Classification and syntaxonomical revision of mesic and semi-dry grasslands in Hungary

Klasifikace mezických a polosuchých trávníků v Maďarsku

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In memoriam Eszter Illyés (1979–2012)

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Mesic and semi-dry grasslands are among the most valuable and species-rich anthropogenic habitats in Hungary. In contrast to the high respect with which they are regarded by conservationists, the diversity of this vegetation and its syntaxonomy were neglected for a long time. In this paper we present the first country-level synthesis and syntaxonomical review of this vegetation based on the numerical classification of the *Arrhenatheretalia* order, and an update of *Brometalia erecti*. After careful data selection and resampling, we classified 1204 relevés to 60 clusters. Clusters representing the same association were merged on the basis of a minimum spanning tree and expert assessment of their species composition. Species composition, geographical distribution and environmental background of each mesic and semi-dry grassland association are discussed. The relationships of associations were also examined by ordination. Evaluation of clusters and associations were based only on those relevés that were unambiguously classified. We recognized 11 associations in the *Arrhenatheretalia* order in two alliances. In the *Arrhenatherion* alliance, several new association names are adopted from the literature of other countries, and a new one is proposed. According to our concept, *Arrhenatherion* includes *Ranunculo-Alopecuretum*, a meso-hygrophilous type; *Filipendulo-Arrhenatheretum* and *Anthoxantho-Festucetum pratensis*, which are typical for meadows of fluctuating soil water level but have a different geographic distribution; *Pastinaco–Arrhenatheretum*, that is a widespread mesic meadow with many generalist species; *Ranunculo bulbosi-Arrhenatheretum* containing drought-tolerant and less nutrient-demanding species; *Tanaceto-Arrhenatheretum*, a semi-ruderal type; and *Diantho-Arrhenatheretum*, that harbours many species of montane meadows. In the *Cynosurion*, four associations are distinguished. *Cynosuro-Lolietum* is an intensively grazed type on nutrient-rich, mesic or moist soil in humid climates; *Alopecuro-Festucetum pseudovinae* is also a heavily grazed type, but in areas with a more continental climate and on packed soil. *Anthoxantho-Festucetum pseudovinae* and *Colchico-Festucetum rupicolae* are lowland mesic pastures that contain some xerophilous species, however, they differ in grazing intensity and regional species pool. Two associations of *Cirsio-Brachypodion* transitional towards more mesic types are detected for the first time in Hungary: *Filipendulo-Brometum* with sub-Atlantic distribution and *Brachypodio-Molinietum* with a more montane and Carpathian distribution. We also recognized *Sanguisorbo-Brometum*, that is a common semi-dry grassland type on rocky soils in Transdanubia; *Polygalo-Brachypodietum*, a colline type with many Pontic species; *Trifolio-Brachypodietum*, an association of more forested and montane landscapes, and *Euphorbio-Brachypodietum*, the semi-dry grassland type of Pannonian loess regions. We concluded it is unlikely that *Phyteumo-Trisetion* and *Bromion erecti* occur in Hungary.

Keywords: *Arrhenatheretalia*, *Brometalia erecti*, Carpathian Basin, classification, clustering, meadow, Hungary, phytosociology, syntaxonomy

Introduction

Mesic and semi-dry grasslands are among the most valuable and species-rich anthropogenic habitats in Hungary. They typically occur on formerly forested sites, and they are maintained by mowing and grazing, and when abandoned they quickly transform into other vegetation types following colonization by shrubs, trees or tall herbaceous plants. There are numerous studies on the factors influencing the dynamics and species richness of semi-natural grasslands in Europe, and most agree that continuous, low-intensity management and spatial and temporal heterogeneity of the environment are essential for sustaining their diversity (Linusson et al. 1998, Huhta et al. 2001, Aavik et al. 2008, Marini et al. 2008, Bernhardt-Römermann et al. 2011, Burrascano et al. 2013, Fajmonová et al. 2013, Janeček et al. 2013, Michalcová et al. 2014, Mathar et al. 2015). As traditional, extensive management declines in Hungary, natural and economic values of semi-natural grasslands are also under threat (Molnár et al. 2008a, b); therefore, documenting their diversity is an urgent task.

Due to the intensive research of central-European grasslands since the earliest decades of phytosociology (Braun-Blanquet 1930), when many of the currently known and widely applied syntaxon names were established, by the end of the 1990s or the first years of the 21st century, comprehensive, national monographs of these vegetation types were published in some countries (e.g. Austria: Ellmauer & Mucina 1993; Czech Republic: Chytrý 2007; Slovakia: Janišová et al. 2007, Hegedüšová Vantarová & Škodová 2014). In contrast, the diversity and syntaxonomy of secondary vegetation in Hungary received relatively little attention compared to other vegetation types, besides investigations with economic or agricultural purposes (e.g. Jeanplong 1987, Vinczeffy 2006) and restoration studies (Török et al. 2011, 2012). Most studies in the 20th century present qualitative descriptions of associations in small geographical areas (e.g. Juhász-Nagy 1959, Máthé & Kovács 1960, Kovács 1994, Varga 1997, Lájer 2002). Not surprisingly, currently country-level summaries depend on generalizations from such local observations, adoption of results from the literature of other countries and the subjective experiences of field botanists (Soó 1971, 1973, Borhidi & Sánta 1999, Borhidi 2003). Quantitative studies were first published in the 21st century, with Horváth's (2002, 2010) publications on the loess forest-steppe vegetation in the Mezőföld region in which he described the unique, xeromesic grassland of the Pannonian, loess-covered lowland and colline areas as a new association, *Euphorbio-Brachypodietum*. Illyés et al. (2007) studied the geographical variation in semi-dry grasslands in central Europe along a continentality gradient, and revised their syntaxonomy in use in Hungary (Illyés et al. 2009). Bauer (2012, 2014) classified the dry and semi-dry grasslands (*Festuco-Brometea*) in the Bakony Mts and adjacent regions. In contrast to these recent contributions to the knowledge on semi-dry grasslands, the mesic meadows and pastures remained rather neglected by Hungarian phytosociologists. Apart from the numerical classification of mesic grasslands in South Transdanubia (Lengyel et al. 2012b), we are not aware of any quantitative contribution that clarified the classification and syntaxonomy of this vegetation type. Therefore, a numerical revision is needed.

