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# Ecological and phytosociological characteristics of the association *Abieti-Fagetum »pannonicum«* Rauš 1969 prov. on Mt. Medvednica (NW Croatia)

IVA DOBROVIĆ[1*], TONI SAFNER[2], SVEN D. JELASKA[3], TONI NIKOLIĆ[1]

[1] Department of Botany, Faculty of Science, University of Zagreb, Marulićev trg 20/2, HR-10000 Zagreb, Croatia

[2] Department of Plant breeding, Genetics and Biometrics, Faculty of Agriculture, University of Zagreb, Svetošimunska 25, HR-10000 Zagreb, Croatia

[3] Oikon d.o.o. – Institute for Applied Ecology, Vlade Prekrata 20, HR-10020 Zagreb, Croatia

The association *Abieti-Fagetum »pannonicum«* Rauš 1969 prov. has an invalid name and a still undefined position in a geobotanical and phytosociological sense. In 2000 and 2001 the flora and different habitat factors of 12 plots (50 x 50 m), within the association *Abieti-Fagetum* s. l. on the central part of Medvednica mountain, were investigated. In all, 119 taxa of vascular plants were recorded. The life form analysis confirmed that Medvednica flora belongs to the moderate continental climate. Canonical correspondence analysis has showed that changes in altitude, pH and inclination have the strongest influence on changes in floristic structure.

**Key words:** vegetation, forest, *Abieti-Fagetum*, CCA, Medvednica, Croatia, phytosociology

## Introduction

Fir-beech forests in Croatia are classified within the alliance *Aremonio-Fagion* (Ht. 1938) Borhidi in Török et al. 1989 (order *Fagetalia sylvaticae* Pawl. 1928, class *Querco-Fagetea* Br.-Bl. et Vlieger 1937). They are mostly distributed in the Dinaric area (surface of ca 130 000 ha), while in the northern, Pannonian, parts of Croatia they cover only 15 000 ha (VUKELIĆ and BARIČEVIĆ 1996, VUKELIĆ and RAUŠ 1998, FRANJIĆ et al. 2001). Some authors estimate that in the Dinaric region these forests are spread over a larger area of 300 000 ha (JELASKA et al. 2005). These two areas differ in climatological, geological and edaphic characteristics, causing in turn differences in floristic and vegetational structure. Dinaric fir-beech forests have been already evaluated (HORVAT 1938, BERTOVIĆ et al. 1966, TRINAJSTIĆ 1970, 1972a, b, PUNCER et al. 1974, PRPIĆ 1979, PUNCER 1980, RAUŠ 1984, VUKELIĆ

* Corresponding author, e-mail: idobro@botanic.hr

1985, ZUPANČIČ and PUNCER 1995, RAUŠ et al. 1996, ACCETTO 1998, MARINČEK and KOŠIR 1998, DAKSKOBLER et al. 2000, ACCETTO 2002, SURINA 2002, JELASKA 2004, JELASKA et al. 2005) and their geobotanical and phytosociological status is clear with the valid name of *Omphalodo-Fagetum* (Tregubov 1957 corr. Puncer 1980) Marinček et al. 1993 (MARINČEK et al. 1992, SURINA 2002). These forests are floristically rich with well developed Illyrian and South-European floral elements (VUKELIĆ and BARIČEVIĆ 1996, FRANJIĆ et al. 2001, SURINA 2002). On the other hand, Pannonian fir-beech forests have rarely been studied (MEDVEDOVIĆ 1991, VUKELIĆ and ŠPANJOL 1990) and their position in geobotanical and phytosociological sense is still undefined. Most authors refer to them with the invalid name of *Abieti-Fagetum »pannonicum«* Rauš 1969 prov. (=*Fagetum croaticum abietetosum boreale* Ht. 1938). Compared to the Dinaric, Pannonian forests are floristically poor in char acteristic and differential Illyricoid species (TRINAJSTIĆ 1992, VUKELIĆ and BARIČEVIĆ 1996, FRANJIĆ et al. 2001).

Mt. Medvednica is situated in the continental part of Croatia (Fig. 1), north of Zagreb. It streches between 15°49'45" and 16°07'45" east longitude and 45°49'00" and 45°59'00" north latitude, in a SW to NE direction, approximately 40 km in length and 9 km in width. The highest peak of Sljeme at 1035 m is in the centre of the massif. The geological structure of the mountain is characterized by the domination of slates, marls, eruptives and sporadically limestone. The soils formed on that silicate bedrock are rather acid with pH 4–5 (MEDVEDOVIĆ 1991). From a climatic point of view, the mountain has moderate continental climate, with a rainfall of 1238 mm/y and a maximum precipitation from May to July. Continuous snow-bed lasts about 62 days, and the number of sunny hours comes to 1999 per year (BÖHM et al. 1979).

