili z metodo Züriško-Montpellierske šole. Primerjali smo acidofilno termofilne gradnove gozdove iz srednje in severozahodne Hrvaške s podobnimi iz Slovenije in hribovja Mecsek na Madžarskem.

Za statistično primerjavo smo zbrali fitocenološke popise v bazi Turboveg. Sledila je klasična sintetska analiza fitocenoloških popisov in multivariatne analize s programom Syntax 2000. Povprečne Ellenbergove indikacijske vrednostiza posamezen popis smo izračunali s programom Juice 6.3.

Primerjava nove asociacije *Potentillo micranthae-Quercetum petraeae* kaže visoko stopnjo neodvisnosti in razlik od podobnih dotedaj opisanih asociacij. V primerjavi z njimi je preučevana asociacija vrstno siromašnejša, tako v številu sinsistematskih kategorij kot po številu elementov iz redov *Fagetalia* in *Quercetalia pubescentis*. Za značilnice, ki se pojavljajo v acidofilnih gradnovih gozdovih lahko imamo vrste *Genista tinctoria, Chamaecytisus hirsutus* in *Dicranella heteromalla*, medtem ko vrste *Galium sylvaticum, Cephalanthera longifolia, Dianthus armeria* in *Viola alba* označimo kot razlikovalnice. Vrste *Potentilla micrantha, Festuca drymeia* in *Luzula forsteri* so zelo pomembne za strukturo, fizionomijo in sindinamiko asociacije. Uvrščamo jo v zvezo *Quercion robori-petraeae*, red *Quercetalia robori-petraeae* in razred *Querco-Fagetea*.

Ključne besede: nomenklaturno-fitocenološka analiza, acidofilni gozdovi, *Potentillo micranthae-Quercetum petraeae*, Zrinska gora, Hrvaška.

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1. INTRODUCTION

Acido-thermophilic forests of sessile oak, placed in the order of *Quercetalia robori-petraeae,* grow in the colline and montane belt of northern Croatia (300–800 m). The soil is acidophilic and the climate is temperate (9–11 °C, precipitation 800 to 1100 mm). Sessile oak, the dominant species in the tree layer, is permanently accompanied by sweet chestnut (*Castanea sativa*), manna ash (*Fraxinus ornus*) and wild service tree (*Sorbus torminalis*), while beech and hornbeam (*Fagus sylvatica* and *Carpinus betulus*), except in some sporadic stands with sweet chestnut, have a subordinate role.

Compared with the related Central European associations of the same syntaxonomic affiliation (*Luzulo-Quercetum* Hillitzer 1932, *Genisto pilosae-Quercetum* Zólyomi et al. 1957, partly *Melampyro vulgati-Quercetum petraeae* Puncer et Zupančič 1979 and others), these forests are characterized by the presence of a large number of species predominantly distributed in southern and south-eastern Europe. These include acido-thermophilic species *Castanea sativa, Chamaecytisus hirsutus, Luzula forsteri, Lathyrus linifolius, Dianthus barbatus,* and thermophilic species on acid soils *Fraxinus ornus, Sorbus torminalis, Potentilla micrantha*, *Campanula persicifolia*, and *Sedum telephium* ssp. *maximum*. Besides these, the following differentiating species of predominantly mesophilic character are also important: *Cruciata glabra, Galium sylvaticum, Cephalanthera longifolia, Festuca drymeia, Carex pilosa* and others. On the other hand, *Betonica officinalis, Teucrium scordonia, Genista pilosa* and *Deschampsia flexuosa* are either absent or occur very rarely in sessile oak communities in Croatia, while *Calamagrostis arundinacea, Vaccinium myrtillus* and *Calluna vulgaris* are relatively rare. In contrast to central Europe, tree species such as *Pinus sylvestris, Picea abies, Quercus robur, Sorbus aucuparia* and *Fraxinus excelsior* do not occur at all (Horvat 1938, Šugar 1972, Hruška Dell' Uomo 1974, Vukelić 1991, Vukelić & Baričević 1996, Baričević 2002, Trinajstić 2008, Vukelić et al. 2008, Medak 2009). For reasons of floristic, geobotanic and ecological differences, it was proposed that the above associations growing south of pre-Alpine-Alpine areas be placed into separate alliances or suballiances (Soó 1962, 1971, Vukelić 1991). This has already been done with the suballiance *Castaneo-Quercenion* (Soó 1962 em. 1971) Kevey in Kevey et Borhidi 2005.

Phytocoenological traits of forests of sessile oak in the area of Zrinska Gora were investigated in 2009. As the phytocoenological analysis showed, these forests could be described as a new association due to the fact that they differed in some basic characteristics from the associations described earlier. The new association was named *Potentillo micranthae-Quercetum petraeae*. A comparison was made with acido-thermophilic forests of sessile oak from central and north-western Croatia, then from Slovenia and the Mescek Mountains in Hungary.

2. MATERIAL AND METHODS

Phytocoenological research was conducted in 16 localities on Zrinska Gora using a method of the Zurich-Montpellier School (Braun-Blanquet 1964) with a six-point scale. Phytocoenological relevés were taken from the plots of 400 m^2 between April and August 2009. Sixteen relevés with their participation percentages are presented in analytical form in Table 1, whereas a comparison between the studied communities and the related communities in adjacent areas (*Luzulo forsteri-Quercetum petraeae* from Mescek, *Festuco drymeiae-Quercetum petraeae* from Moslovačka gora, *Hieracio racemosi-Quercetum petraeae* from NW Croatia and *Melampyro vulgati-Quercetum petraeae* „*submediterraneum*" from Brkini) is shown in Table 2. The species participation percentage in all the relevés is also given.

A statistical comparison was made by entering all the phytocoenological relevés into the Turboveg database (Hennekens & Schaminée 2001). This was followed by a classical synthetic analysis of the phytocoenological relevés and a multivariate analysis using Syntax 2000 software (Podani 2001). Two methods of multivariate statistical analysis were used: cluster analysis (complete link, group average, simple average, incremental sum of squares) and multivariate scaling (Principal coordinate analysis /PCoA). The measure of dissimilarity or similarity was the complement of the "Similarity ratio" coefficient.