In the latest syntaxonomical synthesis of Hungarian vegetation (Borhidi et al. 2012) some of the recent updates by Illyés et al. (2007, 2009) and Bauer (2012) are adopted, however, many questions remain unanswered. The complete list and hierarchy of the respective syntaxa according to Borhidi et al. (2012) are presented in Electronic Appendix 1. Mesic grasslands belong to the *Arrhenatheretalia* order of the *Molinio-Arrhenatheretea* class. In Hungary there are three alliances of *Arrhenatheretalia* according to Borhidi et al. (2012): *Arrhenatherion elatioris* containing mesic, mown meadows in colline to submontane regions, *Cynosurion cristati* containing heavily grazed or frequently cut, mesic grasslands with similar distributions, and *Phyteumo-Trisetion*, montane hay meadows in (sub-)Atlantic areas with a moderate nutrient supply. Semi-dry grasslands form a separate order within the *Festuco-Brometea* class, called *Brometalia erecti* Koch 1926. It is noteworthy that the interpretation of this name is ambiguous and some authors (e.g. Korneck 1974, Mucina et al. 2009) argue that the name *Brachypodietalia pinnati* Korneck 1974 should be used instead. However, in this study we follow the traditional nomenclature of orders, which was also used recently by Austrian (Willner et al. 2013a, b), Slovak (Janišová et al. 2007, Hegedüšová Vantarová & Škodová 2014) and Czech authors (Chytrý 2007). According to Borhidi et al. (2012), there are two alliances of the order *Brometalia erecti* in Hungary: the subcontinental *Cirsio-Brachypodion* and the (sub-)Atlantic and Mediterranean *Bromion erecti*. However, the presence of *Bromion erecti* in Hungary is questioned by Illyés et al. (2007, 2009). Many of the stands of semi-dry and mesic grasslands are difficult to assign to already described types due to the presence of transitions and that the different lower syntaxa share a high number of species. Nevertheless, there is a continuous variation even between associations in the orders *Arrhenatheretalia* and *Brometalia erecti*, despite the fact they are assigned to different classes.

Our aim is to prepare a numerical classification of both Hungarian mesic and semi-dry grasslands. Such a common analysis of these two orders of vegetation would enable (i) a revision of the mesic meadow and pasture associations, (ii) clarification of the transitions between mesic and semi-dry grasslands that complicated most previous analyses, and (iii) a refinement of the previous classifications and updating of our knowledge on semi-dry grasslands in Hungary.

Materials and methods

A data set comprising 2055 phytosociological relevés from Hungary was compiled. The main sources were the ‘CoenoDat’ Hungarian plot database (GIVD ID EU-HU-003, Csiky et al. 2012) and private databases. Relevés needed to fulfil one of the following two criteria: (i) to have been assigned by the original author to the order *Arrhenatheretalia* or *Brometalia erecti*, or to their transitions; (ii) to contain at least eight of a list of characteristic species of *Arrhenatheretalia* and *Brometalia erecti* recorded in the vegetation monographs of Slovakia (Janišová et al. 2007) and the Czech Republic (Chytrý 2007). Only those relevés were included for which geographical coordinates were available. More than 90% of the relevés were collected after 1995 and the oldest in the 1950s. Plot size varied between 4–25 m^2. For the 50 relevés of Juhász-Nagy (1959) there is no information on plot size, but we assumed that he followed the practice of Hungarian phytosociologists at that time, which was for plots of 4–50 m^2 for grassland relevés. Species covers were originally estimated at different scales. Cover codes using Braun-Blanquet-type scales were converted to percentages based on the mid-value of the categories. In the analyses the square-root transformed values of the percentage covers were used. The phytosociological tables of Juhász-Nagy (1959) are incomplete because for species with only a single occurrence there is no cover value. We gave such species a "+" category on the Braun-Blanquet cover scale in order that locally rare species would not have a significant effect on the classification if the table is for a well defined type (Lengyel et al. 2012a). The nomenclature of plant taxa follows Király (2009). Some species with taxonomic or identification issues were merged into species aggregates (Electronic Appendix 2). The records of non-vascular plants, shrubs and trees were deleted from the relevés. For the calculation of between-plot dissimilarities, the Marczewski-Steinhaus index was used, which is the dissimilarity version of the abundance form of Jaccard index (Podani 2000).

The initial data set included many relevés that belonged to syntaxa not relevant to this study. Filtering a data set in order to restrict it more to the focal vegetation is very difficult if the vegetation unit itself lacks a formal definition, which is now the case for Hungarian mesic and semi-dry grasslands. If the filtering is carried out too strictly, there is a strong risk of excluding relevés originally belonging to the type under scope, and this is more serious than including non relevant types in the sample. We decided to leave enough relevés in our data set of non relevant types in order to better detect their transitions with the focal types. To achieve this, a preliminary classification was applied. At the beginning, the unbalanced distribution of plots in compositional similarity and geographical space was reduced by heterogeneity-constrained random resampling with geographical stratification (Lengyel et al. 2011). The retained 1340 relevés were classified hierarchically using the beta-flexible method (beta = –0.25). We informally evaluated the resulting 50 clusters on the basis of species composition and author-supplied syntaxon assignments, and decided whether a cluster contains relevés that potentially belong to the target syntaxa, that is, the orders *Arrhenatheretalia* and *Brometalia*. After this, the distance of each relevé, including those which were omitted during resampling, from each cluster was calculated using the Associa method (van Tongeren et al. 2008). Relevés (re-)assigned to clusters of non relevant types were eliminated from the data set. Excluded relevés represented wet meadows dominated by *Molinia caerulea* agg., alkali grasslands with *Peucedanum officinale*, open, dry grasslands with the dominance of *Stipa* spp., *Festuca valesiaca*, *F. pseudodalmatica*, *F. rupicola*, *Carex humilis* and *Chrysopogon gryllus*. However, a certain number of relevés of non relevant types still remained in the filtered data set, which contained 1424 relevés.

