DIVERSITY OF DRY GRASSLANDS IN THE POVAŽSKÝ INOVEC MTS (SLOVAKIA) – A NUMERICAL ANALYSIS

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Abstract

The paper reveals a numerical and ecological analysis of 128 published relevés of xerothermic vegetation of the Považský Inovec Mts. Four associations have been recognised: *Festuco valesiacae-Stipetum capillatae* Sillinger 1930, *Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993, *Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos. and *Minuartio setaceae-Seslerietum coeruleae* Klika 1931 nom. mut. propos. Through the numerical methods, the study reconsiders the conception of the dry grassland associations, which are traditionally used in the phytocoenological literature. It also defines the indication taxa group of the associations and characterises their environmental conditions. Major environmental gradients influencing the vegetation were interpreted using average Ellenberg indication values. Finally, the classification within the higher vegetation units, the nomenclature of the associations and the environmental threats are discussed.

Key words: classification, cluster analysis, dry grasslands, *Festucetalia valesiacae*, ordination, Považský Inovec Mts, Slovakia, syntaxonomy

Izvleček

V članku je prikazana numerična in ekološka analiza 128 objavljenih popisov kserotermne vegetacije hribovja Považský Inovec. Ugotovljene so štiri asociacije: *Festuco valesiacae-Stipetum capillatae* Sillinger 1930, *Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993, *Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos. in *Minuartio setaceae-Seslerietum coeruleae* Klika 1931 nom. mut. propos. Z numeričnimi metodami je avtorica ponovno preverila sinsistem asociacij suhih travnikov, ki so omenjene v fitocenološki literaturi. Opredelila je skupine značilnih vrst asociacij in značilnosti rastiščnih razmer. S povprečnimi Ellenbergovimi indikacijskimi vrednostmi so prikazani glavni ekološki gradienti, ki vplivajo na floristično sestavo vegetacije suhih travišč. Članek obravnava uvrstitev asociacij v višje sintaksonomske enote, nomenklaturo asociacij in njihovo ogroženost.

Ključne besede: klasifikacija, klastrska analiza, suha travišča, *Festucetalia valesiacae*, ordination, Považský Inovec, Slovaška, sintaksonomija

1. INTRODUCTION

The Považský Inovec Mts are located in the western part of Slovakia along the river Váh in the prae-Carpathian limestone zone (Fig. 1). The central part of the mountains, the Tematínske kopce Hills, is built up by dolomites. In this area, the numerous dry grasslands are located. However, the potential vegetation of this area are the forests, mostly the oak-hornbeam forests (*Carici pilosae-Carpinetum*) and locally the thermophilous oak forests (*Quercion pubescentis-petraeae*; Michalko et al. 1987). The major part of the forest cover had been destroyed during the Turkish war approximately in the 16th and 17th century. These areas later became grasslands.

The dry grassland vegetation is geographically influenced from two directions. From the south, the study area is in near contact with the eu-Pannonian lowland region, which influences the vegetation by numerous Pontic-Pannonian and sub-Mediterranean thermophilous species. From the north, the Carpathian mountain species descend

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Figure 1: Location of the Považský Inovec Mts within Slovakia.
Slika 1: Lokacija hribovja Považský Inovec na Slovaškem.

and build up some dealpine and praealpine elements (Deván et al. 2006).

This vegetation is interesting from the floristical, historical as well as the successional point of view. It was studied in detail only in two older works (Sillinger 1930, Maglocký 1979). Although some works have recently been done (Michálková, Škodová & Mertanová 2006; Janišová 2005, 2006a, b, 2007a, b), no numerical analysis has been performed so far. The presented paper brings a numerical classification of all published relevés. The use of numerical methods endeavours to support or eventually correct the current phytosociological scheme of the dry grasslands of the study area. The aim is also to define the indication taxa group of the associations and some characteristics of their environmental conditions.

2. MATERIAL AND METHODS

The numerical analyses were performed using the published relevés of xerothermic vegetation of the Považský Inovec Mts, created by applying the standard Central-European method (Braun-Blanquet 1964, Westhoff & van der Maarel 1973). The analysed data set comprised 128 relevés from the works Maglocký (1979), Sillinger (1930), Klika (1931) and Michálková, Škodová & Mertanová (2006). The taxa determined only on the level of genus were excluded from the analyses. The layer E_0 was excluded as a whole, because mosses and lichens were not determined in all relevés analysed. Some taxonomically problematic species, which were not distinguished by all authors of the relevés, were classified within higher or more broadly defined taxa: *Anthyllis vulneraria* agg. (subsp. *polyphylla*), *Artemisia campestris* (subsp. *lednicensis*), *Colymbada scabiosa* agg. (*C. badensis*), *Dactylis glomerata* agg. (*D. polygama*), *Acosta rhenana* agg. (*Acosta biebersteinii*), *Helianthemum grandiflorum* s. l. (subsp. *grandiflorum*, subsp. *obscurum*, *H. nummularium*), *Pulsatilla slavica* (*P. subslavica*), *Primula veris* (subsp. *canescens*), *Thalictrum minus* (subsp. *pseudominus*).

Initial data analysis to remove outlier relevés (relevés, of which the species composition did not correspond to the rest of the analysed data set) was carried out using the CANOCO 4.5 package (ter Braak & Šmilauer 2002). It was necessary to exclude 4 relevés (Maglocký 1979: Table 23, relevés 1–3; Table 25, relevé 20). There were 124 relevés used in the subsequent classification. We compared the results of more types of cluster analyses carried out by using different algorithms. The paper presents the results of the cluster analysis processed by the program PC-ORD 4 (McCune & Mefford 1999) where Ward's method and the relative Euclidean distance as a resemblance measure were applied. These results proved to be floristically and ecologically well interpretable and were supported by our field experience as well.

Diagnostically important taxa for the individual clusters were determined by calculating the constancy and fidelity measure of each species to each cluster, using the *phi* coefficient of association (Sokal & Rohlf 1995, Chytrý et al. 2002) in the program Juice (Tichý 2002). The results of the classification were summarised in a synoptic table (Table 1), in which both percentage species frequencies (constancies) and fidelities (φ coefficient multiplied by 100, p<0.001) were shown, and diagnostic species were ranked by decreasing fidelity (Chytrý et al. 2002). Fisher's exact test excluded the accidental species with high fidelity measures (Tichý & Holt 2006). The threshold values of the indication taxa group were selected subjectively: fidelity of **diagnostic species** was higher than 40 %; **constant species** were those with a relative constancy value higher than 60 %; **dominant species** were defined as all species that had cover values higher than 30 %. The number values indicate fidelity for the diagnostic species and constancy for the constant species in the chapter "Nomenclature and species characteristics of the associations". There is also a number given to each dominant species, which stands for the percentage of relevés meeting the threshold criteria. The indication taxa group of each cluster was compared to the diagnostic species from Holub et al. (1967), Chytrý et al. (2007) and Mucina & Kolbek (1993), which enabled interpretation of the associations in terms of higher phytosociological units (orders and alliances, Tab. 1).