Average Ellenberg's values were calculated for each relevé with JUICE 6.3 software (Tichý 2002). The obtained data were processed with STATISTICA 8.0 (StatSoft Inc 1984–2008). The Kruskal-Wallis test was used to determine which ecological factors were important for distinguishing the associations.

Scientific names of the higher plant species follow the web source – Flora Croatica Database (2004) (http://hirc.botanic.hr/fcd/), and the mosses are adjusted according to Koperski et al. (2000).

The names of plant communities are coordinated by the valid Code of Phytocoenological Nomenclature (Weber et al. 2000).

3. ECOLOGICAL FEATURES OF THE STUDY AREA

Zrinska Gora is situated in a wider area of the River Sava on the south-western edge of the Pannonian Plain and in the boundary area with Bosnia and Herzegovina. The massif is characterized by a distinctly indented relief with numerous elongated ridges and deeply cut stream valleys. It reaches a height of up to 616 m. The majority of the massif is covered with deciduous forests (oak, beech, chestnut), whereas lower slopes feature pastures and arable land (Baričević et al. 2009, Medak 2009).

The area of Zrinska Gora is made up of sediment, igneous, ultramaphitic and metamorphic rocks chronostratigraphically distributed from the Palaeozoic to the Quaternary. Most frequently, these are layers of marl, clay, sandstone, sand and gravel with limestone participation. The dominant soil types are luvisol, cambisol, ranker and colluvium.

Zrinska Gora is located at a meeting point of two large relief units: the southern edge of the Pannonian Plain and the northern part of the pre-Dinaric space. Data for Sisak Meteorological Station for the period 1980 to 2006 (source: State Hydro-Meteorological Office) show that, according to Köppen, the climate in the Banovina area is temperate warm and rainy (Cfwbx" type). The mean annual air temperature is 11.1 °C, and the mean air temperature in the vegetation pe-

Figure 1: Characteristic appearance of the association *Potentillo micranthae-Quercetum petraeae* in the area of Zrinska gora
Slika 1: Značilen videz asociacije *Potentillo micranthae-Quercetum petraeae* na območju Zrinske gore.

riod is 17.7 °C. The total annual precipitation is 905.7 mm, of which 508.9 mm, or 56.19 %, occurs in the vegetation period.

The investigated association is predominantly developed on southern expositions, at heights between 300 and 500 m above the sea, with inclinations ranging from 5 and 35 degrees (Figure 1). The dominant soil types are luvisol and dystric cambisol. In the adjacent community *Aposerido foetide-Castanetum sativae*, which is the most represented chestnut phytocoenosis on Zrinska Gora, seven analyzed profiles contain luvisol, in which the pH of the humus-accumulative horizon ranges between 5 and 5.5 (Medak 2009).

3. RESULTS AND DISCUSSION

The floral composition of the association under study is shown in the analytical Table 1. A total of 66 species of higher plants and 9 of mosses were recorded in the relevés. Of these, 24 species are present in over 50 % of the relevés. These include the basic species of the order *Quercetalia robori-petraeae* and lower units: *Castanea sativa, Luzula luzuloides, Hieracium racemosum, Genista tinctoria, Festuca heterophylla, Veronica officinalis, Luzula forsteri, Chamaecytisus hirsutus* and the moss *Dicranella heteromalla*. Ten species from the order *Fagetalia* and lower units were identified (*Fagus sylvatica, Festuca drymeia* and *Galium sylvaticum* in over 50 % of the relevés) and 10 from the order *Quercetalia pubescentis*, of which 3 occurred in over half of the relevés (*Fraxinus ornus, Sorbus torminalis* and *Potentilla micrantha*).

The association *Potentillo micranthae-Quercetum petraeae* was compared with four associations from neighbouring areas, with which it manifests the highest similarity (Table 2). They all belong to the same syntaxonomic units, with sessile oak as the edifier. In relation to similar forests north of the Alps, they are characterized by the Mediterranean influence, which has had an effect on their floristic composition. In addition to the larger number of species from the order *Quercetalia robori-petraeae*, there are also mesophilic species of the order *Fagetalia* and thermophilic species of the order *Quercetalia pubescentis*, depending on the local characteristics of the mountains. The following associations were compared:

Festuco drymeiae-Quercetum petraeae (Janković 1968) Hruška Dell' Uomo 1974 stretches from Fruška Gora in the east to Moslavačka Gora in the west, where it represents the boundary community *Quercetalia robori-petraeae* towards beech and hornbeam forests (Hruška Dell' Uomo 1974, Janković & Mišić 1980, Baričević 2002). Compared with the analyzed communities, the differentiating species, besides the dominant *Festuca drymeia*, include "fagetal" mesophites *Dryopteris filix-mas, Euphorbia amygdaloides, Mycelis muralis, Galium odoratum, Salvia glutinosa, Sanicula europaea, Cyclamen purpurascens* and others. The overall number of the species in this and the compared association *Potentillo micranthae-Quercetum petraeae* is 142. There are 43 species, or 30 %, occurring in both associations.

Luzulo forsteri-Quercetum petraeae (A.O. Horvat 1963) Borhidi et Kevey 1996 is described as the local association of the Mescek Mountains in Hungary. Occurring at heights between 300 and 500 m, it covers northern expositions and inclinations of 3 to 25 degrees. The floral composition features some important sub-Mediterranean species, which discriminates this association from other acidophilic forests in the Mescek Mountains, the west Zadunavlje region and central Hungarian uplands (A. O. Horvat 1972, Borhidi and Kevey 1996, Kevey 2008). This analysis showed some similarities with the mountains of western Croatia. Compared with the analyzed forests of Western Balkans (Table 2), the differentiating species feature *Hieracium lachenalli* and *Veronica officinalis* in the first place, then *Prunus avium*, *Symphytum tuberosum* and *Brachypodium sylvaticum* of the order *Fagetalia* and species of wider social affiliation *Pyrus pyraster*, *Crataegus monogyna*, *Melica uniflora*, *Rosa arvensis*, *Carex digitata* and *Hepatica nobilis*. Special mention should be made of the differentiating importance of the species *Quercus cerris*, *Tilia tomentosa* and *Genista tinctoria* ssp. *ovata,* which do not occur in related communities, or at least not in such numbers. The percentage of common species in comparison with *Potentillo micranthae-Quercetum petraeae* is only 29 %.