The HCR resampling procedure with the same settings as mentioned above was carried out on this filtered data set which reduced its size to 1204 relevés. The geographical distribution of the relevés in the final data set is shown in Fig. 1. Many hierarchical classification methods were tried in order to recover as many patterns as possible from this data

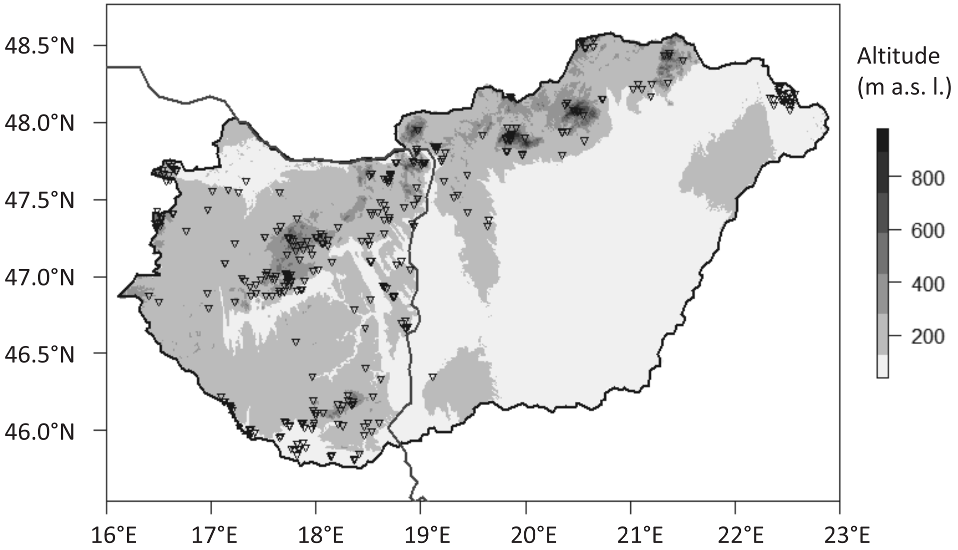

Fig. 1. – The geographical distribution in Hungary of the relevés analysed.

set. A common weakness of simple, hierarchical classifications is the resulting clusters consist of relevés that belong to different associations. Such clusters may not be useful for syntaxonomic purposes, thus we tried improving our methodology using three methods. Firstly, a non-hierarchical method, partitioning around medoids (PAM, Kaufman & Rousseeuw 1990), was used to classify relevés, and then we looked for hierarchical relations less formally based on among-cluster patterns and syntaxonomical interpretation. Non-hierarchical methods tend to produce more homogenous clusters without constraining the classification into a perfectly nested structure (Podani 2000). Secondly, a relatively fine solution consisting of 60 clusters was used to ensure that each cluster includes a relatively narrow vegetation unit. Several methods (Optimclass with several different thresholds for p-values, Tichý et al. 2010; average silhouette, Kaufman & Rousseeuw 1990; the bootstrap method of Tichý et al. 2011) were tried in order to determine the optimal number of clusters, but they all gave different results; however, in several cases, optima fell between 40 and 60 clusters, therefore, the 60-cluster solution seemed to be fine enough to detect all the important types, even though some of the clusters may eventually be shown to belong to the same association. Thirdly, the silhouette index (Rousseeuw 1987) was calculated for each relevé and only those with a positive silhouette index were included in the evaluation of clusters. Hereafter we call the relevés with positive silhouette values within the frame of any classification ‘core relevés’, while those with non-positive silhouette value are ‘non-core relevés’. For analysing the relationships between clusters, a matrix was calculated that contains the average dissimilarities between core relevés of pairs of clusters. This dissimilarity matrix was classified using the minimum spanning tree method (MST, Podani 2000). The MST provides a 2-dimensional, non-hierarchical representation of single linkage clustering with lengths of between-neighbour branches corresponding to chaining values along the vertical axis of a dendrogram. MST can reveal the closest neighbourhoods of clusters, thus it is an effective tool for analysing gradual variation among clusters. In some cases certain clusters are placed in the same association. For studying the relationships between associations, we merged the relevés of such clusters into one group, including non-core relevés. Only such clusters were used for merging, which appeared as closest neighbours in the MST. After merging, we re-calculated the silhouette values of relevés and so re-defined the sets of core relevés for each cluster or group of clusters. Only core relevés obtained after merging were used for constructing synoptic tables and summary statistics. The fidelity of species to clusters was defined in terms of the phi coefficient (Chytrý et al. 2002) with equalized group sizes (Tichý & Chytrý 2006). Only fidelities with phi > 20 (on a 0 to 100 scale) and Fisher's exact test $P < 0.001$ were considered meaningful.

The relationships of associations was also examined using a principal coordinate analysis (PCoA) of core relevés. The associations were graphed on two dimensions of a spider plot. Two separate ordinations were carried out, one including both orders and one separately for *Arrhenatheretalia*.

Data management and calculations were done using software TurboVeg (Hennekens & Schaminée 2001), Juice (Tichý 2002) and R (R Core Team 2013), the latter with the vegan (Oksanen et al. 2013), MASS (Venables & Ripley 2002), cluster (Maechler et al. 2013), vegclust (De Cáceres et al. 2010) and rapport (Blagotić & Daróczi 2013) packages.

Results and discussion

Interpretation of the minimum spanning tree

There were 831 relevés with positive silhouette values in the 60 clusters of the PAM classification. The minimum spanning tree (Fig. 2) revealed major gradients in species composition in the data set. The left part of the graph, from Clusters 1 to 30, consisted mostly of mesic types (including all associations of *Arrhenatheretalia* order) and the right side, from Clusters 31 to 60, drier types are presented (including all but one association of the order *Brometalia erecti*). Within the mesic part, two large and a small, well-interpretable branches connected by Cluster 14 can be recognized. The first main branch consisted of Clusters 1 to 11. This group of clusters include lowland or colline hay meadow associations on mostly nutrient-rich, mesic or wet soils. Clusters 1 to 7 includes *Arrhenatherion* communities dominated by *Arrhenatherum elatius* (*Ranunculo bulbosi-Arrhenatheretum*, *Tanaceto-Arrhenatheretum*, *Pastinaco-Arrhenatheretum*) and an unidentified cluster. In Clusters 8 to 13 the species of wet meadows have high frequency and cover; however, these types differ in syntaxonomical affiliation: Clusters 8 to 10 are wet meadows (in *Deschampsion*; out of scope), Cluster 11 and 13 are two associations in *Arrhenatherion* temporally or permanently affected by high ground water (*Filipendulo-Arrhenatheretum*, *Ranunculo repentis-Alopecuretum*), while Cluster 12 contains intermediate stands and old-fields sown with *Alopecurus pratensis*. The small branch from Clusters 14 to 18 contains mostly lowland pastures with dry (typically mid- to late summer) and wet (especially autumn to spring) periods during the year (*Colchico-Festucetum rupicolae*, *Anthoxantho-Festucetum pseudovinae*, *Alopecuro-Festucetum pseudovinae*). They are characterized by a mixture of mesophilous and xerophilous species. Cluster 19 and 20 are two types with a high cover of *Arrhenatherum elatius* and high frequency of xerophilous species (*Diantho-Arrhenatheretum* and an unidentified type). The common feature of