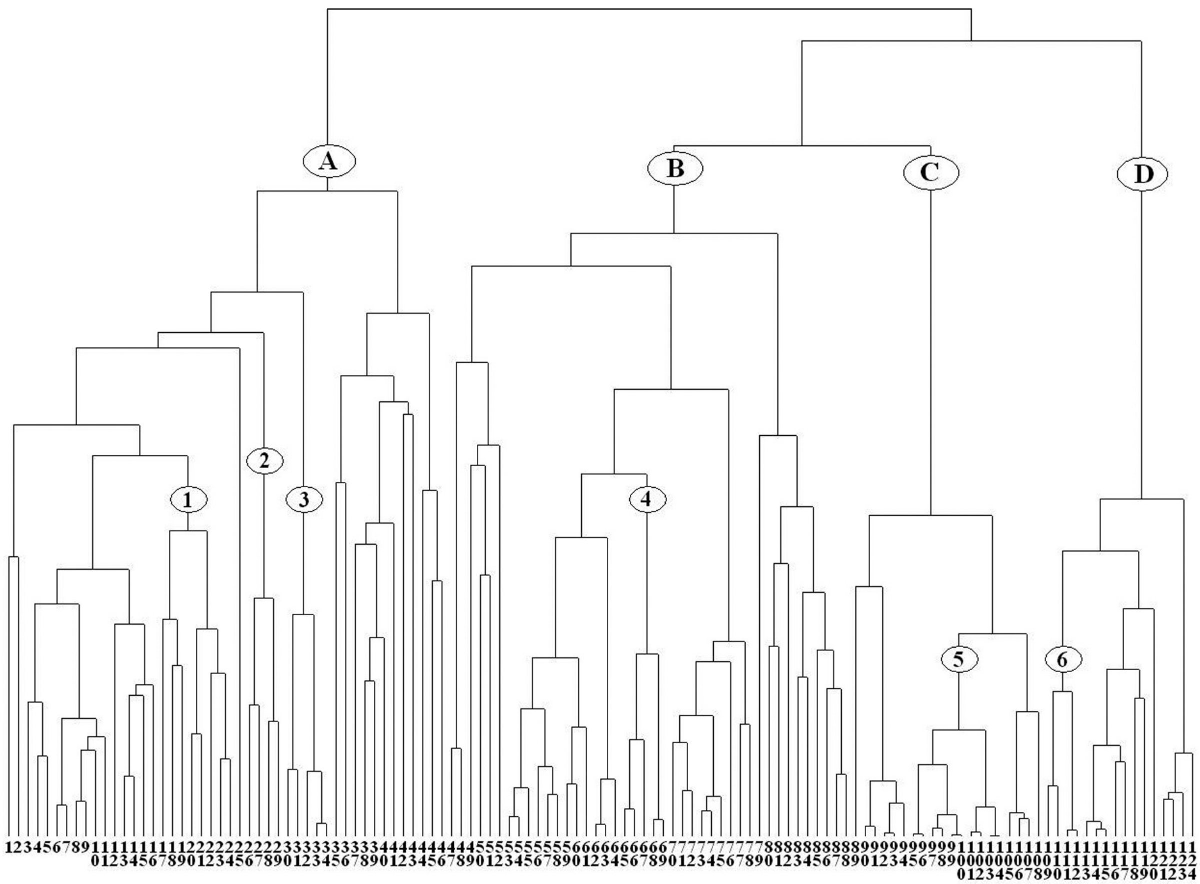

Figure 2: Dendrogram of the cluster analysis (Ward's method, relative Euclidean distance).

Slika 2: Dendrogram klastrske analize (Wardova metoda, relativna Evklidska razdalja).

A – *Festuco valesiacae-Stipetum capillatae* (1 – *festucetosum rupicoae*, 2 – *botryochloetosum ischaemii*, 3 – *caricetosum caryophyllae*), **B** – *Festuco pallentis-Caricetum humilis* (4 – *typicum*, *Koeleria macrantha*-variant), **C** – *Poo badensis-Festucetum pallentis* (5 – *jovibarbetosum hitrae*), **D** – *Minuartio setaceae-Seslerietum caeruleae* (6 – *festucetosum pallentis*).

Sources of relevés (Viri popisov): Cluster A: 1-2 – d: rel. 1, 2; **3-24** – a: Table 27, rel. 4, 12, 16, 5, 7, 6, 20, 9, 8, 28, 29, 32, 34, 33, 17, 18, 19, 21, 22, 23, 24, 25; **25** – d: rel. 3; **26-34** – a: Table 27, rel. 26, 27, 30, 31, 10, 11, 13, 14, 15; **35-36** – d: rel. 4, 5; **37** – Chytrý 1995, ined.; **38-40** – a: Table. 27, rel. 1, 2, 3; **41-43** – b: p. 36, rel. 2, 1, 3; **44-46** – d: rel. 6-8; **Cluster B: 47-48** – d: rel. 9, 10; **49-52** – b: p. 36, rel. 4, 5, 6, 7; **53** – c: p. 363, rel. 14; **54** – a: Table 26, rel. 18; **55** – c: p. 363, rel. 15; **56-78** – a: Table 26, rel. 14, 21, 23, 5, 15, 8, 19, 20, 22, 11, 12, 13, 16, 17, 1, 6, 7, 4, 24, 10, 3, 2, 9; **79-88** – d: rel. 11-20; **Cluster C: 89** – c: p. 363, rel. 13; **90-108** – a: Table 22, rel. 2, 6, 7, 9, 11, 1, 15, 8, 10, 14, 16, 13, 17, 18, 19, 3, 4, 5, 12; **Cluster D: 109** – c: p. 370, rel. 29; **110-124** – a: Table 25, rel. 3, 2, 6, 10, 13, 15, 12, 21, 24, 25, 22, 16, 18, 17, 23. **Abreviations (Okrajšave): a** – Maglocký (1979), **b** – Sillinger (1930), **c** – Klika (1931), **d** – Michálková, Škodová & Mertanová (2006).