Hieracio racemosi-Quercetum petraeae Vukelić 1991 nom. invalid occurs on southern slopes of north-western mountains in Croatia, where it reaches a height of 700 m. It grows on shallow and medium deep dystric cambisol above schists and sandstones. Due to the geographic position there is a more distinct presence of acidophilic forests of the central European region. In addition to other species, the association features *Vaccinium myrtillus*, *Calluna vulgaris*, *Molinia caerulea* ssp.

arundinacea, *Calamagrostis arundinacea*, *Prenanthes purpurea*, which are either absent or much less frequent in sessile oak communities growing more eastwards. Particularly distinct are *Hieracium umbellatum*, *Lathyrus linifolius*, thermophilic *Lathyrus niger*, *Tanacetum corymbosum*, *Sorbus aria* and fagetal *Knautia drymeia* ssp. *drymeia* and *Cruciata glabra*. The total number of species also occurring in the association *Potentillo micranthae-Quercetum petraeae* is 130, of which 37 are common to all (28 %).

Melampyro vulgati-Quercetum petraeae „*submediterraneum*" Puncer et Zupančič 1979, described in the area of Brkinov in Slovenia, covers southern positions up to 740 m. It contains a large number of differentiating species of acidophilic forests of sessile oak from the Atlantic – sub-Atlantic and continental region. In addition to the species mentioned in the previous association, of special interest are *Potentilla erecta*, *Chamaespartium sagittale*, *Deschampsia caespitosa*, *Genista pilosa*, *Juniperus communis* and others (Puncer & Zupančič 1979). There are 23 % species that also occur in the association *Potentillo micranthae-Quercetum petraeae*.

The association *Potentillo micranthae-Quercetum petraeae* features the fewest number of species. Its differentiating species clearly discriminate it from other associations. Of the syntaxonomic categories to which it belongs, it contains the species *Genista tinctoria, Chamaecytisus hirsutus* and the moss *Dicranella hetermomalla*. Beech species include *Cephalanthera longifolia* and *Galium sylvaticum*, and species of broader sociological tolerance include *Viola alba* and *Dianthus armeria*. This set of differentiating species characterizes the community both in the sociological and ecological sense. *Potentilla micrantha*, the species which gives the association its name, is a clear indicator of ecological-sociological relations in the association. *Potentilla micrantha* is a species of dry, slightly acidic, medium poor to rich, skeletal, aerated soils, semi-light terrains and warm sites. It is native to southern and especially south-eastern Europe and Asia Minor. It is significantly represented in forests of oriental hornbeam (*Carpinus orientalis*) in northern Greece, southern Bulgaria and Macedonia, subcontinental forests of sweet chestnut (*Castanea sativa*), and especially in forests of Hungarian oak in Serbia (*Quercus frainetto*). Thus, in the thermophilous deciduous forests in Southeastern Europe (Bergmeier & Dimopoulos 2008, Čarni et a. 2009). In the western part of the Balkan Peninsula it is very common in acidophilic forests of sessile oak and continental chestnut forests, but less frequent in Illyrian beech forests of the alliance *Aremonio-Fagion*. It may even reach the range of Illyrian beech-fir forests. Most authors classify it among the characteristic species of the order *Quercetalia pubescentis*, and less frequently among *Quercetalia robori-petraeae*.

Five described associations with a total of 93 relevés were compared in Table 2. 88 species were identified which either differentiate the associations from one another or from group to group. These species largely coincide with the species which the authors have denoted as characteristic or differential in the original description of the associations. However, the species that identify the association do not include only the differentiating and other species, but also those that do not grow in the association but are represented in other associations. This "negative differentiation" is partly reflected in the results of statistical comparison of the associations in Table 2. Namely, a comparison of the associations, especially the species of the order *Quercetalia robori-petraeae,* gives the impression that the studied association is the most similar to the association *Luzulo forsteri-Quercetum petraeae* from Mescek in Hungary, and that it could possibly be joined to the latter. These two associations are linked by a large number of joint species from the order *Quercetalia robori- petraeae*. Other important links are *Luzula forsteri, Tilia tomentosa* and *Potentilla micrantha*.

Statistical analysis (Figure 2), however, shows completely different relations. These associations are different and individual at a very high level. The Hungarian association, in comparison with the others, shows distinct independence. Unfortunately, in the relevés at our disposal, no mosses were recorded in the association derived from the Mescek Mountains. With mosses, the comparison would be more reliable. The difference between the association *Potentillo micranthae-Quercetum petraeae* and the others is reflected in the fact that the former either lacks or contains very few of the important species of acido-thermophilic sessile oak forests, such as *Melampyrum vulgatum*, *Chamaecytisus supinus*, *Solidago virgaurea*, *Lembotropis nigricans* and *Hieracium sabaudum*. Of the species from the order *Quercetalia pubescentis* these are *Tanacetum corymbosum, Convallaria majalis, Lathyrus niger,* partly *Quercus cerris* and others. These species are present in all the other compared associations to a significant extent.

A synthetic analysis of 93 phytocoenological relevés and multivariate statistical analysis clearly identified five separate groups of relevés (Figure 2). The first group is made up of the relevés of the association *Hieracio recemosi-Quercetum petraeae* (1–20), the second groups consists of the relevés of the association *Luzulo forsteri-Quercetum petraeae* (21–45), the third group is formed from the relevés of the association *Festuco drymeiae-Quercetum petraeae* (46–58), the fourth group consists of the relevés of the association *Potentillo micranthae-Quercetum petraeae* from Zrinska Gora (59–74), and the fifth group is made up of the relevés of the association *Melampyro-Quercetum petraeae submediterraneum* (75–93).

Cluster analysis and other statistical methods also showed the closest similarity between the association *Potentillo micranthae-Quercetum petraeae* and the association *Festuco drymeiae-Quercetum petraeae*. Of all the observed associations, that of *Luzulo forsteri-Quercetum petraeae* proved to be the most different.