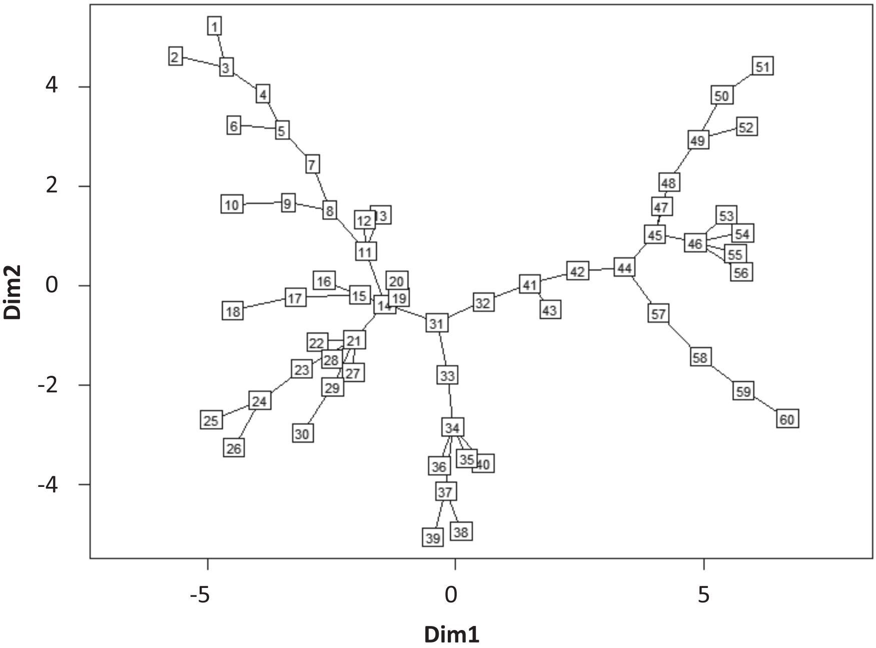

Fig. 2. – The minimum spanning tree of the 60 clusters distinguished in the vegetation of mesic and semi-dry grasslands in Hungary.

Clusters 21 to 28 is that they occur in the most humid areas in Hungary, and they contain many montane, acidophilous or hygrophilous species. These clusters vary in management regime, since they include pastures, hay meadows and abandoned areas. According to the syntaxonomic system, they include types from *Arrhenatherion (Anthoxantho-Festucetum pratensis)*, *Cynosurion* (unidentified at association level), *Cirsio-Brachypodion (Brachypodio-Molinietum)* and *Violion caninae* (out of scope) alliances. Cluster 29 and 30 are also joined to this branch of clusters, indicating a transition towards the nutrient-rich and less acidic but intensively grazed *Cynosuro-Lolietum* association of *Cynosurion*. In the semi-dry half of the minimum spanning tree, Clusters 31 to 40 are semi-dry or dry types with high occurrence of species of rocky grasslands. Within this branch, there is a moisture gradient from Clusters 31 and 32 (mesic-xeromesic; *Filipendulo-Brometum* and a transitional type) through Cluster 33 to 36 (xeromesic; *Sanguisorbo-Brometum*) to Clusters 37 to 40 (dry grasslands; *Festucion valesiacae* and *Bromo-Festucion pallentis*; out of scope). Grasslands represented by Cluster 41 and onwards, with a few exceptions, thrive on deeper soils, either on loess-covered lowlands or in colline to montane forest clearings, and they are usually dominated by *Brachypodium pinnatum*. Four well-delimited associations are recognized within this large group of clusters, which are differentiated according to base-rock, phytogeographical character and landscape context. Clusters 41 to 43 belong to *Polygalo-Brachypodietum*, which is a termophilous, colline type. Clusters 44 to 48 include *Euphorbio-Brachypodietum*, the widespread semi-dry grassland of loess-covered lowland plateaus and foothills. Clusters 57 to 59 include *Trifolio-Brachypodietum,* which occurs in montane, forested areas. The latter two associations are accompanied by some clusters of out-of-scope types (Clusters 49 to 51: *Festucion rupicolae* and *Geranion sanguinei*, Cluster 60: *Stipenion tirsae*) and clusters with unclear interpretation but belonging to *Cirsio-Brachypodion* (Clusters 53 to 56).

Description of identified associations of the orders Arrhenatheretalia and Brometalia erecti

After merging clusters representing the same type, 33 groups remained, for which there were 898 core relevés. The summaries of types identified as associations of the orders *Arrhenatheretalia* and *Brometalia* with faithful, constant and dominant species, and their distribution maps are presented in Electronic Appendix 3. A synoptic table is also supplied in Electronic Appendix 4.

Ranunculo bulbosi-Arrhenatheretum Ellmauer 1993 [in *Arrhenatherion*; Clusters 2, 3]

This association has not been reported before from Hungary. According to Chytrý (2007), Willner et al. (2013a) and Uhliarová et al. (2014), *Ranunculo-Arrhenatheretum* is characterized by the dominance of *Arrhenatherum elatius* and the presence of less nutrient-demanding species of mesic and semi-dry meadows. In our data set, its dominant species are *Arrhenatherum elatius*, *Bromus erectus*, *Danthonia alpina* and *Trisetum flavescens*. The accompanying species are elements of mesic or semi-dry, mown meadows with moderate nutrient availability (e.g. *Festuca rubra*, *Ranunculus polyanthemos*, *Vicia sativa* agg., *Rhinanthus minor*, *Anthoxanthum odoratum*, *Salvia pratensis*). This association includes two variants depending on the soil base status, Cluster 1 is the base-rich subtype and Cluster 2 the acidic one. Its relations to similar associations are presented in the discussion of respective types.