The mountain stands out with its developed relief, geological structure, climatological and hydrological conditions and biodiversity of flora and fauna. In 1981, according to the Nature Protection Act, the western part of Medvednica massif was declared a Nature Park. The Park covers an area of 228.26 km$^2$ out of which approx 10 km$^2$ belong to eight special reserves of forest vegetation. It is mostly covered by forest (63,6%), while the rest is grasslands, cultivated ground, settlements and roads (BÖHM et al. 1979). Floristic research took place on the central part of Medvednica Nature Park, both on the northern and southern slopes of the mountain. Twelve plots were investigated in the area of the association *Abieti-Fagetum* s. l. in an altitude range from 600 to 950 m a.s.l. (Fig. 1). The whole of the area surveyed belongs to the Illyrian province of Euro-Siberian-North American forest region (European beech forests subregion). In the phytogeographical sense the Medvednica massif is divided into two different vegetational belts: European-colline vegetational belt and European-montane vegetational belt. In the montane belt two well developed types of forests can be found: beech forests, *Lamio orvale-Fagetum sylvaticae* (Ht. 1938) Borhidi 1963, and fir-beech forests, *Abieti-Fagetum »pannonicum»* Rauš 1969 prov. (=*Fagetum croaticum abietetosum boreale* Ht. 1938) (BÖHM et al. 1979, TRINAJSTIĆ 1995, VUKELIĆ and RAUŠ 1998).

The oldest floristic data regarding this area originate from 1861 when VON KLINGGRÄFF studied the flora of Zagreb region. Hitherto on Mt. Medvednica botanists have been investigating different systematic groups (STRINEKA 1929, HRŠAK et al. 1999, SOČO et al. 2002, CIGIĆ et al. 2003), vegetation (ŠARIĆ 1902, FORENBACHER 1908, MEDVEDOVIĆ 1991) or flora (HULINA 1994, JELASKA et al. 2003). The complete flora of Medvednica Nature Park is in preparation for publication.

The aims of this paper were to determine the floristic structure of fir-beech forests on Mt. Medvednica and its dependence on different habitat factors, in order to give new insights that will contribute to the differentiation and nomenclature of the synsystematic revision of this forest association.

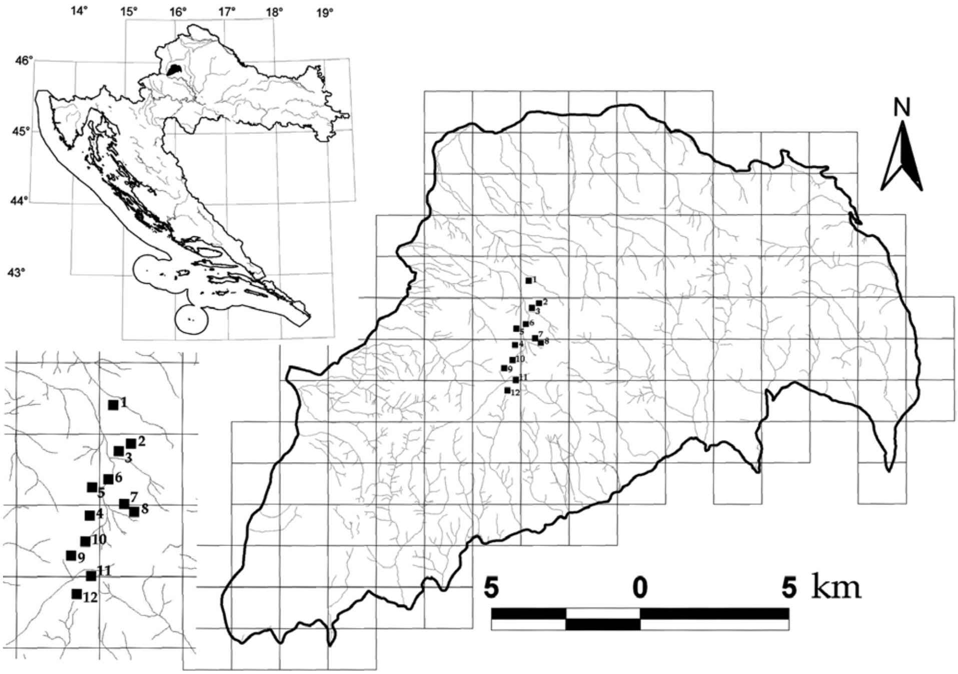


**Fig. 1.** The position of Medvednica Nature Park in Croatia and the position of the researched plots in Medvednica Nature Park.

## Materials and methods

The fieldwork was carried out in 2000 and 2001 fitting all seasons. Twelve plots (50 x 50 m) were chosen in the area of the association *Abieti-Fagetum* s. l. in range from 600 to 950 m a.s.l., both on the northern and southern slopes of the central part of Medvednica mountain.