The associations from Table 2 were compared in terms of Ellenberg's ecoindicator values of the floristic composition. The Kruskal-Wallis test ($p<0.05$) was used to determine the ecological factors that were important for differentiating the associations. Ratios for light, temperature, humidity, continentality, as well as soil and nutrient reaction, were taken into consideration. The results are given in Table 3 (bold indicates a statistically significant difference between association *Potentillo micranthae-Quercetum petraeae* and individual associations for each ecological factor).

Taking into consideration all the facts mentioned in the discussion, it can be concluded that the newly established association *Potentillo micranthae-Quercetum petraeae* shows a high degree of independence and differentiation from other similar associations described to date. In relation to others, it is poorer in species, both in terms of systematic categories to which it belongs and the number of elements from the orders of *Fagetalia* and *Quercetalia pubescentis*. Of the spe-

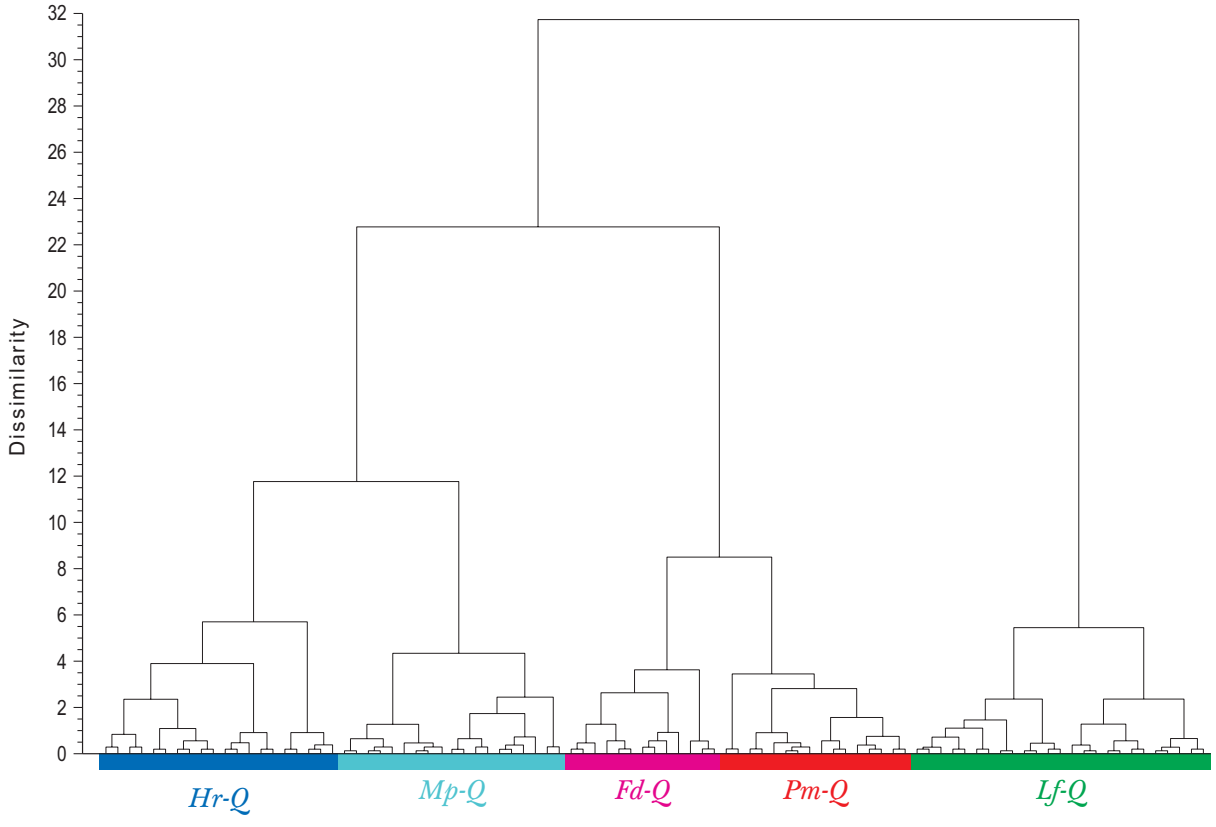

Figure 2: Dendrogram constructed with cluster analysis – Increment sum of squares method.
Slika 2: Dendrogram kot rezultat klastrske analize – Increment sum of squares method.

cies occurring in acidophilic forests of sessile oak, *Genista tinctoria, Chamaecytisus hirsutus* and *Dicranella heteromalla* can be considered characteristic species, whereas *Galium sylvaticum, Cephalanthera longifolia, Dianthus armeria* and *Viola alba* can be termed differentiating species. The species *Potentilla micrantha, Festuca drymeia* and *Luzula forsteri* are very important for the structure, physiognomy and syndynamics of the association. The relevé number 15 in Table 1 is taken as the nomenclatural type. The final group of diagnostically decisive species and other features will be determined after the association has been investigated in other Pannonian hills of Croatia and neighbouring areas.

The forest of sessile oak with pink barren strawberry is predominantly of primary origin, but some stands are in regression due to anthropogenic impacts, irregular cutting operations and the removal of leaf litter. In the progressive direction, the coenosis develops towards forests of sessile oak and sweet chestnut, while regression ends with bracken and heath.

4. CONCLUSION

Phytocoenological research conducted in acidophilic forests of sessile oak on Zrinska Gora resulted in the establishment of a new association of sessile oak with pink barren strawberry (*Potentillo micranthae-Quercetum petraeae* as. nova hoc loco). Growing on dystric cambisol and cambisol of acid to weakly acid reaction, it occurs on southern slopes at elevations from 300 to 600 m. It is subordinated to the alliance *Quercion roboripetraeae*, the order *Quercetalia robori-petraeae* and the class *Querco-Fagetea*. Its characteristic species include *Genista tinctoria, Chamaecytisus hirsutus* and *Dicranella heteromalla*, and the differentiating species are *Galium sylvaticum, Cephalanthera longifolia, Viola alba* and *Dianthus armeria*. A group of species including *Festuca drymeia, Luzula forsteri* and *Potentilla micrantha* is also important for diagnostic identification, structure and syndynamics of the association. Some important species of acidophilic and thermo-acidophilic forests of sessile oak are either absent or are present to a much lesser degree than in other communities. These are, for example, *Melampyrum vulgatum, Chamaecytisus supinus, Solidago virgaurea, Lembotropis nigricans* and *Hieracium sabaudum,* whereas species of the order *Querdetalia pubescentis* include *Tanacetum corymbosum, Convallaria majalis, Lathyrus niger*, partly *Quercus cerris* and others.