Tanaceto-Arrhenatheretum Fischer ex Ellmauer 1993 [in *Arrhenatherion*; Clusters 4–6]

This association is also reported for the first time from Hungary. Its relevés include mostly semi-ruderal stands dominated by *Arrhenatherum elatius* that are either in abandoned meadows, or at disturbed or successional sites. Its characteristic features are the presence of ruderal and disturbance-tolerant species (e.g. *Medicago sativa*, *Eragrostis minor*, *Convolvulus arvensis*, *Artemisia vulgaris*, *Tanacetum vulgare*, *Anchusa officinalis*, *Potentilla argentea*) and the relatively low frequency of typical elements of *Arrhenatherion* (Ellmauer & Mucina 1993).

Pastinaco-Arrhenatheretum (Knapp 1954) Passarge 1964 [in *Arrhenatherion*; Cluster 7]

The dominant species is usually *Arrhenatherum elatius*, but other tall grasses (*Alopecurus pratensis*, *Bromus erectus*, *Dactylis glomerata*, *Festuca pratensis*) are also frequent. Constant and differential species are typical elements of productive, mesic meadows (e.g. *Cirsium canum*, *Pastinaca sativa*, *Ranunculus acris*, *Galium mollugo* agg.). These relevés come from colline to montane regions of different parts of Hungary. *Pastinaco-Arrhenatheretum* is often considered as a 'central' type in *Arrhenatherion* and it is especially difficult to distinguish from some very closely related associations (see also Stančić 2008, Willner et al. 2013a). According to our concept, *Pastinaco-*

Arrhenatheretum in Hungary can be recognized by the dominance of tall grasses (see species mentioned above), the presence of mid-height grasses (e.g. *Trisetum flavescens*, *Poa pratensis*) and the high frequency of generalistic mesic meadow-elements (e.g. *Trifolium pratense*, *Vicia sativa* agg., *Leucanthemum vulgare* agg., *Campanula patula*, *Ranunculus acris*, *Galium mollugo* agg., *Cirsium canum*, *Pastinaca sativa*, *Tragopogon orientalis*). Although *Geranium pratense* is a diagnostic species of this association in neighbouring countries with a more mountainous landscape, in Hungary it is rare and occurs in moister habitats. Species typical of more nutrient-poor habitats (e.g. *Agrostis capillaris*, *Festuca rubra*, *Luzula campestris* agg., *Thymus pulegioides*) and share elements with semi-dry grasslands (*Plantago media*, *Salvia pratensis*, *Trifolium montanum*, *Briza media*) are rare (however, not completely absent), thus they can be used for separation from the otherwise very similar *Ranunculo bulbosi-Arrhenatheretum*. In *Pastinaco-Arrhenatheretum*, species of *Molinietalia* (e.g. *Symphytum officinale*, *Ranunculus repens*, *Carex otrubae*, *Gentiana pneumonanthe*, *Selinum carvifolia*, *Succisa pratensis*) are in general also rare, aiding its separation from wet meadows, where they are much more common. Several subassociations of *Pastinaco-Arrhenatheretum* are reported by Hungarian authors (Lájer 2002, Borhidi 2003) but we could not recognize them as separate clusters.

Filipendulo vulgaris-Arrhenatheretum Hundt et Hübl ex Ellmauer 1995 [in *Arrhenatherion*; Cluster 11]

The relevés representing this association not yet reported from Hungary are mostly from the southern and western parts of Transdanubia. These stands are situated on floodplains and along brooks on intermittently moist, less aired soils that have a wet and a dry period during the year. Due to the fluctuation of the water table, *Filipendulo-Arrhenatheretum* is transitional in character between semi-dry, mesic and wet conditions, containing species with different optima along the moisture gradient. An important feature of these grasslands is the presence of species that indicate fluctuations in soil moisture, e.g. *Alopecurus pratensis*, *Betonica officinalis* and *Potentilla alba,* and the high cover of *Holcus lanatus* and *Helictotrichon pubescens*. There is usually no single dominant species in this type, probably because of the fluctuating water table. According to Ellmauer & Mucina (1993) and Willner et al. (2013a), this association develops on less nutrient-rich soils than *Pastinaco-Arrhenatheretum*, which is indicated by the presence of species like *Anthoxanthum odoratum*, *Briza media* and *Luzula campestris* agg. It differs from *Ranunculo bulbosi-Arrhenatheretum* in the higher frequency of species indicating temporarily moist, packed soils, e.g. *Holcus lanatus*, *Betonica officinalis*, *Potentilla alba*, and in the lower frequency of drought-tolerant species, e.g. *Plantago media*, *Securigera varia*, *Centaurea scabiosa*, *Onobrychis viciifolia*. Nevertheless, Cluster 11 differs from the Austrian data on *Filipendulo-Arrhenatheretum* in that *Bromus erectus* is rare, whereas it is constant and can reach high cover in the relevés of Willner et al. (2013a). In Hungarian relevés *Arrhenatherum elatius* is not a typical dominant species, although, it is subconstant and sometimes it can reach over 20% cover. Some of the relevés in Cluster 11 are dominated by *Holcus lanatus* and also contain several species of wetter meadows, like *Lychnis flos-cuculi*, *Cardamine pratensis*, *Silaum silaus* and *Sanguisorba officinalis*. Such relevés resemble the *Holcetum lanati* Issler 1934 association in *Deschampsion* alliance, however, this is not sufficiently differentiated from *Arrhenatherion* communities (Stančić 2008). Here we interpret *Filipendulo vulgaris-Arrhenatheretum* in a broad sense, including wetter stands similar to *Holcetum lanati* and drier ones, where the cover of *Festuca rupicola* reaches 15%. Further studies may clarify the relationship of *Holcetum lanati* and other associations of *Molinion* and *Arrhenatherion*.