Data on the floristic composition of the stands, altitude, inclination and aspect of the investigated plots, their soil acidity, canopy closure and geographical position were gathered. The positions of the plots were geo-referenced with the Magellan 2000 GPS (Global Positioning System) device. The canopy closure was expressed in percent of crowns covering the sky above the investigated surface (HORVAT 1949:43). The soil samples were diagonally collected within the plots as described in SCHOLZ et al. (1994). The pH value was measured in a water solution and in 0.1 mol $dm^{-3}$ KCl (ŠKORIĆ 1982) using the Hanna Checker glass electrode. The relevés were sampled and elaborated by the standard central European method (BRAUN-BLANQUET 1964). The system of the multi-dimensional subdivision of vegetation units was accepted from HORVAT (1962) and SURINA (2002). The nomenclature of ferns and phanerogams follows *Index florae Croaticae* (NIKOLIĆ 1994, 1997, 2000). Mosses were excluded from this research. The plant life form spectrum is according to HORVAT (1949).

Pearson's correlation coefficient was calculated for all pairs of habitat variables. The correlation between variables pH ($H_2O$) and pH (KCl) was very high ($r = 0.952$; $p<0.0001$), so the latter was excluded from further analysis. The pH (KCl) value was measured to determine how the different water amounts in the soil influence the pH value. All soil samples showed the same relative decrease of pH value in 0.1 mol $dm^{-3}$ KCl as in the water, as expected. The species *Cyclamen purpurascens* has the same cover-abundance index for all plots, so it was kept out of the analysis as well. Because of its circular nature, terrain aspect was transformed into a continuous north-south gradient (northness) by calculating the cosine of aspect values (GUISAN et al. 1999) and increased by 1 to avoid negative values obtaining the range from zero to two.

CANOCO 4.02 for Windows was used for ordination statistical analysis. Before the processing abundance-cover values were transformed into an ordinal scale (VAN DER MAAREL 1979). The influence of habitat factors on the floristic variability of the plots was estimated by canonical correspondence analysis (CCA) (TER BRAAK 1986, 1987).

## Results

On Mt. Medvednica the association *Abieti-Fagetum »pannonicum«* Rauš 1969 prov. is developed in the zone between ca 600–1000 m a.s.l., on the relatively steep surface with acid soil reaction, on both the northern and southern slopes of the mountain. In all, 119 taxa of vascular plants were recorded within twelve investigated plots. Floristic composition as well as the different habitat information regarding the plots researched is shown in the table 1.

Within the tree layer the most frequent species are silver fir (*Abies alba*) and beech (*Fagus sylvatica*) that are at the same time the edifying species that determine the appearance of the association. Other important tree species include *Acer pseudoplatanus*, *A. platanoides*, *Ulmus glabra* and *Fraxinus excelsior.* The shrub layer is dominated by the *Rubus* species, mountain ash (*Sorbus aucuparia*), hazel (*Corylus avellana*) and spurge laurel (*Daphne laureola*). The ground vegetation abounds in different ferns (*Dryopteris filix-mas*, *Athyrium filix-femina*, *Polystichum setiferum* etc.), grasses (*Festuca drymeja*,

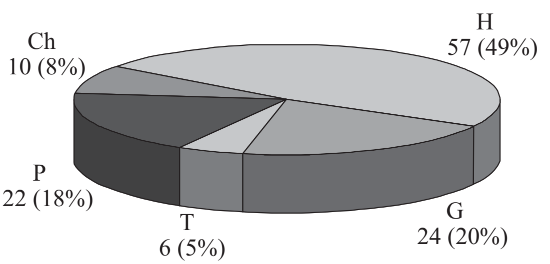


**Fig. 2.** Plant life form spectrum of the association *Abieti-Fagetum* s. l. on Mt. Medvednica (Ch – *Chamaephyta*; G – *Geophyta*; H – *Hemicryptophyta*; P – *Phanerophyta*; T – *Therophyta*).