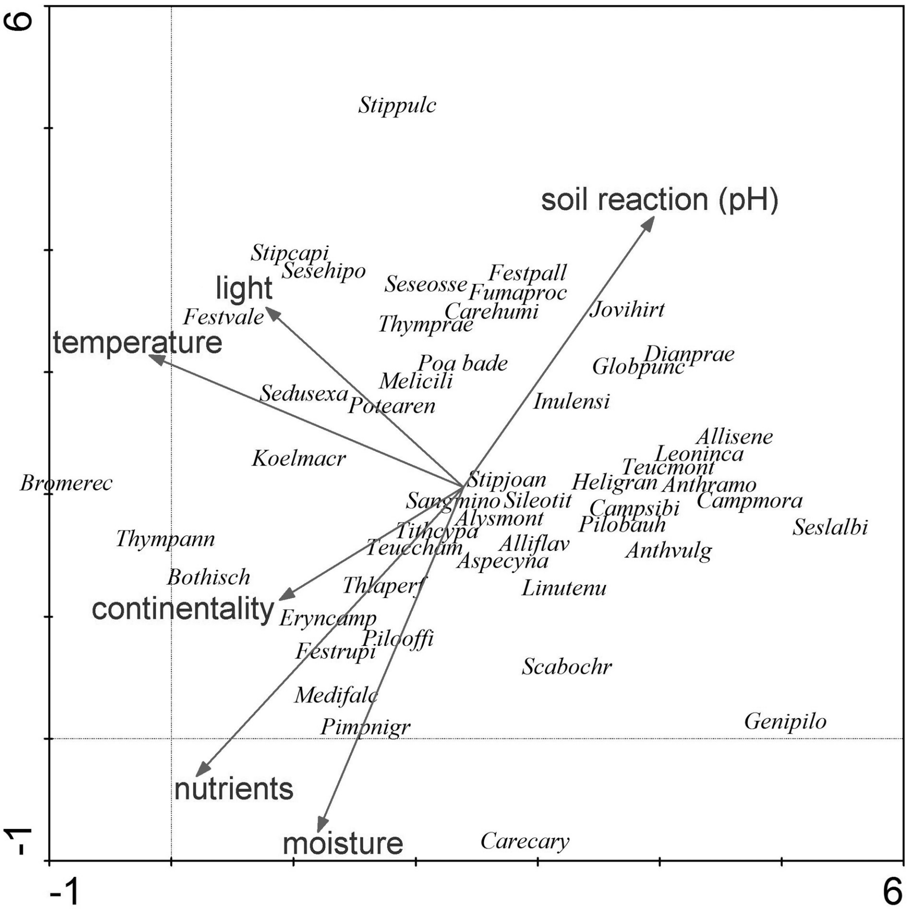

Figure 3: Detrended correspondence analysis (DCA) ordination diagram of the species occurring in the dry grassland vegetation of the Považský Inovec Mts.

Slika 3: Ordinacijski diagram korespondenčne analize z odstranjenim trendom (DCA) floristične sestave suhih travnikov na hribovju Považský Inovec.

Species list (Seznam vrst): *Allium flavum*, *A. senescens* ssp. *montanum*, *Alyssum montanum*, *Anthericum ramosum*, *Anthyllis vulneraria*, *Asperula cynanchica*, *Bothriochloa ischaemum*, *Bromus erectus*, *Campanula moravica*, *C. sibirica*, *Carex caryophyllea*, *C. humilis*, *Dianthus praecox* ssp. *lumnitzerii*, *Eryngium campestre*, *Festuca pallens*, *F. rupicola*, *F. valesiaca*, *Fumana procumbens*, *Genista pilosa*, *Globularia punctata*, *Helianthemum grandiflorum*, *Inula ensifolia*, *Jovibarba hirta* ssp. *glabrescens*, *Koeleria macrantha*, *Leontodon incanus*, *Linum tenuifolium*, *Medicago falcata*, *Melica ciliata*, *Pilosella bauhinii*, *P. officinarum*, *Pimpinella nigra*, *Poa badensis*, *Potentilla arenaria*, *Sanguisorba minor*, *Scabiosa ochroleuca*, *Sedum sexangulare*, *Seseli hippomarathrum*, *S. osseum*, *Sesleria albicans*, *Silene otites*, *Stipa capillata*, *S. joannis*, *S. pulcherrima*, *Teucrium chamaedrys*, *T. montanum*, *Thlaspi perfoliatum*, *Thymus pannonicus*, *T. praecox*, *Tithymalus cyparissias.*

The ordination techniques, using the detrended correspondent analysis (DCA) from the CANOCO 4.5 package, defined the major gradients in the spatial arrangement of species of the analysed data set. For ecological interpretation of the ordination axes, average Ellenberg indication values (Ellenberg et al. 2001) for relevés were plotted onto a DCA ordination diagram as supplementary environmental data (Fig. 3 and 4).

The nomenclature of vascular plants follows Marhold & Hindák (1998). The nomenclature of higher syntaxa is in accordance with Chytrý et al. (2007) and Mucina & Kolbek (1993). Phytosociological nomenclature of associations is reconsidered according to Weber, Moravec & Theurillat (2000). For the individual associations, these abbreviations were used in Fig. 4 and 5: **Fv-Sc** – *Festuco valesiacae-Stipetum capillatae*, **Fp-Ch** – *Festuco pallentis-Caricetum humilis*, **Pb-Fp** – *Poo badensis-Festucetum pallentis* and **Ms-Sc** – *Minuartio setaceae-Seslerietum caeruleae.*

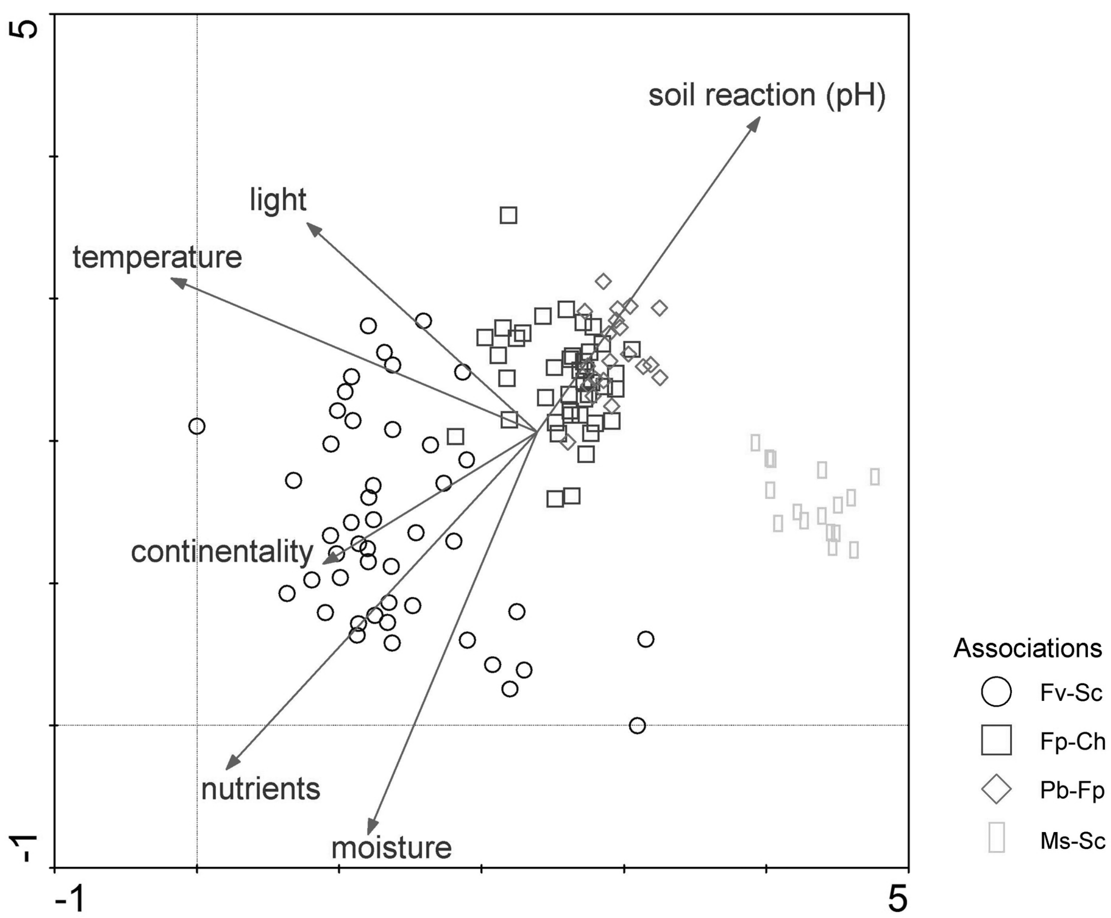

Figure 4: Detrended correspondence analysis (DCA) ordination diagram of the relevés, based on average Ellenberg indicator values.