Ranunculo repentis-Alopecuretum pratensis Ellmauer 1993 [in *Arrhenatherion*; Cluster 13]

Cluster 13 includes mesic meadows on nutrient-rich soils with the dominance of *Alopecurus pratensis, Trisetum flavescens, Festuca pratensis*, and other nutrient-demanding species. The constant and faithful species are also nutrient-demanding elements of *Arrhenatherion*, e.g. *Poa trivialis*, *Trisetum flavescens*, *Taraxacum officinale* and *Glechoma hederacea*. In the Hungarian phytosociological literature, this type was formerly frequently identified with "*Alopecuro-Arrhenatheretum* (Máthé et Kovács) Soó 1971". This name was introduced by Soó (1971) and it included the *"Arrhenatheretum alopecuretosum"* and the *"Festuco-Cynosuretum arrhenatheretosum"* tables of Máthé & Kovács (1960). However, as pointed out by Borhidi et al. (2012), all these names are invalid. Based on the original relevés, Borhidi et al. (2012) describe *Anthoxantho-Festucetum pratensis* Borhidi 2012 to replace the former name, and *Anthyllido-Festucetum rubrae arrhenatheretosum* Borhidi 2012 to validate the latter (for update on this subassociation, see *Diantho-Arrhenatheretum*). However, according to the original relevés of Máthé & Kovács (1960) and the descriptions of Borhidi et al. (2012), both syntaxa are characterized by species of nutrient-poor soils, e.g. *Polygala vulgaris*, *Ranunculus auricomus*, *Dianthus deltoides*, therefore, Cluster 13 should not be identified with any of them, and the former interpretation of *"Alopecuro-Arrhenatheretum"* by Hungarian authors was mistaken. Nevertheless, the *Ranunculo repentis-Alopecuretum* Ellmauer 1993 association described from Austria is rather similar to Cluster 13, which indicates this association occurs in Hungary. It occurs in the valleys of colline and montane areas. It differs from *Pastinaco-Arrhenatheretum*, *Ranunculo-Alopecuretum* in the higher proportion of nutrient-demanding and wet grassland species, e.g. *Alopecurus pratensis*, *Crepis biennis*, *Carex hirta*, *Poa trivialis*; however, the delimitation of these two associations is unclear. The relationship between *Ranunculo-Alopecuretum* and *Deschampsion* associations also needs further study.

Diantho-Arrhenatheretum (Máthé et Kovács 1960) Lengyel nom. nov. [in *Arrhenatherion*; Cluster 20]

Synonyms: *Festuco rubrae-Cynosuretum arrhenatheretosum* Máthé et Kovács 1960, *Anthyllido-Festucetum rubrae arrhenatheretosum* (Máthé et Kovács 1960) Borhidi 2012

Lectotypus: Máthé et Kovács (1960), Table III., Relevé 5, designated by A. Borhidi for *Anthyllido-Festucetum rubrae arrhenatheretosum* in Borhidi et al. (2012).

Cluster 20 is very similar to the relevés and description of *Anthyllido-Festucetum rubrae arrhenatheretosum* (Máthé et Kovács 1960) Borhidi 2012. (For more discussion on *Anthyllido-Festucetum rubrae*, see *Festuca rubra*-type.) However, in our classification we could not recognize the other subassociations with sufficient confidence, including the typical *Anthyllido-Festucetum*, therefore we propose to raise *arrhenatheretosum* to the level of an association with the name *Diantho deltoidis-Arrhantheretum elatioris*

(Máthé et Kovács 1960) Lengyel nom. nov.. *Diantho-Arrhenatheretum* is a meadow type found in mountain areas that were traditionally mown and grazed in the past, but after the cessation of grazing tall grasses became dominant. The characteristic feature of this cluster is the joint occurrence of less nutrient-demanding plants (e.g. *Agrostis capillaris*, *Festuca rubra*, *Viola canina, Thymus pulegioides*) and drought-tolerant species (e.g. *Teucrium chamaedrys*, *Trifolium montanum*, *Thesium linophyllon*), elements of forest edges (e.g. *Melampyrum nemorosum*, *Luzula luzuloides*, *Primula veris, Cruciata glabra*) and dominance of tall grasses, usually *Arrhenatherum elatius* or *Helictotrichon pubescens*. *Diantho-Arrhenatheretum* is similar to other nutrient-poor types of *Arrhenatherion*: *Ranunculo bulbosi-Arrhenatheretum* and *Filipendulo vulgaris-Arrhenatheretum*. From the latter two, *Diantho-Arrhenatheretum* differs in a higher number and constancy of elements of *Violion caninae* (e.g. *Thymus pulegioides*, *Dianthus deltoides, Viola canina, Carlina acaulis*) and forest edge species (e.g. *Luzula luzuloides*, *Primula veris*, *Cruciata glabra*). This association shows a landscape-scale change in vegetation due to the disappearance of traditional, extensive farming, since it is most common at high altitudes, where it replaces former mountain pastures. Nowadays these stands are mown or abandoned.

Anthoxantho-Festucetum pratensis Borhidi 2012 [in *Arrhenatherion*; Cluster 23]

The dominant species are *Festuca pratensis* and *Agrostis capillaris*, while there are many elements of wet meadows, forests and clearings among the diagnostic species: *Ranunculus auricomus*, *Galium boreale*, *Carex pallescens*, *Lysimachia nummularia* and *Ranunculus repens*. Similarly to *Filipendulo-Arrhenatheretum*, this type thrives on soils with wet and dry periods during a year but *Anthoxantho-Festucetum pratensis* occurs in colder areas, and includes more species of wet meadows and montane forests (e.g. *Carex pallescens*, *Ranunculus auricomus*) and acidic grasslands (e.g. *Agrostis capillaris*, *Polygala vulgaris*, *Viola canina*, *Dianthus deltoides*). Many of the stands sampled belonging to this cluster were previously grazed as is indicated by the presence of *Cynosurion* elements (e.g. *Plantago major*, *Leontodon autumnalis*, *Cynosurus cristatus*). This association occurs at high altitudes in the North Hungarian Mountains.