**Tab. 1.** Analytical table of the association *Abieti-Fagetum »pannonicum«* Rauš 1969 prov. on Mt. Medvednica.

| Number | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | Presence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Altitude (in m) | | 650 | 600 | 650 | 800 | 700 | 700 | 830 | 860 | 950 | 920 | 870 | 820 | |
| Aspect | | S | NNE | NNW | WSW | W | NNW | W | W | NNW | WNW | ESE | SW | |
| Inclination (in °) | | 27 | 36 | 35 | 32 | 29 | 28 | 38 | 25 | 35 | 39 | 21 | 36 | |
| Canopy closure (in %) | | 70 | 55 | 50 | 85 | 65 | 90 | 85 | 65 | 80 | 90 | 60 | 65 | |
| pH value in water solution | | 5.65 | 4.81 | 5.26 | 4.79 | 5.09 | 5.45 | 4.81 | 4.98 | 5.1 | 4.81 | 5.37 | 4.66 | |
| pH value in 0,1 mol/dm$^3$ KCl | | 4.8 | 3.82 | 4.48 | 3.93 | 4.14 | 4.45 | 3.89 | 3.87 | 4.03 | 3.91 | 4.34 | 3.80 | |
| Number of species | | 48 | 44 | 43 | 45 | 60 | 40 | 32 | 46 | 43 | 40 | 54 | 37 | |
| **Edifying species of the association *Abieti-Fagetum »pannonicum«*** Rauš 1969 prov. | | | | | | | | | | | | | | |
| *Fagus sylvatica* | A | 3 | 1 | 2 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 12 |
| *Abies alba* | A | 3 | 2 | 2 | 1 | 3 | 1 | 2 | 3 | + | 1 | 1 | 1 | 12 |
| ***Aremonio-Fagion*** (Ht. 1938) Borhidi in Török et al. 1989 | | | | | | | | | | | | | | |
| *Cyclamen purpurascens* | C | + | + | + | + | + | + | + | + | + | + | + | + | 12 |
| *Polystichum setiferum* | C | + | 1 | + | 1 | 1 | 1 | + | + | + | + | + | · | 11 |
| *Cardamine trifolia* | C | · | · | 1 | 2 | + | 1 | + | 1 | + | 1 | · | · | 8 |
| *Cardamine enneaphyllos* | C | + | + | · | + | + | + | · | + | · | · | 1 | + | 8 |
| *Festuca drymeja* | C | 2 | + | 3 | + | · | · | 3 | 2 | · | 2 | · | · | 7 |
| *Lamium orvala* | C | 1 | 1 | + | · | + | · | · | · | · | · | + | · | 5 |
| *Ruscus hypoglossum* | C | + | · | + | · | + | + | · | + | · | · | · | · | 5 |
| *Daphne laureola* | B | + | + | · | · | + | + | · | · | · | · | · | · | 4 |
| *Cardamine waldsteinii* | C | · | · | · | · | · | · | · | · | + | · | 4 | · | 2 |
| *Aremonia agrimonoides* | C | · | · | · | + | · | · | · | · | + | · | · | · | 2 |
| ***Fagetalia sylvaticae*** Pawlowski 1928 | | | | | | | | | | | | | | |
| *Fagus sylvatica* | A | 3 | 1 | 2 | 4 | 2 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 12 |
| *Galium odoratum* | C | 1 | + | + | 2 | 1 | 2 | + | + | 3 | + | 1 | + | 12 |
| *Cardamine bulbifera* | C | + | + | + | + | 1 | + | + | + | + | + | 1 | + | 12 |
| *Mycelis muralis* | C | + | + | + | + | 1 | + | + | + | + | + | + | + | 12 |
| *Sanicula europaea* | C | 1 | + | + | + | + | 1 | + | + | · | + | + | · | 10 |
| *Prenanthes purpurea* | C | · | + | + | + | + | + | + | + | + | + | · | + | 10 |
| *Lunaria rediviva* | C | · | · | 1 | 2 | 2 | 2 | · | + | 4 | 1 | 3 | + | 9 |

**Tab. 1.** – continued

| Number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Pres-ence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Fraxinus excelsior* | B | · | · | + | + | 1 | + | + | · | + | · | 1 | + | 8 |
| *Circaea lutetiana* | C | + | · | · | + | + | + | · | + | + | + | + | · | 8 |
| *Lamium galeobdolon* | C | + | + | + | + | + | + | · | · | + | · | + | · | 8 |
| *Acer pseudoplatanus* | A | · | 1 | · | + | · | + | · | + | 2 | · | + | 1 | 7 |
| *Polygonatum multiflorum* | C | + | + | · | · | + | + | · | · | + | · | + | + | 7 |
| *Mercurialis perennis* | C | 1 | + | · | + | · | + | · | · | · | + | + | · | 6 |
| *Adoxa moschatellina* | C | + | · | · | + | + | + | · | · | + | · | + | · | 6 |
| *Acer platanoides* | B | · | · | · | + | · | + | · | · | + | · | + | + | 5 |
| *Epilobium montanum* | C | + | · | · | + | + | · | · | · | + | + | · | · | 5 |
| *Impatiens noli-tangere* | C | · | · | · | + | + | · | · | + | + | · | + | · | 5 |
| *Sambucus nigra* | B | · | + | + | + | + | · | · | · | · | · | · | + | 5 |
| *Scrophularia nodosa* | C | · | · | + | · | · | · | · | + | + | + | + | · | 5 |
| *Ulmus glabra* | B | · | + | · | + | · | + | · | · | · | · | + | + | 5 |
| *Urtica dioica* | C | · | · | · | + | + | + | · | · | + | · | + | · | 5 |
| *Acer pseudoplatanus* | B | · | · | + | · | 1 | · | + | · | · | 1 | · | · | 4 |
| *Actaea spicata* | C | · | + | · | · | + | + | · | · | · | · | + | · | 4 |
| *Paris quadrifolia* | C | · | · | + | · | + | · | · | · | · | + | + | · | 4 |
| *Viola reichenbachiana* | C | + | · | · | · | + | + | · | · | · | + | · | · | 4 |
| *Glechoma hirsuta* | C | · | · | · | + | · | · | · | · | · | + | 2 | · | 3 |
| *Fraxinus excelsior* | A | · | · | · | + | · | · | · | + | · | 1 | · | · | 3 |
| *Aruncus dioicus* | C | · | · | · | · | · | · | + | · | + | + | · | · | 3 |
| *Pulmonaria officinalis* | C | + | · | · | · | · | + | · | · | · | · | + | · | 3 |
| *Salvia glutinosa* | C | · | + | · | · | + | + | · | · | · | · | · | · | 3 |
| *Fagus sylvatica* | B | · | + | · | · | · | · | · | · | · | · | · | 1 | 2 |
| *Acer platanoides* | A | · | · | · | · | · | + | · | · | + | · | · | · | 2 |
| *Cardamine impatiens* | C | + | · | · | · | + | · | · | · | · | · | · | · | 2 |
| *Carex pendula* | C | · | · | · | · | + | · | · | + | · | · | · | · | 2 |
| *Carex sylvatica* | C | · | · | + | · | + | · | · | · | · | · | · | · | 2 |
| *Euphorbia amygdaloides* | C | + | · | · | · | · | · | · | · | · | · | + | · | 2 |
| *Ilex aquifolium* | B | + | + | · | · | · | · | · | · | · | · | · | · | 2 |
| *Neottia nidus-avis* | C | · | · | · | · | + | · | + | · | · | · | · | · | 2 |