Slika 4: DCA ordinacijski diagram popisov na osnovi povprečnih Ellenbergovih indikacijskih vrednosti.

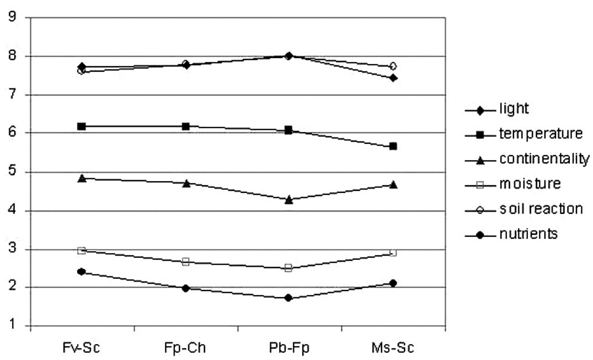

Figure 5: Average Ellenberg indication values of the ecological factors of vascular plants occurring in individual clusters (associations) produced as outputs of the cluster analysis.

Legend (Ellenberg et al. 2001): Light: 7 – plants in well lit places, sometimes occurring in partial shade, 8 – light-loving plants. Temperature: 5 – indicator of fairly warm condition, 7 – warmth indicator. Continentality: 4 – sub-oceanic, 5 – intermediate. Moisture: 1 – indicator of extreme dryness, 3 – dry sites indicator. Soil reaction: 7 – indicator of weekly acid to weekly basic conditions, never found on very acid soils, 9 – basic reaction and lime indicator. Nutrients: 1 – indicator of sites extremely poor in available nitrogen, 3 – indicator of sites more or less poor in available nitrogen.

Slika 5: Povprečne Ellenbergove indikacijske vrednosti posameznih klastrov (asociacij). ki so rezultat klastrske analize.

Legenda (Ellenberg et al. 2001): Svetloba: 7 – rastline svetlobe, včasih uspevajo v delni senci, 8 – rastline svetlobe. Temperatura: 5 – nakazovalke zmerno toplih razmer, 7 – indikatorji relativno toplih razmer. Kontinentalnost: 4 – suboceanske razmere, 5 – vmesne razmere. Vlažnost: 1 – indikatorji skrajno sušnih razmer, 3 – indikatorji sušnih razmer. Kemična reakcija tal: 7 – indikatorji slabo kislih oziroma slabo bazičnih tal, tovrstnih rastlin nikoli ne najedmo na zelo kislih tleh, 9 – nakazovalke bazične reakcije ali zelo karbonatnih tal. Hrabnila: 1 – nakazovalke rastišč, najrevnejših z razpoložljivim dušikom, 3 – nakazovalke rastišč, revnih z razpoložljivim dušikom.

3. RESULTS

3.1 Cluster analysis

Interpreting the results of the cluster analysis, four associations have been distinguished in the dendrogram at the third highest level of dissimilarity (Fig. 2). They are: *Festuco valesiacae-Stipetum capillatae* Sillinger 1930 (Fig. 6), *Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993 (Fig. 7), *Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos. and *Minuartio setaceae-Seslerietum calcariae* Klika 1931 nom. mut. propos. All of these vegetation units, using different synonyms, have been traditionally diagnosed in the phytocoenological literature (cf. Maglocký 1979).

Figure 6: *Festuco valesiacae-Stipetum capillatae* in the Nature Reserve Beckovské skalice (township of Beckov). Photo: D. Michálková, 19. 7. 2005

Slika 6: Asociacija *Festuco valesiacae-Stipetum capillatae* v naravnem rezertvatu Beckovské skalice (občina Beckov). Foto: D. Michálková, 19. 7. 2005

Figure 7: Spring aspect of *Festuco pallentis-Caricetum humilis*. Photo: M. Janišová, 24. 5. 2005.
Slika 7: Spomladnski aspekt asociacije *Festuco pallentis-Caricetum humilis*. Foto: M. Janišová, 24. 5. 2005.

3.1.1 Nomenclature and species characteristics of the associations (cf. Table 1)

Cluster A – *Festuco valesiacae-Stipetum capillatae* Sillinger 1930

Orig. (Sillinger 1930: 35): *Festuceto* (*valesiacae*)-*Stipetum capillatae*

Phantom name: *Festuco valesiacae-Stipetum capillatae* Sillinger 1931 (in Mucina & Maglocký 1985: 189), *Stipo capillatae-Festucetum valesiacae* Sillinger 1931 (in Maglocký 1979: 92)

Nomenclatural type: Sillinger 1930: 36, rel. 3, holotypus

Remark: We considered the possibility of suggesting the inversion of the order of species names in *Festuco valesiacae-Stipetum capillatae* Sillinger 1930. *Festuca valesiaca* seems to dominate over *Stipa capillata* in the growths of this association and therefore it should stay in the second position of the association's name (Art. 10b). However, *Stipa capillata* grows at the higher herb level compared to *Festuca valesiaca* and it dominates in a few stands in Southern Moravia (Chytrý in litt.). For these reasons we decided to keep the name in its original form described by Sillinger (1930).

Diagnostic taxa: *Festuca valesiaca* 77.8, *Medicago falcata* 74.4, *Eryngium campestre* 69.1, *Securigera varia* 61.5, *Pimpinella nigra* 60.8, *Acosta rhenana* agg. 57.7, *Thymus pannonicus* 54.4, *Festuca rupicola* 52.9, *Carex caryophyllea* 49.8, *Koeleria macrantha* 48.5, *Astragalus onobrychis* 47.8, *Medicago lupulina* 47.8, *Plantago lanceolata* 46.7, *Poa angustifolia* 46.4, *Salvia pratensis* 45.7, *Fragaria viridis* 44.6, *Teucrium chamaedrys* 44.2, *Adonis vernalis* 41.5, *Agrimonia eupatoria* 41.5, *Galium verum* 41.5, *Achillea collina* 41.4, *Ranunculus bulbosus* 40.4

Constant taxa: *Sanguisorba minor* 83, *Potentilla arenaria* agg. 74, *Tithymalus cyparissias* 72, *Asperula cynanchica* 61, *Pilosella officinarum* 61

Dominant taxa: *Festuca valesiaca* 22, *Bothriochloa ischaemum* 11, *Carex caryophyllea* 9

Cluster B – *Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993

Orig. (Sillinger 1930: 28): Asociace *Festuca glauca-Carex humilis* (*Glauceto-Caricetum humilis*)

Syntax. syn.: *Scabioso suaveolentis-Caricetum humilis* Klika 1931

Nomenclatural type: Michálková, Škodová & Mertanová (2006): Table 1, rel. 12, lectotypus hoc loco.

Diagnostic taxa: *Alyssum montanum* 55.0, *Stipa joannis*

51.5, *Poa badensis* 47.2, *Colymbada scabiosa* agg. 41.0, *Carex humilis* 40.5

Constant taxa: *Helianthemum grandiflorum* s. lat. 93, *Thymus praecox* 93, *Sanguisorba minor* 93, *Globularia punctata* 86, *Tithymalus cyparissias* 86, *Potentilla arenaria* agg. 83, *Teucrium montanum* 83, *Festuca pallens* 76, *Leontodon incanus* 69, *Anthyllis vulneraria* agg. 64, *Linum tenuifolium* 64, *Asperula cynanchica* 62

Dominant taxa: *Carex humilis* 55, *Stipa joannis* 12

Cluster C – *Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos.