Colchico autumnalis-Festucetum rupicolae **Lengyel, Csiky, Dénes et Király ass. nova hoc loco** [in *Cynosurion*; Clusters 14–16]

Holotypus: Author: Andrea Dénes; Date: 20 May 1997; Location (WGS84): N 45.885°, E 17.764°, Drávafok (Hungary); Altitude: 100 m.a.s.l. Relevé area: 16 m^2. Species covers are in percentages. Herb layer: *Festuca rupicola* 35, *Luzula campestris* agg. 20, *Anthoxanthum odoratum* 15, *Filipendula vulgaris* 15, *Plantago lanceolata* 7, *Holcus lanatus* 4, *Centaurea jacea* agg. 3, *Colchicum autumnale* 2, *Ononis arvensis* s.lat. 2, *Saxifraga bulbifera* 1, *Trifolium montanum* 1, *Achillea millefolium* agg. 0.5, *Ajuga genevensis* 0.5, *Betonica officinalis* 0.5, *Carex caryophyllea* 0.5, *Cerastium vulgare* 0.5, *Euphorbia cyparissias* 0.5, *Fragaria viridis* 0.5, *Galium verum* 0.5, *Lathyrus pratensis* 0.5, *Leontodon hispidus* 0.5, *Leucanthemum vulgare* agg. 0.5, *Moenchia mantica* 0.5, *Myosotis ramosissima* 0.5, *Orchis morio* 0.5, *Ornithogalum umbellatum* agg. 0.5, *Pastinaca sativa* 0.5, *Polygala comosa* 0.5, *Ranunculus acris* 0.5, *Ranunculus bulbosus* 0.5, *Rumex acetosa* s. lat. 0.5, *Taraxacum officinale* 0.5, *Veronica chamaedrys* agg. 0.5, *Viola canina* 0.5. Total cover of herb layer: 100%. Cryptogamous plants were not recorded.

This association includes extensive pastures and, occasionally, less productive hayfields that are transitional between mesic and semi-dry grasslands. They are similar to but drier than the driest forms of *Filipendulo vulgaris-Arrhenatheretum* but still contain many mesophilous species. The dominant species is usually *Festuca rupicola*, but other, short or medium-height grasses (e.g. *Briza media, Cynosurus cristatus*) can also be abundant, while tall grasses are scarce. Most relevés are from lowlands and floodplains in the Transdanubian Region and the north-eastern part of the Great Hungarian Plain. Such stands can develop in former wet habitats that have dried out due to river regulation and also in clearings of alluvial forests that have been converted into pastures. They are typically located on the highest parts of sandy dunes, just above the levels directly affected by spring flooding. Cluster 14 and 15 include relevés of the most typical, species-rich and moderately grazed or mown stands and Cluster 16 includes a weedier, heavily grazed subtype, however, we think they all belong to the same association. Some of the relevés were published under the name *Anthoxantho-Festucetum pseudovinae* Juhász-Nagy 1959 and were assigned to its least intensively grazed variant dominated by *Festuca rupicola* (Juhász-Nagy 1959). Borhidi (2003) refers to the same type as "*Anthoxantho-Festucetum rupicolae* Dénes 1997", however, Dénes (1997) did not present a valid syntaxonomic description (Weber et al. 2000: 5. §). In our classification, the relevés from the *Festuca rupicola*-variant of *Anthoxantho-Festucetum pseudovinae* by Juhász-Nagy together with many other relevés from Transdanubia were separated from the 'typical' *Anthoxantho-Festucetum pseudovinae*, therefore, we describe the type included in Clusters 14 to 16 as a new association, *Colchico autumnalis-Festucetum rupicolae*. As this is typically a pasture type, and physiognomically is more similar to *Cynosurion* communities, we assign it to this alliance. However, a much needed international revision of *Cynosurion* communities may refine its position in the future. *Colchico autumnalis-Festucetum rupicolae* can be recognized by the dominance of *Festuca rupicola* with *Briza media* and *Anthoxanthum odoratum* as subdominant grasses, the low cover of tall grasses (*Helictotrichon pubescens*, *Alopecurus pratensis*, *Arrhenatherum elatius*), the occurrence of mesic meadow species (e.g. *Campanula patula*, *Leucanthemum vulgare, Colchicum autumnale, Trisetum flavescens*), drought-tolerant species (e.g. *Dianthus pontederae*, *Trifolium montanum*, *Filipendula vulgaris, Viola hirta*), and, occasionally, species preferring periodically waterlogged soils (e.g. *Carex pallescens*, *C. tomentosa, Sanguisorba officinalis*). Species of nutrient-poor and acidic grasslands are also often present (e.g. *Luzula campestris*, *Agrostis capillaris*, *Rumex acetosella*). This association occurs at the periphery of lowlands in the Carpathian Basin but also in colline landscapes. The *Colchico autumnalis-Festucetum rupicolae* is maintained by moderate grazing, but after abandonment or replacement of grazing by mowing, stands can transform into *Filipendulo-Arrhenatheretum*.

Anthoxantho odorati-Festucetum pseudovinae Juhász-Nagy 1959 [in *Cynosurion*; Cluster 17]

Lectotypus: Juhász-Nagy (1959), Table IV., Relevé 14., designated here.

Cluster 17 includes a type that is similar to the previous one in its environmental conditions, but it is more heavily grazed and the dominant species is usually *Festuca pseudovina* instead of *F. rupicola*. Most of the relevés are from Juhász-Nagy's (1959) tables of the typical form of *Anthoxantho-Festucetum pseudovinae*. In the original description no holotype relevé was selected, therefore we identify Relevé 14 in Table IV of Juhász-Nagy (1959) as a lectotype. Despite some similarities in species composition and environmental conditions between *Anthoxantho-Festucetum pseudovinae* and *Colchico-Festucetum rupicolae*, we suggest they are treated as two separate associations. That their dominant species differ may indicate differences in management or environmental factors and several species in the original description of the former are absent or rare in the relevés from the wide distribution range of the latter. Such characteristic elements mentioned by Juhász-Nagy (1959) are *Hieracium auriculoides*, *H. caespitosum*, *Viola pumila* and *Linum catharticum*, which could have been typical elements of grasslands on the Bereg Plain. The presence of grazing-tolerant species (e.g. *Veronica serpyllifolia*, *Myosotis stricta*) and the lack or a low frequency of mesophilous species of more humid regions (e.g. *Trisetum flavescens*, *Cynosurus cristatus*, *Moenchia mantica*) also indicate *Anthoxantho-Festucetum pseudovinae*. Since this is a low-grass pasture type with many grazing-tolerant species, we place this association in the alliance *Cynosurion*, in contrast to Borhidi et al. (2012) who assign it to *Arrhenatherion*. Most relevés are from the north-eastern corner of the Great Hungarian Plain and lowland areas in West Transdanubia. According to Juhász-Nagy (1959), this type was much more widespread on floodplains, but due to the decline in extensive animal husbandry and probably also a drop in the level of ground water in the Great Hungarian Plain, it became much rarer.