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Table 1: Floral composition of the association *Potentillo micranthae-Quercetum petraeae.*
Tabela 1: Floristična sestava asociacije *Potentillo micranthae-Quercetum petraeae.*

Number of relevé		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Date		5/09	5/09	5/09	5/09	5/09	6/09	6/09	6/09	6/09	6/09	6/09	6/09	6/09	6/09	6/09	6/09	
Altitude (m)		315	320	330	325	340	360	320	300	320	380	350	372	363	429	444	478	
Releve area (m)		400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	
Exposition (ş)		180	80	0	90	60	190	205	170	205	190	180	210	220	190	200	210	
Inclination (°)		5	4	30	15	15	20	30	25	35	25	20	35	35	25	27	20	
Cover (%)	A	90	80	85	95	80	80	70	80	70	75	70	80	80	90	95	90	
	B	40	30	30	20	10	20	30	20	40	40	35	35	30	35	35	30	
	C	20	25	85	50	60	60	70	30	90	60	80	85	85	70	65	60	
Number of species		20	17	28	32	34	27	32	28	27	26	27	28	28	24	35	30	

Presence degree

Characteristic and differentiating species of the association

Genista tinctoria	B	.	+	1	1	+	2	+	+	2	1	1	1	+	+	+	+	V
Chamaecytisus hirsutus		.	.	+	+	+	+	+	+	+	.	+	1	1	+	+	+	V
Galium sylvaticum	C	.	.	1	.	+	1	2	+	1	1	1	+	+	+	1	+	V
Cephalanthera longifolia		+	.	+	+	1	+	+	.	.	.	.	+	.	+	+	1	IV
Viola alba		+	.	.	+	+	.	.	.	.	+	.	.	.	+	+	+	III
Dianthus armeria		.	.	.	.	.	1	+	.	+	.	.	.	+	.	+	+	II
Dicranella heteromalla	D	.	.	.	+	+	1	.	1	+	.	+	1	.	.	+	.	III
Quercetalia robori-petraeae																		
Castanea sativa	A	+	.	+	.	.	.	.	.	+	.	.	+	+	+	.	.	II
Castanea sativa	B	1	1	1	1	1	+	.	1	1	1	1	2	+	+	1	+	V
Genista tinctoria		.	+	1	1	+	2	+	+	2	1	1	1	+	+	+	+	V
Chamaecytisus hirsutus		.	.	+	+	+	+	+	+	+	.	+	1	1	+	+	+	V
Pteridium aquilinum	C	1	1	.	1	+	+	+	2	3	+	2	4	1	+	1	+	V
Luzula luzuloides		.	+	2	+	+	3	3	2	4	3	2	3	4	+	+	1	V
Hieracium racemosum		.	+	1	1	1	1	2	1	2	+	1	1	+	1	+	+	V
Festuca heterophylla		+	.	.	2	2	3	3	1	1	3	1	+	+	2	2	1	V
Veronica officinalis		+	.	+	+	.	.	.	+	+	.	+	+	1	.	.	+	III
Luzula forsteri		.	+	1	1	1	1	+	+	.	.	+	.	.	.	.	+	III
Hieracium murorum		.	.	.	+	+	1	+	1	.	.	+	.	.	.	.	.	II
Galium lucidum		.	.	.	.	.	.	+	.	.	+	.	.	+	.	.	.	I
Melampyrum pratense		.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	I
Serratula tinctoria		.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Aremonio-Fagion																		
Festuca drymeia	C	1	2	3	1	3	1	+	+	2	2	3	2	3	3	2	3	V
Ruscus hypoglossum		.	.	1	.	+	.	.	.	.	+	.	.	.	+	.	.	II
Fagetalia sylvaticae																		
Fagus sylvatica	A	+	.	+	.	.	2	+	+	+	.	.	.	+	.	+	+	III
Carpinus betulus		+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Fagus sylvatica	B	1	1	1	+	1	+	1	+	1	+	1	+	.	.	.	1	V
Prunus avium		.	.	+	.	+	+	.	.	.	.	.	+	+	.	.	.	II
Carpinus betulus		.	+	.	.	.	.	.	.	.	+	.	.	+	.	.	.	I
Galium sylvaticum	C	.	.	1	.	+	1	2	+	1	1	1	+	+	+	1	+	V
Lathyrus vernus		.	.	1	.	+	.	.	.	.	.	.	.	.	.	+	+	II
Fagus sylvatica		.	.	.	.	.	+	+	.	.	.	+	.	.	+	.	.	II
Cardamine bulbifera		.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	+	I
Dryopteris filix-mas		.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Mycelis muralis		.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	I
Galium odoratum		.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	I