Orig. (Klika 1931: 360): *Festuca glauca-Poa badensis*-Assoziation

Nomenclatural type: Klika 1931: 363, rel. 16, lectotypus (assigned in Toman 1975)

Diagnostic taxa: *Fumana procumbens* 54.8, *Festuca pallens* 50.5, *Draba lasiocarpa* 44.6

Constant taxa: *Teucrium montanum* 100, *Thymus praecox* 100, *Helianthemum grandiflorum* s.lat. 85, *Leontodon incanus* 85, *Globularia punctata* 65, *Potentilla arenaria* agg. 65

Dominant taxa: *Festuca pallens* 30, *Poa badensis* 5

Cluster D – *Minuartio setaceae-Seslerietum caeruleae* Klika 1931 nom. mut. propos.

Orig. (Klika 1931: 367): *Sesleria calcaria-Alsine setacea*-Assoziation (*Alsine setacea* = *Minuartia setacea*, *Sesleria calcaria* = *S. caerulea*, Art. 45)

Syn.: *Seslerio-Caricetum humilis* Sillinger 1930 (Art. 31), *Carici humilis-Seslerietum calcariae* Sillinger 1930 nom. invers. (Art. 31)

Non: *Carici humilis-Seslerietum calcariae* Zlatník 1928

Nomenclatural type: Klika 1931: 369, rel. 21, lectotypus (assigned in Toman 1975)

Diagnostic taxa: *Sesleria albicans* 96.9, *Genista pilosa* 74.2, *Thalictrum minus* 70.1, *Thesium linophyllon* 67.0, *Phyteuma orbiculare* 60.7, *Allium senescens* ssp. *montanum* 56.6, *Thlaspi montanum* 55.7, *Bupleurum falcatum* 51.2, *Polygala amara* ssp. *brachyptera* 51.0, *Campanula moravica* 50.0, *Bromus monocladus* 44.7, *Carex humilis* 40.5

Constant taxa: *Teucrium montanum* 100, *Helianthemum grandiflorum* s.lat. 88, *Anthericum ramosum* 81, *Leontodon incanus* 75, *Sanguisorba minor* 69, *Globularia punctata* 62

Dominant taxa: *Sesleria albicans* 100, *Genista pilosa* 25

3.2 Ordination and analysis of Ellenberg indication values

The detrended gradient analysis (DCA) has been used to define the major gradients in the species composition of the dry grassland vegetation (Fig. 3 and 4, Table 2). Figure 4 shows the species scatter plot of DCA based on individual relevés. Ellenberg indication values, plotted onto the ordination diagram, show that the major variation in species composition of the dry grasslands corresponds to the combination of several gradients. The first axis of the ordination diagram interprets 7.6 % of the variability of the data set (lengths of gradient 4.763, eigenvalue 0.642) and it may be more or less associated with the temperature gradient. The second axis (lengths of gradient 3.587, eigenvalue 0.398) is associated with the soil reaction gradient, which negatively correlates to the moisture (which could be later combined with the soil nutrient availability gradient).

Individual clusters strikingly differ in their relationships to major environmental factors (Fig. 3 and 4). Connected to the temperature gradient, vegetation of cluster A (*Festuco valesiacae-Stipetum capillatae*) occupies very warm sites, while cluster D (*Minuartio setaceae-Seslerietum caeruleae*) is confined to the coolest sites. The gradients of soil nutrients and moisture are mutually correlated, with cluster A (*Festuco valesiacae-Stipetum capillatae*) associated with high values and clusters B (*Festuco pallentis-Caricetum humilis*) and C (*Poo badensis-Festucetum pallentis*) with low values.

There is a relatively variable association of ***Festuco valesiacae-Stipetum capillatae*** dissociated in the left lower part of the diagram. In comparison to the rest of the data set, this unit includes the vegetation of warm and moist stands, which are the richest in soil nutrients and the most continental (Fig. 5). This closed vegetation occurs in the stands with deeper soil, which indicates also its species composition (Table 1). These dry grasslands were used as pastures in the past. They occur in the near vicinity of the rural settlements on the slight slopes at lower altitudes.

There are relevés of ***Minuartio setaceae-Seslerietum caeruleae*** separated in the right part of the ordination space (Fig. 4). This is the most cool-liking association, in which some mountain plant species are present. *Sesleria albicans, Phyteuma orbiculare* and *Acinos alpinus* are the examples of the dealpine species, while *Leontodon incanus, Thlaspi montanum* and *Biscutella laevigata* are the prealpine taxa. In comparison to the other associations, *Minuartio setaceae-Seslerietum caeruleae* grows in the humid stands and it does not have high light requirements (Fig. 5). It occurs at the highest altitudes in the NE to NW expositions. *Bromus monocladus* (*B. pannonicus* ssp. *monocladus*), a remarkable endemic of the Western Carpathians, prefers less extreme, mesophilous stands.

Table 2: The outputs of the detrended correspondence analysis (DCA) of the phytocoenological relevés of the dry grassland vegetation of the Považský Inovec Mts.

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues:	0.642	0.398	0.329	0.192	8.461
Lengths of gradient:	4.763	3.587	3.533	2.228	
Cumulative percentage variance of spec. data:	7.6	12.3	16.2	18.5	
Sum of all eigenvalues					8.461

There are two associations (***Festuco pallentis-Caricetum humilis*** and ***Poo badensis-Festucetum pallentis***) located in the central part of the diagram (Fig. 4). Their inter-separation is rather poorly presented in this projection of the ordination space. Both associations positively correlate to the increasing of the basic character of the substrate and negatively to the amount of soil nutrients and moisture. The more extreme open vegetation of *Poo badensis-Festucetum pallentis* naturally occurs on the dolomite and limestone screes with the minimal amount of soil available, which contains nutrients and holds water.

3.3 Exposition and inclination of the slopes

The exposition of slopes is an important environmental factor, which influences the distribution of dry grassland associations in the study area (Maglocký 1978, Janišová 2005). While the *Minuartio setaceae-Seslerietum caeruleae* evidently prefers the northern expositions, all the other associations tend to occur mostly on the south facing slopes (Fig. 8). The *Festuco valesiacae-Stipetum capillatae* occurs on