**Tab. 1.** – continued

| Number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Presence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Phyteuma spicatum* | C | · | · | · | · | · | · | · | + | · | + | · | · | 2 |
| *Ranunculus lanuginosus* | C | · | · | · | · | + | · | · | · | + | · | · | · | 2 |
| *Stachys sylvatica* | C | · | · | · | · | + | · | · | + | · | · | · | · | 2 |
| *Ulmus glabra* | A | · | · | · | · | + | · | · | · | + | · | · | · | 2 |
| *Veronica montana* | C | · | · | · | · | · | · | · | · | + | + | · | · | 2 |
| *Corydalis bulbosa* | C | · | · | · | · | · | · | · | · | · | · | 2 | · | 1 |
| *Laburnum alpinum* | B | · | · | · | · | · | · | · | · | · | · | · | 2 | 1 |
| *Leucojum vernum* | C | · | · | · | · | · | · | · | · | · | · | 1 | · | 1 |
| *Allium ursinum* | C | · | · | · | · | · | + | · | · | · | · | · | · | 1 |
| *Asplenium scolopendrium* | C | · | · | · | · | · | + | · | · | · | · | · | · | 1 |
| *Cephalanthera longifolia* | C | + | · | · | · | · | · | · | · | · | · | · | · | 1 |
| *Corydalis solida* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Festuca gigantea* | C | · | · | · | · | + | · | · | · | · | · | · | · | 1 |
| *Heracleum sphondylium* | C | · | · | · | · | · | · | · | · | + | · | · | · | 1 |
| *Lilium martagon* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Polystichum aculeatum* | C | · | · | · | · | · | · | · | · | + | · | · | · | 1 |
| *Symphytum tuberosum* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Tilia cordata* | B | · | · | + | · | · | · | · | · | · | · | · | · | 1 |
| ***Quercetalia pubescentes*** Klika 1933 s. l. | | | | | | | | | | | | | | |
| *Fraxinus ornus* | A | + | · | · | · | · | · | · | · | · | · | · | · | 1 |
| ***Quercion robori-petraeae*** (Malcuit 1929) Br.-Bl. 1932. | | | | | | | | | | | | | | |
| *Castanea sativa* | B | · | · | · | · | · | · | · | · | · | · | · | + | 1 |
| ***Querco-Fagetea*** Br.-Bl. et Vlieg. 1937 s. l. | | | | | | | | | | | | | | |
| *Hedera helix* | C | + | + | + | + | 1 | 1 | + | + | + | + | · | · | 10 |
| *Corylus avellana* | B | + | 1 | 1 | + | + | · | + | + | · | · | + | + | 9 |
| *Platanthera bifolia* | C | + | · | + | + | + | · | · | · | · | · | + | + | 6 |
| *Moehringia trinervia* | C | + | · | + | · | + | · | · | · | · | · | + | · | 4 |
| *Veronica officinalis* | C | · | · | + | · | + | · | · | + | · | · | · | + | 4 |
| *Clematis vitalba* | C | + | · | · | · | + | + | · | · | · | · | · | · | 3 |