Number of relevé		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Carpinus betulus		.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Pulmonaria officinalis		.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Quercetalia pubescentis																		
Fraxinus ornus	A	.	.	.	.	.	.	1	.	.	.	.	+	+	+	+	.	II
Sorbus torminalis		.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	I
Fraxinus ornus	B	1	+	+	2	1	1	1	+	2	2	2	1	1	+	+	+	V
Sorbus torminalis		1	1	+	+	+	+	+	+	1	+	+	1	+	1	1	+	V
Chamaecytisus supinus		.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	I
Cornus mas		.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Sorbus domestica		.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	I
Potentilla micrantha	C	.	.	.	+	+	.	1	+	+	+	+	+	+	+	1	+	IV
Fraxinus ornus		.	+	.	1	1	.	1	.	+	+	+	1	.	.	.	.	III
Campanula persicifolia		.	.	.	.	.	.	.	.	+	+	+	+	.	.	+	+	II
Sorbus torminalis		+	+	.	.	.	+	.	.	.	.	.	.	1	.	.	.	II
Melittis melissophyllum		.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.	I
Lathyrus niger		.	.	.	.	.	.	+	.	.	+	.	.	.	.	1	.	I
Convallaria majalis		.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	I
Querco-Fagetea																		
Quercus petraea	A	5	5	5	+	5	4	4	5	4	5	4	4	5	5	5	5	V
Tilia tomentosa		.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	I
Tilia tomentosa	B	.	.	.	.	.	.	+	.	+	1	.	.	+	1	1	.	II
Quercus petraea		.	+	+	.	+	.	.	.	.	.	.	.	.	.	+	.	II
Acer campestre		+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Crataegus monogyna		+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Corylus avellana		+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Tilia cordata		.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Quercus petraea	C	+	1	+	+	+	1	+	.	1	1	1	.	+	+	.	.	V
Cephalanthera longifolia		+	.	+	+	1	+	+	.	.	.	.	+	.	+	+	1	IV
Dactylis glomerata ssp. *aschersoniana / D. glomerata*		.	.	.	.	.	+	1	.	.	+	.	.	.	2	+	1	II
Cruciata glabra		+	+	.	.	1	.	.	.	.	+	.	.	.	.	.	.	II
Acer campestre		.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	I
Platanthera bifolia		.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I
Tilia tomentosa		.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	I
Galium schultesii		.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	I
Other species																		
Robinia pseudoacacia	B	.	.	.	.	.	.	1	.	.	.	+	.	.	.	.	.	I
Juniperus communis		.	.	.	+	.	.	+	+	+	.	.	.	.	.	.	.	II
Veronica chamaedrys	C	.	.	+	+	+	+	+	+	+	+	+	.	+	.	1	+	IV
Hypericum perforatum		.	.	+	+	.	.	+	+	+	.	+	+	1	+	+	+	IV
Rubus hirtus		1	+	+	+	+	.	.	.	.	.	+	+	+	.	.	+	III
Viola alba		+	.	.	+	+	.	.	.	.	+	.	.	.	+	+	+	III
Erigeron annuus		.	.	.	+	+	.	+	+	.	.	.	+	+	.	+	.	III
Dianthus armeria		.	.	.	.	.	1	+	.	+	.	.	.	+	.	+	+	II
Silene viridiflora		.	.	.	.	.	.	1	.	+	.	.	.	.	.	.	.	I
Calystegia sepium		.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	I
Carex flacca		+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	I
Ajuga reptans		.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	I
Cardaminopsis arenosa		.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I
Carex sp.		.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I
Campanula sp.		.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	I
Clinopodium vulgare		.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	I
Campanula patula		.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	I

Number of relevé		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Gentiana asclepiadea		.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	I
Silene viscosa		.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	I
Verbena officinalis		.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	I
Mosses																		
Polytrichum formosum	D	.	+	+	+	.	1	+	2	+	1	1	1	+	+	1	+	V
Leucobryum glaucum		.	+	.	.	+	.	.	+	+	+	.	.	+	+	1	.	III
Dicranella heteromalla		.	.	.	+	+	1	.	1	+	.	+	1	.	.	+	.	III
Hypnum cupressiforme		+	+	+	.	.	+	.	1	.	.	.	+	.	.	.	+	III
Atrichum undulatum		+	.	+	.	.	+	.	+	.	.	.	+	.	+	.	.	II
Diphyscium foliosum		.	.	.	+	+	+	.	.	.	.	+	+	.	.	+	.	II
Brachythecium velutinum		.	.	.	+	.	+	.	.	.	.	.	.	.	.	+	.	I
Eurhynchium sp.		.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	I
Hypnum sp.		.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	I

A – tree layer, B – shrub layer, C – layer of ground vegetation, D – layer of moss

Table 2: Comparison of association *Potentillo micranthae-Quercetum petraeae* with related associations of order *Quercetalia robori-petraeae*.
Tabela 2: Primerjava asocicije *Potentillo micranthae-Quercetum petraeae* s sorodnimi asocicijami reda *Quercetalia robori-petraeae.*

Number of column		1	2	3	4	5
Number of species*		75	134	118	97	87
Number of relevés		16	25	13	20	19
		Percentage frequencies				
a *Genista tinctoria*	B	**94**	.	46	60	32
Chamaecytisus hirsutus		**81**	.	23	30	.
c *Galium sylvaticum*	C	**81**	.	23	**90**	11
f *Hypericum perforatum*		**69**	20	.	.	16
e *Cephalanthera longifolia*		**63**	8	.	30	.
f *Dianthus armeria*		**38**	.	.	.	.
Erigeron annuus		**44**	.	.	.	.
Viola alba		**44**	24	.	.	.
a *Dicranella heteromalla*	D	**50**	.	.	.	.
d *Sorbus torminalis*	A	**13**	**24**	.	.	.
e *Tilia tomentosa*		**6**	**8**	.	.	.
d *Sorbus torminalis*	B	**100**	**72**	23	25	.
e *Tilia tomentosa*		**38**	**60**	.	.	.
d *Potentilla micrantha*	C	**75**	**68**	.	30	.
a *Luzula forsteri*		**56**	**68**	.	.	.
d *Sorbus torminalis*		**25**	**76**	.	.	.
e *Tilia tomentosa*		**6**	**60**	.	.	.
b *Festuca drymeia*		**100**	28	**100**	15	.
a *Pteridium aquilinum*		**94**	.	**77**	40	58
c *Prunus avium*	A	.	**16**	.	.	.
e *Pyrus pyraster*		.	**12**	.	.	.
c *Prunus avium*	B	.	**60**	15	20	.
e *Crataegus monogyna*		6	**44**	.	.	16
Pyrus pyraster		.	**64**	8	.	.
Rosa canina		.	**40**	.	.	21
d *Sorbus domestica*		6	**24**	.	.	.
e *Ligustrum vulgare*		.	**24**	.	.	.
a *Veronica officinalis*	C	56	**84**	23	.	21