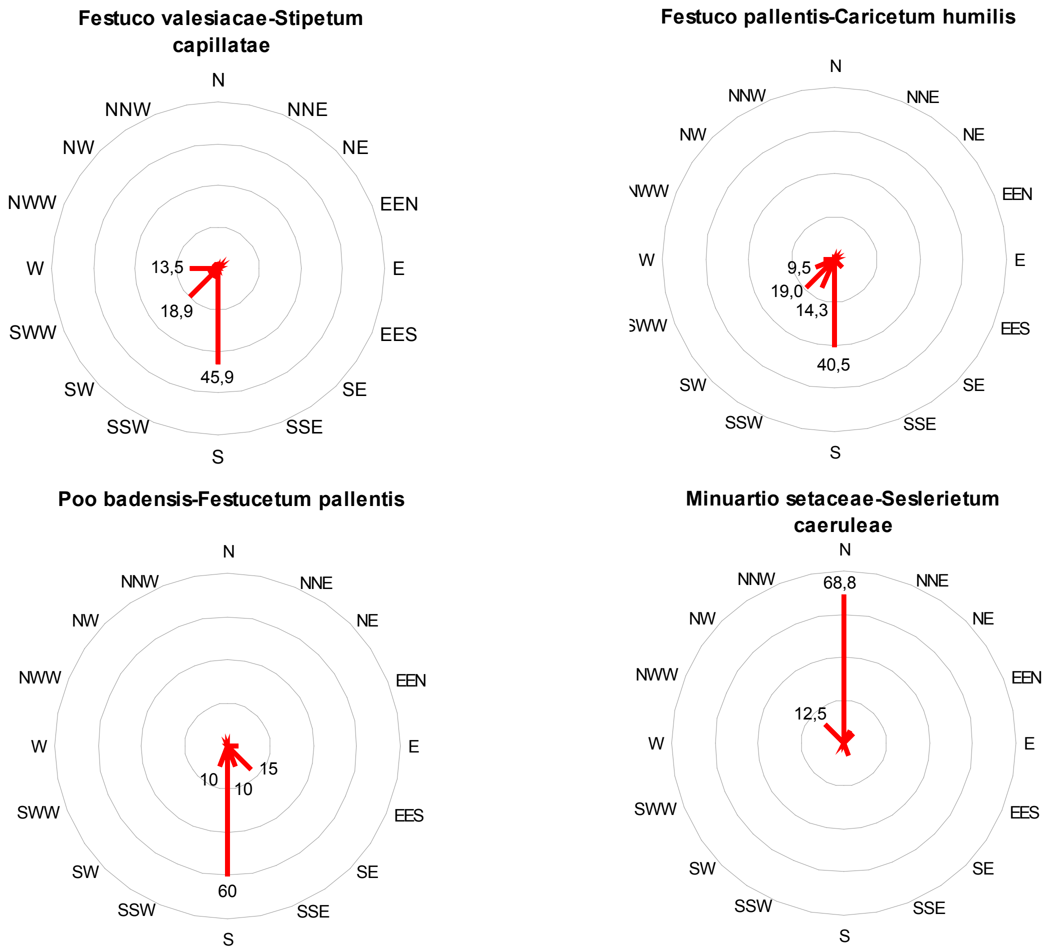

Figure 8: Circle diagrams indicating the slope and exposition priorities of the associations. Green circle scale measures show 20, 40, 60 and 80 %. The number values are marked starting from 9 %.

Slika 8: Krožni diagrami prikazujejo nebesno lego in naklon rastišč posameznih asociacij. Zeleni krogi prikazujejo naklon: 20, 40, 60 and 80 %. Vrednosti so označene od 9 % naprej.

the slight slopes (Tab. 1, average inclination 11°) in the warm expositions (S, SW, W). The driest association *Poo badensis-Festucetum pallentis* prefers south to east facing slopes, which are relatively steep (average inclination 26°). *Festuco pallentis-Caricetum humilis* grows usually in south to west expositions, mostly at the ridges of the hills (Fig. 9).

4. SYNTAXONOMY

Festuco-Brometea Br.-Bl. et Tx. ex Soó 1947
Festucetalia valesiacae Br.-Bl. et Tx. ex Br.-Bl. 1949
Festucion valesiacae Klika 1931
***Festuco valesiacae-Stipetum capillatae* Sillinger 1930**
Bromo pannonici-Festucion pallentis Zólyomi 1936 corr. 1966
***Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993**
***Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos.**
Diantho lumnitzeri-Seslerion albicantis (Soó 1971) Chytrý et Mucina in Mucina et Kolbek 1993
***Minuartio setaceae-Seslerietum caeruleae* Klika 1931 nom. mut. propos.**

The classification of the associations within the class *Festuco-Brometea* is rather problematic. The traditional conception of the class division into orders and alliances (cf. Mucina & Maglocký 1985) is not identical to the more recent works (cf. Mucina & Kolbek 1993, Michálková & Šibík 2006, Chytrý et al. 2007).

Only the classification of the *Festuco valesiacae-Stipetum capillatae* appears to be definite, because both in the traditional and modern literature sources, the association is classified within the subcontinental alliance *Festucion valesiacae* (cf. Maglocký 1979, Mucina & Maglocký 1985, Moravec et al. 1995, Chytrý et al. 2007).

The author of the description of *Festuco pallentis-Caricetum humilis* did not classify this association within any higher syntaxon. At the time of its publication in Sillinger (1930), no alliances of the class *Festuco-Brometea* had yet been described. On the other hand, the association *Scabioso suaveolentis-Caricetum humilis* (syntax. syn. of the *Festuco pallentis-Caricetum humilis*) was included by the author of its description in *Festucion valesiacae* (Klika 1931). Some authors later followed this conception (Maglocký 1979, Mucina & Maglocký 1985). These dry grasslands are classified in the works of Mucina & Kolbek (1993: 475) and Chytrý et al. (2007) within *Bromo pannonici-Festucion pallentis*. This alliance includes the circum-Pannonian thermophilous grassland biotopes on dolomite bedrocks.

The association *Poo badensis-Festucetum pallentis* is classified in Mucina & Kolbek (1993: 473) and Chytrý et al. (2007) within the alliance *Bromo pannonici-Festucion pallentis*. On the other hand, in older works (Klika 1931, Maglocký 1979, Mucina & Maglocký 1985) it was considered as a part of the broadly defined alliance *Seslerio-Festucion pallentis* Klika 1931 corr. Zólyomi 1966. Considering the nomenclatural remark in Mucina & Kolbek (1993: 460), we regard it as a nomen ambiguum. According to the presence of numerous diagnostic taxa of the alliance *Bromo pannonici-Festucion pallentis* in the vegetation of both associations (cf. Table 1), we agree with this newer concept.

The alliance *Seslerio-Festucion pallentis* has been divided into two alliances in recent literature. One of them is *Bromo pannonici-Festucion pallentis*. The other, *Diantho lumnitzeri-Seslerion albicantis*, includes the closed dealpine xerophilous vegetation on the limestone bedrock, mostly dominated by *Sesleria albicans*. The association *Minuartio setaceae-Seslerietum caeruleae* belongs to this alliance (cf. Mucina & Kolbek 1993, Chytrý et al. 2007).

5. DISCUSSION AND CONCLUSION

The results of the presented numerical analyses support the traditional conceptions (Sillinger 1930, Klika 1931, Maglocký 1979), which were created through the deductive classification methods. It is very important that the clusters representing individual associations include the relevés of the original association description (cf. Fig. 2, sources of relevés). The relevés of the original description of the *Festuco valesiacae-Stipetum capillatae* (cluster A) are in Sillinger (1930: 36, rel. 1, 2 and 3). Cluster B (*Festuco pallentis-Caricetum humilis*) contains the relevés of the original description also from Sillinger (1930: 36, rel. 4, 5, 6 and 7). Cluster C (*Poo badensis-Festucetum pallentis*) includes a relevé from Klika (1931: 363, rel. 13). Cluster D (*Minuartio setaceae-Seslerietum caeruleae*) does not involve any relevés from Sillinger (1930), because there is only a synoptic table in this work. However, cluster D contains only one relevé from the Považský Inovec Mts, which occurs in Klika (1931: 370, rel. 29).