**Tab. 1.** – continued

| Number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Presence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Carex digitata* | C | + | · | · | · | · | · | + | · | · | · | · | · | 2 |
| *Pteridium aquilinum* | C | + | · | + | · | · | · | · | · | · | · | · | · | 2 |
| *Quercus petraea* | B | · | · | · | · | · | · | · | + | · | · | · | + | 2 |
| *Anemone nemorosa* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Euonymus latifolia* | C | · | · | · | · | + | · | · | · | · | · | · | · | 1 |
| *Galanthus nivalis* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| ***Vaccinio-Piceetea*** Br.-Bl. 1939 emend. Zupančič 1976 s. l. | | | | | | | | | | | | | | |
| *Abies alba* | A | 3 | 2 | 2 | 1 | 3 | 1 | 2 | 3 | + | 1 | 1 | 1 | 12 |
| *Abies alba* | B | + | 1 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 12 |
| *Rubus hirtus* | B | + | 4 | 3 | 1 | 2 | + | + | 2 | + | 1 | · | 1 | 11 |
| *Oxalis acetosella* | C | · | + | + | + | + | + | + | + | 1 | + | + | + | 11 |
| *Sorbus aucuparia* | B | + | + | 2 | + | + | · | + | + | · | + | · | · | 8 |
| *Galium rotundifolium* | C | + | + | + | · | + | + | + | + | · | · | + | · | 8 |
| *Viscum album* ssp. *abietis* | A | + | + | + | · | + | + | + | + | · | + | · | · | 8 |
| *Luzula luzuloides* | C | · | · | · | + | · | · | + | + | + | 1 | · | + | 6 |
| *Solidago virgaurea* | C | · | + | + | · | · | · | · | + | · | + | · | + | 5 |
| *Dryopteris dilatata* | C | · | + | + | + | · | · | · | + | · | · | · | · | 4 |
| *Gentiana asclepiadea* | C | · | · | · | · | · | · | · | + | + | + | · | + | 4 |
| *Hieracium rotundatum* | C | · | · | · | + | · | · | + | · | · | + | · | + | 4 |
| *Hieracium murorum* | C | · | + | · | + | + | · | · | · | · | · | · | · | 3 |
| *Calamagrostis arundinacea* | C | · | · | · | · | · | · | · | · | · | + | · | 3 | 2 |
| *Picea abies* | B | · | + | + | · | · | · | · | · | · | · | · | · | 2 |
| *Luzula sylvatica* | C | · | · | · | · | · | · | · | + | · | · | · | · | 1 |
| ***Adenostyletalia*** G. et J. Br.-Bl. 1931 s. l. | | | | | | | | | | | | | | |
| *Petasites albus* | C | + | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | + | 1 | 1 | 12 |
| *Senecio ovatus* | C | + | 1 | 1 | 1 | 2 | 1 | 1 | + | 1 | 1 | 1 | 1 | 12 |
| *Dryopteris filix-mas* | C | + | 1 | 1 | 1 | 1 | 1 | + | + | 2 | 1 | 1 | + | 12 |
| *Athyrium filix-femina* | C | · | 1 | 1 | 1 | + | + | + | 1 | 1 | 1 | + | + | 11 |
| *Rubus idaeus* | B | · | 1 | 2 | · | 1 | · | · | + | + | + | + | + | 8 |
| *Doronicum austriacum* | C | · | + | · | + | · | · | + | + | · | · | + | 1 | 6 |

**Tab. 1.** – continued

| Number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | Presence |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chrysosplenium alternifolium* | C | · | · | · | · | · | · | · | + | + | · | · | · | 2 |
| *Geranium robertianum* | C | + | · | · | · | + | · | · | · | · | · | · | · | 2 |
| *Milium effusum* | C | · | · | · | + | · | · | · | · | + | · | · | · | 2 |
| ***Asplenietea trichomanis*** Br.-Bl. in Meier et Br.-Bl. 1934 | | | | | | | | | | | | | | |
| *Asplenium trichomanes* | C | · | + | · | · | · | · | · | · | · | · | · | · | 1 |
| *Chelidonium majus* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| ***Atropetalia*** Vlieger 1937. | | | | | | | | | | | | | | |
| *Fragaria vesca* | C | + | · | · | + | + | · | + | + | · | + | + | + | 8 |
| *Atropa bella-donna* | C | + | + | · | · | · | · | · | · | · | · | · | · | 2 |
| *Eupatorium cannabinum* | C | + | + | · | · | · | · | · | + | · | · | · | + | 4 |
| **Other species** | | | | | | | | | | | | | | |
| *Anthriscus sylvestris* | C | · | · | · | · | + | · | · | · | + | · | + | · | 3 |
| *Galeopsis speciosa* | C | · | · | · | + | · | · | · | · | + | · | + | · | 3 |
| *Cardamine pratensis* | C | · | · | · | · | + | · | · | + | · | · | · | · | 2 |
| *Bromus ramosus* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Cirsium oleraceum* | C | · | + | · | · | · | · | · | · | · | · | · | · | 1 |
| *Geranium phaeum* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Hypericum perforatum* | C | · | · | · | · | + | · | · | · | · | · | · | · | 1 |
| *Logfia minima* | C | + | · | · | · | · | · | · | · | · | · | · | · | 1 |
| *Pinus strobus* | B | · | · | + | · | · | · | · | · | · | · | · | · | 1 |
| *Prunella vulgaris* | C | · | · | + | · | · | · | · | · | · | · | · | · | 1 |
| *Senecio vulgaris* | C | · | · | · | · | · | · | · | · | · | · | + | · | 1 |
| *Stachys germanica* | C | + | · | · | · | · | · | · | · | · | · | · | · | 1 |
| *Torilis japonica* | C | + | · | · | · | · | · | · | · | · | · | · | · | 1 |
| *Verbascum nigrum* | C | · | · | · | · | · | · | · | · | · | · | · | + | 1 |