Number of column		1	2	3	4	5
Number of species*		75	134	118	97	87
Number of relevés		16	25	13	20	19
e *Poa nemoralis*		.	**92**	23	35	.
Melica uniflora		.	**88**	46	25	.
c *Symphytum tuberosum*		.	**80**	8	35	.
Prunus avium		31	**60**	.	.	.
f *Galium mollugo*		.	**60**	15	.	.
e *Galium schultesii*		6	**32**	.	.	.
Pyrus pyraster		.	**64**	.	.	.
Carex digitata		.	**44**	.	.	.
Crataegus monogyna		.	**44**	.	.	.
Rosa canina		.	**40**	.	.	.
Hepatica nobilis		.	**28**	.	.	.
f *Luzula campestris*		.	**28**	.	.	.
a *Hieracium lachenalii*		.	**24**	.	.	.
Lembotropis nigricans	B	.	**44**	**38**	**35**	**47**
d *Chamaecytisus supinus*		.	**68**	**8**	**45**	**95**
a *Melampyrum pratense*	C	13	**72**	**31**	**90**	**95**
Solidago virgaurea		.	**44**	**23**	**55**	**74**
Hieracium sabaudum		.	**20**	**23**	**45**	**89**
Genista tinctoria ssp. *ovata*	B	.	**40**	**31**	.	.
c *Carex pilosa*	C	.	**92**	**69**	.	.
f *Ajuga reptans*		6	**44**	**38**	.	.
d *Hypericum montanum*		.	**44**	**23**	15	.
e *Hedera helix*		.	**36**	**23**	5	.
c *Viola reichenbachiana*		.	**52**	**46**	.	37
Mycelis muralis		13	36	**54**	.	.
Galium odoratum		13	20	**46**	.	.
Dryopteris filix-mas	C	13	.	**54**	10	.
Brachypodium sylvaticum		.	8	**38**	10	.
Euphorbia amygdaloides		.	28	**69**	.	.

Number of column			1	2	3	4	5
Number of species*			75	134	118	97	87
Number of relevés			16	25	13	20	19
	Sanicula europaea		.	12	**31**	.	.
f	*Luzula pilosa*		.	.	**62**	5	.
b	*Cyclamen purpurascens*		.	.	**38**	15	.
c	*Carex sylvatica*		.	.	**38**	.	.
a	*Hieracium praecurrens*		.	.	**38**	.	.
f	*Circaea lutetiana*		.	.	**38**	.	.
	Cruciata laevipes		.	.	**31**	.	.
c	*Salvia glutinosa*		.	.	**31**	.	.
b	*Polystichum setiferum*		.	.	**23**	.	.
c	*Asarum europaeum*		.	.	**23**	.	.
f	*Viola hirta*		.	.	**23**	.	.
b	*Omphalodes verna*		.	.	**23**	.	.
f	*Senecio sylvaticus*		.	.	**23**	.	.
c	*Cephalanthera damasonium*		.	.	**23**	**25**	.
d	*Melittis melissophyllum*		19	.	**23**	**30**	.
	Sorbus aria	A	.	.	.	**25**	.
	Tanacetum corymbosum	C	.	16	15	**70**	26
e	*Cruciata glabra*		25	.	23	**65**	16
a	*Hieracium umbellatum*		.	.	23	**40**	.
	Lathyrus linifolius		.	.	.	**35**	5
c	*Euphorbia dulcis*		.	.	15	**35**	.
b	*Knautia drymeia*		.	.	.	**25**	.
f	*Achillea distans*		.	.	.	**30**	.
a	*Genista germanica*	B	.	12	.	**30**	**74**
f	*Vaccinium myrtillus*		.	.	.	**35**	**42**
d	*Convallaria majalis*	C	6	32	23	**50**	**53**
f	*Calamagrostis arundinacea*		.	.	8	**55**	**58**
	Molinia caerulea ssp. *arundinacea*		.	.	8	**25**	**26**
a	*Calluna vulgaris*		.	.	15	**25**	**95**
	Deschampsia flexuosa		.	.	.	**35**	**89**
c	*Prenanthes purpurea*		.	.	.	**45**	**32**
e	*Juniperus communis*	B	25	16	15	10	**89**
	Genista pilosa		.	16	.	.	**42**
f	*Frangula alnus*		.	.	15	.	**37**
e	*Anemone nemorosa*	C	.	.	23	5	**42**
a	*Potentilla erecta*		.	.	.	.	**68**
	Chamaespartium sagittale		.	.	.	.	**32**
d	*Silene italica*		.	.	.	.	**42**
	Phyteuma zahlbruckneri		.	.	.	.	**37**
	Betonica officinalis ssp. *serotina*		.	.	.	.	**26**
f	*Pleurozium schreberi*	D	.	.	.	.	**47**
a	***Quercetalia robori-petraeae***						
	Castanea sativa	A	38	4	15	40	26
	Castanea sativa	B	94	20	31	85	68
	Hieracium murorum	C	38	100	62	70	79
	Luzula luzuloides		94	100	46	100	89
	Hieracium racemosum		94	88	38	95	100
	Festuca heterophylla		88	76	69	80	63
	Serratula tinctoria		6	16	15	30	5
	Hieracium bauhinii		6	12	.	.	.
	Castanea sativa		.	20	23	45	11
	Polypodium vulgare		.	4	8	20	5