On the other hand, the cluster analyses did not support the validity of the numerous subasso-

Figure 9: Influence of slope exposition on the distribution of the dry grassland associations. In front is the *Festuco pallentis-Caricetum humilis*. The *Poo badensis-Festucetum pallentis* is marked by a red rectangle in the background. Locality Hradlová nivka (township of Lúka). Photo: M. Janišová, 7. 5. 2005.

Slika 9: Vpliv naklona in nebesne lege na razširjenost asociacij suhih travnikov. V ospredju sestoji asociacije *Festuco pallentis-Caricetum humilis*. Sestoj asociacije *Poo badensis-Festucetum pallentis* je označen z rdečim pravokotnikom v ozadju. Lokacija Hradlová nivka (občina Lúka). Foto: M. Janišová, 7. 5. 2005.

ciations and variants assigned in Maglocký (1979). According to Art. 5 of the International Code of Phytosociological Nomenclature (Weber, Moravec & Theurillat 2000), these subassociations were invalidly described, because there was no nomenclatorical typus designated in the paper. In this study, only some relevés of Maglocký's subassociations aggregated at the lower hierarchical level of the dendrogram (Fig. 2, numbers 1–6). In the *Festuco valesiacae-Stipetum capillatae festucetosum rupicoae,* 8 from 9 relevés published in Maglocký (1979) grouped together. In the *F. v.-S. c. botryochloetosum ischaemii* it was 6 from 9 relevés and in the *F. v.-S. c. caricetosum caryophyllae* 6 from 7 relevés (Fig. 2, numbers 1–3). None of the subassociations described in the dry grasslands, which Maglocký named *Scabioso suaveolentis-Caricetum humilis,* were confirmed by the analysis. Only 5 from 8 relevés of *S. s.-C. h. typicum, Koeleria macrantha*–variant aggregated in the dendrogram (Fig. 2, number 4). All seven relevés of *Poo badensis-Festucetum pallentis jovibarbetosum hirtae* from Maglocký (1979) gathered together. Moreover two other relevés joined this group (Fig. 2, number 5). A small cluster was created by all of the three relevés of *Minuartio setaceae-Seslerietum caeruleae* (syn. *Carici humilis-Seslerietum calcariae*) *festucetosum pallentis* (Fig. 2, number 6). This study does not attempt to solve the problems of variability within the studied associations. For this purpose, it is necessary to analyse a representative data set consisting of the relevés from the whole area of the associations' occurrence.

Nowadays, the dry grasslands in the Považský Inovec Mts have to face many threats. First of all, the abandonment of the pastures (mostly *Festuco valesiacae-Stipetum capillatae*) causes successional changes in the species composition as well as shrub progression. Mostly deer and mouflons (*Ovis ammon* subsp.

musimon) graze the vegetation of *Festuco pallentis-Caricetum humilis*, which can be found at the higher altitudes, away from the settlements. However, the non-native mouflons, introduced into this area in the past, can cause the erosion (particularly in the *Poo badensis-Festucetum pallentis*) and increase the amount of nitrogen in the soil. In the past decades, an intensive planting of non-native *Pinus nigra* and *Fraxinus ornus* was accomplished in large areas. This destroyed or eventually reduced the size of many sites where mostly *Festuco pallentis-Caricetum humilis* and *Minuartio setaceae-Seslerietum caeruleae* had occurred. In some areas, the grasslands of *Festuco valesiacae-Stipetum capillatae* were completely destroyed by ploughing in order to intensify the agricultural production in the communistic times (Maglocký in verb., Deván et al. 2006).

Because of the consistent reduction of the area of the dry grasslands, it is necessary to continue with the management activities. Although this vegetation is secondary and human-influenced, it represents a refuge for many rare thermophilous species and it is a valuable contribution to the diversity of habitats in Slovakia.

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Table 1: A synoptic table produced by cluster analysis. The values are percentage frequencies. The fidelities (φ coefficient multiplied by 100) are in upper index.

Tabela 1: Sinoptična tabela narejena na osnovi rezultatov klastrske analize. Vrednosti so frekvence v odstotkih. Nadpisana vrednost je navezanost (φ koeficient pomnožen s 100).

Association (cluster)	**A**		**B**		**C**		**D**	
Number of relevés	46		42		20		16	
Average number of species	34		32		20		26	
Average inclination	11°		22°		26°		28°	
Festuco valesiacae-Stipetum capillatae								
Festuca valesiaca	**87**	**77,8**	21	---	.	---	.	---
Medicago falcata	**76**	**74,4**	7	---	.	---	6	---
Eryngium campestre	**63**	**69,1**	7	---	.	---	.	---
Securigera varia	**48**	**61,5**	2	---	.	---	.	---
Pimpinella nigra	**63**	**60,8**	19	---	.	---	.	---
Acosta rhenana agg.	**50**	**57,7**	2	---	.	---	6	---
Thymus pannonicus	**39**	**54,4**	2	---	.	---	.	---
Festuca rupicola	**50**	**52,9**	2	---	.	---	12	---
Carex caryophyllea	**39**	**49,8**	7	---	.	---	.	---
Koeleria macrantha	**72**	**48,5**	43	---	15	---	.	---
Astragalus onobrychis	**28**	**47,8**	.	---	.	---	.	---
Medicago lupulina	**28**	**47,8**	.	---	.	---	.	---
Plantago lanceolata	**35**	**46,7**	.	---	.	---	6	---
Poa angustifolia	**37**	**46,4**	2	---	.	---	6	---
Salvia pratensis	**26**	**45,7**	.	---	.	---	.	---
Fragaria viridis	**33**	**44,6**	.	---	.	---	6	---
Teucrium chamaedrys	**80**	**44,2**	52	---	.	---	38	---
Galium verum	**22**	**41,5**	.	---	.	---	.	---
Adonis vernalis	**22**	**41,5**	.	---	.	---	.	---
Agrimonia eupatoria	**22**	**41,5**	.	---	.	---	.	---
Achillea collina	**35**	**41,4**	7	---	5	---	.	---
Ranunculus bulbosus	**24**	**40,4**	2	---	.	---	.	---
Festuco pallentis-Caricetum humilis								
Alyssum montanum B-F	37	---	**81**	**55**	5	---	19	---
Stipa joannis	4	---	**38**	**51,5**	.	---	.	---
Poa badensis B-F	7	---	**40**	**47,2**	5	---	.	---
Colymbada scabiosa agg.	11	---	**33**	**41**	.	---	.	---
Poo badensis-Festucetum pallentis								
Festuca pallens B-F	13	---	76	22,7	**100**	**50,5**	38	---
Fumana procumbens B-F	7	---	57	21,8	**85**	**54,8**	6	---
Draba lasiocarpa	.	---	21	---	**50**	**44,6**	6	---
Minuartio setaceae-Seslerietum caeruleae								
Sesleria albicans D-S	.	---	5	---	.	---	**100**	**96,9**
Genista pilosa	17	---	29	---	5	---	**100**	**74,2**
Thalictrum minus	.	---	.	---	.	---	**56**	**70,1**
Thesium linophyllon	2	---	7	---	.	---	**62**	**67**
Phyteuma orbiculare D-S	.	---	.	---	.	---	**44**	**60,7**
*Allium *montanum* D-S	4	---	31	---	10	---	**75**	**56,6**
Thlaspi montanum D-S	.	---	.	---	.	---	**38**	**55,7**
Bupleurum falcatum	7	---	29	---	.	---	**62**	**51,2**
*Polygala *brachyptera* D-S	4	---	.	---	.	---	**38**	**51**