Midpoints coordinates for plots 1-12:
1. lat. 45°55'50", long. 15°58'03"; 2. 45°55'22", 15°58'15"; 3. 45°55'18", 15°58'11"; 4. 45°54'39", 15°57'45"; 5. 45°54'52", 15°57'46"; 6. 45°54'57", 15°57'51"; 7. 45°54'46", 15°58'08"; 8. 45°54'43", 15°58'13"; 9. 45°54'16", 15°57'26"; 10. 45°54'26", 15°57'43"; 11. 45°54'00", 15°57'46"; 12. 45°53'51", 15°57'33".

*Calamagrostis arundinacea* etc.), bitter-cress (*Cardamine bulbifera*, *C. enneaphyllos*, *C. waldsteinii*), woodruff (*Galium odoratum*), baneberry (*Actaea spicata*), sanicle (*Sanicula europaea*), honesty (*Lunaria rediviva*), *Cyclamen purpurascens*, *Petasites albus*, *Mycelis muralis*, *Oxalis acetosella* and others.

Regarding the systematic categories most of the species belong to the *Fagetalia* order, while all the other groups are less represented.

The plant life form analysis showed the predomination of hemicryptophytes (49%), followed by geophytes (20%) and phanerophytes (18%) (Fig 2).

Summary of CCA (Tab. 2) shows that the first four canonical axes interpret 48.3% of species variability and 89.8% of species-environment relation. The first two axes both comprise 55.1% of species-environment relation, and are outlined in the biplot (Fig. 3). As can be seen from their vectors length, the changes in altitude, pH and inclination have the strongest influence on the changes of floristic structure. The first ordination axis is most influenced with inclination and soil acidity and the second with altitude.

**Tab. 2.** Summary of canonical correspondence analysis (CCA).

| Axes | 1 | 2 | 3 | 4 | Total inertia |
|---|---|---|---|---|---|
| Eigenvalues: | 0.221 | 0.220 | 0.146 | 0.133 | 1.490 |
| Species-environment correlations: | 0.925 | 0.949 | 0.952 | 0.942 | |
| Cumulative percentage variance of species data: | 14.9 | 29.6 | 39.4 | 48.3 | |
| of species-environment relation: | 27.6 | 55.1 | 73.2 | 89.8 | |

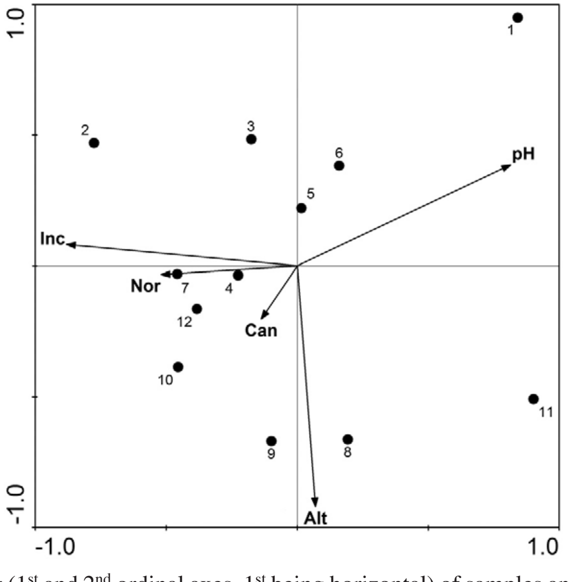


**Fig. 3.** CCA biplot (1st and 2nd ordinal axes, 1st being horizontal) of samples and environmental variables. pH-acidity, Inc-inclination, Nor-northness of aspect, Can-canopy closure, Alt-altitude.