Number of column			1	2	3	4	5
Number of species*			75	134	118	97	87
Number of relevés			16	25	13	20	19
	Agrostis capillaris		.	.	.	.	21
b	***Aremonio-Fagion***						
	Ruscus hypoglossum	C	25	16	38	.	.
	Tamus communis		.	8	15	.	.
	Helleborus odorus		.	20	.	.	.
c	***Fagetalia***						
	Fagus sylvatica	A	56	92	38	30	16
	Tilia platyphyllos		.	.	.	5	.
	Fagus sylvatica	B	81	96	46	65	53
	Tilia cordata		6	20	23	.	.
	Acer platanoides		.	16	15	10	.
	Acer pseudoplatanus		.	16	23	30	.
	Rosa arvensis		.	24	.	5	.
	Tilia platyphyllos		.	.	.	15	.
	Lathyrus vernus	C	25	36	31	30	.
	Cardamine bulbifera		19	24	31	15	.
	Pulmonaria officinalis		6	4	31	10	.
	Polygonatum multiflorum		.	28	15	20	16
	Fagus sylvatica		25	96	.	10	.
	Primula vulgaris		.	8	23	10	.
	Moehringia trinervia		.	16	23	.	.
	Scrophularia nodosa		.	.	15	15	.
	Mercurialis perennis		.	.	23	5	.
	Tilia cordata		.	20	.	.	.
	Athyrium filix-femina		.	.	23	.	.
	Acer pseudoplatanus		.	.	.	20	.
d	***Quercetalia pubescentis***						
	Fraxinus ornus	A	31	48	31	15	.
	Quercus cerris		.	60	.	.	63
	Fraxinus ornus	B	100	100	38	75	47
	Cornus mas		6	28	15	.	.
	Malus sylvestris		.	8	8	.	.
	Quercus cerris		.	36	.	.	37
	Euonymus verrucosus		.	20	.	.	.
	Lathyrus niger	C	19	20	62	70	63
	Campanula persicifolia	C	38	96	8	11	70
	Fraxinus ornus		50	100	.	45	.
	Vincetoxicum hirundinaria		.	8	15	.	.
	Anthericum ramosum		.	24	.	.	11
	Digitalis grandiflora		.	.	.	15	16
	Quercus cerris		.	64	.	.	.
	Cornus mas		.	28	.	.	.
	Euonymus verrucosus		.	20	.	.	.
	Carex montana		.	12	.	.	16
e	***Querco-Fagetea***						
	Quercus petraea	A	100	100	100	100	100
	Quercus petraea	B	25	84	46	75	100
	Acer campestre		13	16	8	.	.
	Corylus avellana		6	.	.	30	37

Number of column		1	2	3	4	5
Number of species*		75	134	118	97	87
Number of relevés		16	25	13	20	19
Cornus sanguinea		.	4	8	.	.
Clematis vitalba		.	20	.	.	.
Platanthera bifolia	C	6	28	15	20	16
Rubus hirtus		56	44	62	30	.
Dactylis glumerata ssp. *aschersoniana / D. glomerata*		38	80	54	40	.
Quercus petraea		81	100	.	90	21
Fragaria vesca		.	20	38	40	42
Acer campestre		6	16	.	.	.
Sedum telephium ssp. *maximum*		.	28	.	40	.
Epipactis helleborine		.	12	.	20	.
Fallopia dumetorum		.	20	.	.	.
Melittis melissophyllum ssp. *carpatica*		.	20	.	.	.
Neottia nidus-avis		.	20	.	.	.
f **Other species**						
Betula pendula	I/II	.	4	23	.	11
Pinus nigra		.	4	.	.	.
Abies alba	A	.	.	.	30	6
Picea abies		.	.	.	5	37
Pinus sylvestris		.	.	.	5	5
Robinia pseudacacia		.	.	23	.	.
Populus tremula		.	.	.	5	.
Robinia pseudacacia	B	13	.	15	.	.
Pinus sylvestris		.	4	.	.	21
Populus tremula		.	.	8	.	16
Veronica chamaedrys	C	75	20	23	45	37
Campanula patula		6	4	23	25	.

Number of column		1	2	3	4	5
Number of species*		75	134	118	97	87
Number of relevés		16	25	13	20	19
Gentiana asclepiadea		6	.	23	20	11
Silene viridiflora		13	32	.	.	.
Clinopodium vulgare		13	36	.	.	.
Lysimachia punctata		.	4	23	.	.
Prunella vulgaris		.	4	31	.	.
Lychnis viscaria		.	36	.	25	.
Alliaria petiolata		.	4	.	10	.
Achillea millefolium		.	4	.	.	16
Trifolium montanum		.	4	.	.	11
Dianthus barbatus		.	.	15	20	.
Aposeris foetida		.	.	15	15	.
Pinus nigra		.	8	.	.	.
Glechoma hirsuta		.	.	23	.	.
Vicia sepium		.	.	.	20	.
Thymus serpyllum		.	.	.	.	26
Dianthus monspessulanus		.	.	.	.	26
Anthoxanthum odoratum		.	.	.	.	21
Mosses						
Atrichum undulatum	D	38	.	.	.	47
Brachythecium velutinum		19	.	38	.	.
Dicranum scoparium		.	.	.	20	11
Diphyscium foliosum		38	.	.	.	.
Hypnum cupressiforme		44	.	.	20	95
Leucobryum glaucum		50	.	23	15	79
Polytrichum formosum		88	.	38	50	84
Cladonia pyxidata		.	.	.	.	16
Thuidium tamariscinum		.	.	.	.	21

A – tree layer, B – shrub layer, C – layer of ground vegetation, D – layer of moss
a-f – sinsystematic affiliation

Assocations:
1. *Potentillo micranthae-Quercetum petraeae*, Vukelić et al., Zrinska gora (Croatia) hoc loco
2. *Luzulo forsteri-Quercetum petraeae*, Kevey et Borhidi 1995, Mescek (Hungary)
3. *Festuco drymeiae-Quercetum petraeae*, Hruška Dell' Uomo 1974, Moslovačka gora (Croatia)
4. *Hieracio racemosi-Quercetum petraeae*, Vukelić 1991, NW Croatia
5. *Melampyro vulgati-Quercetum petraeae "submediterraneum"*, Puncer et Zupančič 1979, Brkini (Slovenia)

*The table excludes species that are represented in one column, up to 20%

Table 3: Average Ellenberg index values for the selected ecological factors.
Tabela 3: Povprečne indikatorske Ellenbergove vrednosti za izbrane ekološke faktorje.

Breakdown Table of Descriptive Statistics N=93 (No missing data in dep. var. list).

Association	Light	Temperature	Continentality	Moisture	Soil Reaction	Nutrients	N
			Means				
Hr-Q	5,22	**6,00**	3,52	4,55	5,33	3,66	20
Lf-Q	4,91	6,10	**3,57**	4,42	6,20	4,07	25
Fd-Q	**4,72**	**5,76**	3,44	**4,86**	5,97	**4,70**	13
Pm-Q	*5,21*	*6,30*	*3,41*	*4,49*	*5,83*	*3,84*	*16*
Mp-Q	**5,73**	**5,87**	**3,66**	4,37	**4,27**	**3,05**	19
All Groups	5,17	**6,02**	3,53	4,51	5,52	3,82	93