Association (cluster)	A		B		C		D	
Campanula moravica	7	---	24	---	60	---	**88**	**50**
Bromus monocladus	.	---	.	---	.	---	**25**	**44,7**
Festucion valesiacae								
Carex humilis	28	---	**100**	**40,5**	40	---	**100**	**40,5**
Silene otites	15	---	55	34,2	30	---	12	---
Asperula cynanchica	61	---	62	---	55	---	38	---
Erysimum odoratum	11	---	17	---	5	---	19	---
Pilosella bauhinii	33	---	38	---	60	---	44	---
Allium flavum	24	---	40	---	45	---	19	---
Scabiosa ochroleuca	52	---	40	---	20	---	44	---
Jurinea mollis	4	---	26	---	25	---	12	---
Onosma visianii	2	---	36	34,9	20	---	.	---
Stachys recta	15	---	26	---	10	---	.	---
Veronica prostrata	22	---	7	---	5	---	.	---
Pseudolysimachion spicatum	4	---	21	---	.	---	25	---
Artemisia campestris	17	---	10	---	.	---	6	---
Seseli hippomarathrum	15	---	12	---	.	---	6	---
Vincetoxicum hirundinaria	.	---	31	33,3	5	---	12	---
Bothriochloa ischaemum	39	37,1	24	---	.	---	.	---
Dianthus carthusianorum	28	39,5	7	---	.	---	.	---
Stipa capillata	33	---	36	---	.	---	.	---
Arenaria leptoclados	7	---	10	---	.	---	.	---
Elytrigia intermedia	17	36,9	.	---	.	---	.	---
Medicago minima	17	36,9	.	---	.	---	.	---
Bromo pannonici-Festucion pallentis								
Thymus praecox	37	---	93	30,4	100	39,3	44	---
Teucrium montanum	28	---	83	---	100	30,8	100	---
Melica ciliata	20	---	57	33,5	45	---	.	---
Potentilla arenaria	74	---	83	---	65	---	38	---
Campanula sibirica	11	---	52	23,8	50	---	19	---
Scorzonera austriaca	4	---	48	38,8	5	---	25	---
Sedum album	2	---	24	---	45	---	25	---
*Jovibarba *glabrescens*	7	---	38	---	45	---	19	---
Scabiosa canescens	2	---	24	---	5	---	19	---
Diantho lumnitzeri-Seslerion albicantis								
Leontodon incanus	17	---	69	---	85	---	75	---
Biscutella laevigata	4	---	19	---	40	---	50	---
Seslerio-Festucion pallenis								
Anthericum ramosum	7	---	60	---	45	---	81	38,3
Linum tenuifolium	33	---	64	31,3	30	---	25	---
Seseli osseum	22	---	48	---	30	---	31	---
*Dianthus *lumnitzerii*	7	---	38	---	45	---	38	---
Minuartia rubra	13	---	17	---	20	---	.	---
Dorycnium herbaceum agg.	17	---	12	---	.	---	6	---
Cyanus triumfetti	2	---	5	---	.	---	6	---
Galium glaucum	9	---	7	---	.	---	19	---
Saxifraga tridactylites	2	---	2	---	15	---	.	---
Hornungia petraea	.	---	19	---	10	---	.	---
Festucetalia valesiacae								
Inula ensifolia	9	---	33	---	10	---	25	---
Linaria genistifolia	15	---	24	---	.	---	6	---

Association (cluster)	A		B		C		D	
Viola collina	.	---	5	---	10	---	31	---
Veronica austriaca	.	---	7	---	.	---	19	---
Lactuca viminea	17	36,9	.	---	.	---	.	---
Festuco-Brometea								
Helianthemum grandiflorum	48	---	93	20,4	85	---	88	---
Sanguisorba minor	83	---	93	---	50	---	69	---
Tithymalus cyparissias	72	---	86	---	60	---	50	---
Carlina vulgaris	17	---	10	---	5	---	6	---
Acinos arvensis	30	35,1	10	---	5	---	.	---
Arenaria serpyllifololia	13	---	26	---	25	---	.	---
Allium sphaerocephalon	2	---	7	---	5	---	.	---
Arabis hirsuta	20	---	31	---	.	---	12	---
Pimpinella saxifraga	11	---	10	---	.	---	19	---
Plantago media	28	---	10	---	.	---	44	---
Potentilla heptaphylla	17	---	12	---	.	---	44	---
Trinia glauca	17	---	7	---	5	---	.	---
Seseli annuum	20	35,7	2	---	.	---	.	---
Leontodon hispidus	20	30,8	.	---	.	---	6	---
Trifolium campestre	17	---	.	---	.	---	6	---
Crinitina linosyri	11	---	10	---	.	---	.	---
Avenula pubescens	9	---	10	---	.	---	.	---
Phleum phleoides	20	39,3	.	---	.	---	.	---
Other taxa								
Pilosella officinarum	61	34,9	38	---	25	---	6	---
Globularia punctata	15	---	86	33,4	65	---	62	---
Anthyllis vulneraria	37	---	64	29	20	---	38	---
Sedum acre	11	---	12	---	20	---	6	---
Asperula tinctoria	2	---	10	---	5	---	25	---
Sedum sexangulare	46	---	33	---	25	---	.	---
Thlaspi perfoliatum	37	---	29	---	20	---	.	---
Arabis auriculata	24	---	5	---	15	---	.	---
Cerastium brachypetalum	7	---	7	---	25	---	.	---
Cerastium pumilum	7	---	7	---	5	---	.	---
Pulsatilla grandis	.	---	7	---	10	---	12	---
Acinos alpinus	.	---	2	---	15	---	19	---
Galium austriacum	.	---	5	---	20	---	19	---
Hypericum perforatum	37	---	24	---	.	---	6	---
Euphrasia stricta agg.	13	---	5	---	.	---	19	---
Hippocrepis comosa	9	---	5	---	.	---	12	---
Pulsatilla slavica	2	---	7	---	.	---	6	---
Inula hirta	2	---	5	---	.	---	6	---
Silene vulgaris	2	---	2	---	.	---	6	---
Linum catharticum	30	31,9	.	---	.	---	19	---
Sideritis montana	17	36,9	.	---	.	---	.	---
Chondrilla juncea	15	34,4	.	---	.	---	.	---

Abreviations:
A – *Festuco valesiacae-Stipetum capillatae* Sillinger 1930, **B** – *Festuco pallentis-Caricetum humilis* Sillinger 1930 corr. Gutermann et Mucina 1993, **C** – *Poo badensis-Festucetum pallentis* Klika 1931 corr. Zólyomi 1966 nom. invers. propos., **D** – *Minuartio setaceae-Seslerietum caeruleae* Klika, **B-F** – *Bromo pannonici-Festucion pallentis* Zólyomi 1936 corr. 1966, **D-S** – *Diantho lumnitzeri-Seslerion albicantis* (Soó 1971) Chytrý et Mucina in Mucina et Kolbek 1993.