## Discussion

The association *Abieti-Fagetum »pannonicum«* Rauš 1969 prov. has an invalid name and still undefined position in a geobotanical and phytosociological sense. Acidophilic fir-beech forests of thermophilic character and relatively poor floristic composition, between Sava and Drava river, have been classified as the association *Luzulo-Abietetum* Oberd. 1957 within alliance *Vaccinio-Piceeion* (TRINAJSTIĆ 1986). The same forests have been subsequently placed into a completely different systematisation (association *Luzulo--Abieti-Fagetum*, alliance *Luzulo-Fagion*, class *Quercetalia roboris-petraeae*) (BERTOVIĆ and LOVRIĆ 1987). After detailed research of the Pannonian fir-beech forests, MEDVEDOVIĆ (1991) retained the original, now invalid, syntaxonomy, as well as the name *Abieti-Fagetum »pannonicum«*. Resolving the syntaxonomic status of the investigated forest community was out of the scope of this paper. However, the results obtained give us a new contribution to the ecology of *Abieti-Fagetum »pannonicum«*. The large proportion and the dominance of the species of the *Fagetalia* order show that the researched association still comprises a certain amount of the Illyricoid species, but to a far lesser degree than the Dinaric fir-beech forests. The species of other systematic categories, such as of the class *Vaccinio-Piceetea*, the order *Quercetalia robori-petraeae* or *Quercetalia pubescentis*, are scarcer.

The lack of *Sorbus aucuparia* in relevés of Pannonian fir-beech forests (VUKELIĆ and ŠPANJOL 1990, MEDVEDOVIĆ 1991) led some authors to think of it as a differential species for Dinaric fir-beech forests (VUKELIĆ and BARIČEVIĆ 1996, VUKELIĆ and RAUŠ 1998). In our research it was noted at eight out of twelve plots (67%), so it can hardly be regarded as a differential species. Dinaric and Pannonian associations are distinguished on the basis of their different ecological and floristic characteristics, but the presence of the species *Sorbus aucuparia* is not one of the differences.

The species *Festuca drymeja*, *Carex pilosa* and *Luzula luzuloides* are incorrectly regarded as differential species for the Panonnian fir-beech forests (VUKELIĆ and BARIČEVIĆ 1996, VUKELIĆ and RAUŠ 1998). A new subassociation with *Festuca drymeja* was described by ACCETTO (1998) for the Dinaric fir-beech forests (*Omphalodo-Fagetum festucetosum drymejae*). The latter species has also been recorded in other relevés of Dinaric forests (SURINA 2002), so it does not present a good differential species for the Pannonian stands. The same applies to the species *Luzula luzuloides*, which often occurs in Dinaric stands (DAKSKOBLER et al. 2000, SURINA 2002), although in Pannonian fir-beech forests it is more frequent (VUKELIĆ and ŠPANJOL 1990, MEDVEDOVIĆ 1991). The only species that could be considered a differential species is *Carex pilosa*, because it has previously been recorded only in Pannonian stands (TRINAJSTIĆ 1972b, ACCETTO 1998, MEDVEDOVIĆ 1991, VUKELIĆ and ŠPANJOL 1990, DAKSKOBLER et al. 2000, SURINA 2002). However, during our research *Carex pilosa* has not been found at all, while *Festuca drymeja* and *Luzula luzuloides* were both found on more than 50% of the investigated plots.

The predomination of hemicryptophytes (49%), followed by geophytes (20%) and rather high percent of phanerophytes (18%) in the plant life form spectrum confirmed that the Medvednica flora is developed within the moderate continental climate (cf. WALTER 1960).

The canopy closure is an important factor in a forest community, because the total amount of the sunlight and atmospheric precipitation that reaches the herb layer is conditional upon it (HORVAT 1949:108). The denser the canopy closure gets, the more the amount of heliophytes should decrease. The typical heliophyte, *Rubus hirtus*, had cover-abundance indices 4 and 3 on the plots with smaller canopy closure (the plots 2 and 3), while on the other »darker« plots it was less present.

The species *Luzula luzuloides* and *Calamagrostis arundinacea* are known to be edaphic indicators of soil acidity (SURINA 2002). The species *Luzula luzuloides* is present only on plots with a pH value lower than 5.1. The species *Calamagrostis arundinacea* grows on plots with an acid soil reaction as well and it is densely spread (cover-abundance index 3) on plot 12 with the lowest pH value of 4.66.

The location of the plots on the biplot is correspondent with their habitat characteristics and floristic structure (Fig. 3). Plots with acid soil reaction (4, 7, 10 and 12), similar aspects and inclinations are located near each other on the graph. Stands 1 and 11 are located aside from all others because of their specific characteristics. Plot 1 is the only south-exposed site, at 650 m a.s.l., with 70% canopy closure that allows enough sunlight. The thermophilous species *Fraxinus ornus* was noted only on this location. Plot 11 is the least inclined plot (21°), with a rather high pH value (5.37) and early spring species grow only on this site, such as *Galanthus nivalis*, *Leucojum vernum*, *Corydalis bulbosa* etc. As can be seen from their vector lengths (Fig. 3), the changes in altitude, pH and inclination have the strongest influence on the changes of floristic structure of the stands.

Further research should be focused on the relevés sampling in the ecologically stratified area throughout the complete field of distribution of this problematic association.

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