Alopecuro pratensis-Festucetum pseudovinae Juhász-Nagy 1959 [in *Cynosurion*; Cluster 18]

Alopecuro-Festucetum pseudovinae is a wetter substituent of *Anthoxantho-Festucetum pseudovinae* with more water-demanding species but similar, or with even a more marked effect of grazing. The relevés are from Juhász-Nagy's (1959) paper, which were included in the original description of this association. Soon after its description, Soó (1964) mentions it as a subassociation *Carici vulpinae-Alopecuretum pratensis festucetosum pseudovinae* within *Molinietalia*, but later Botta-Dukát (2004) proposes it be excluded from the syntaxa of wet meadows. Similar to the concept applied in Slovakia (Janišová et al. 2014), we consider *Alopecuro-Festucetum pseudovinae* an association in *Cynosurion*. This type develops on packed soils of wet meadows, as a result of heavy grazing. The stands are dominated by *Festuca pseudovina*, and taller grasses are usually not abundant. The accompanying species are remnants of the original wet habitats (e.g. *Alopecurus pratensis*, *Inula britannica*), disturbance-tolerant plants of lowland areas (e.g. *Eryngium planum*, *Galega officinalis*) and pioneer species (e.g. *Erophila verna*, *Anthemis arvensis*, *Ranunculus sardous*) but elements of the order *Arrhenatheretalia* are usually rare. On the Great Hungarian Plain, degraded wet meadows dominated by *Festuca pseudovina* are common in various environmental and land-use conditions, and their appropriate place in the syntaxonomic system needs to be clarified in future studies.

Cynosuro cristati-Lolietum perennis Br.-Bl. et De Leeuw 1936 [in *Cynosurion*; Cluster 30]

Synonym: *Lolio-Cynosuretum* Tx. 1937, for explanation of nomenclature, see Willner et al. 2013a

This association consists of overgrazed, nutrient-rich pastures on mesic or wet soils. They are usually dominated by *Trifolium repens*, *Cynodon dactylon*, or *Cynosurus cristatus*, while the most faithful species are *Lolium perenne*, *Bromus racemosus* agg., and *Poa annua*. However, in the moister stands, more hygrophilous and salt-tolerant species also occur, e.g. *Carex distans*, *Agrostis stolonifera* agg., and, (regionally) *Hordeum secalinum*. We use the name *Cynosuro-Lolietum* in a broad sense, because we include also those relevés that are from wetter habitats and are probably transitional towards *Deschampsion*. Their more accurate position should be investigated in the future. It can easily be separated from *Colchico-Festucetum rupicolae*, *Anthoxantho-Festucetum pseudovinae* and *Alopecuro-Festucetum pseudovinae* by the low cover of xerophilous *Festuca* species and high cover and frequency of nutrient-demanding, grazing-tolerant species (e.g. *Trifolium repens*, *Lolium perenne*, *Poa annua*, *Agrostis stolonifera*). This association was previously reported in the submontane and montane regions in Hungary (Borhidi et al. 2012), but it also occurs at lower altitudes, if the climate is humid enough to provide mesic conditions.

Brachypodio pinnati-Molinietum arundinaceae Klika 1939 [in *Cirsio-Brachypodion*; Cluster 26]

The relevés in Cluster 26 were collected from meadows in mountain ranges, dominated by *Brachypodium pinnatum* and containing species of semi-dry grasslands (e.g. *Cirsium pannonicum*, *Helianthemum ovatum*, *Carex montana*), acidic grasslands (e.g. *Viola canina*, *Luzula campestris*), forest edges (e.g. *Cruciata glabra*, *Genista germanica*, *Potentilla alba*) and *Molinion* meadows (e.g. *Molinia caerulea* agg., *Succisa pratensis*, *Gladiolus imbricatus*). Based on its mixed species composition, we identify this cluster as *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939, which until now was known only to occur in the Czech and Slovak parts of the Western Carpathians (Chytrý 2007, Škodová & Ujházy 2014, Chytrý et al. 2015). However, the stands in Hungary are rather fragmented and their development may also be a result of their special vegetation dynamics. These stands were mown in the past, but currently many of them are abandoned. After abandonment, *Brachypodium pinnatum* and *Molinia caerulea* agg. spread and can quickly become dominant. The occurrence of some forest species (e.g. *Convallaria majalis*, *Symphytum tuberosum* agg.) is probably due to the landscape context, that is, mixed patches of forest and meadows. The presence of forest and edge species is also due to the mass effect, since these stands are usually situated in smaller forest clearings. Stands with similar species composition are rare in Hungary, we have data only from a few locations in the Mátra, Bükk and Zemplén Mts. This association can be recognized as it contains xeromesic, mesic, wet grassland and forest edge elements. *Brachypodio-Molinietum* was assigned to *Bromion* by Chytrý (2007) and Škodová & Ujházy (2014), however, we follow the concept of Roleček et al. (2014) who classified it to *Cirsio-Brachypodion*.

Filipendulo vulgaris-Brometum erecti Hundt et Hübl ex Willner 2013 [in *Cirsio-Brachypodion*; Cluster 31]

In Cluster 31, the dominant species is *Bromus erectus* and is accompanied by a mixture of mesophilous and xero-mesophilous species, e.g. *Dianthus carthusianorum*, *Saxifraga bulbifera*, *Festuca rupicola*. In the Hungarian literature, this type is sometimes referred to as "*Arrhenathero-Brometum erecti* Balázs 1951", however this is an invalid name, since Balázs (1951) uses it only as a workname, which does not require the describing of a new syntaxon. "*Arrhenathero-Brometum*" is not mentioned by Borhidi et al. (2012) who assign similar stands to *Onobrychido viciifoliae-Brometum erecti* within the alliance

Bromion erecti. Illyés et al. (2009) did not support the presence of the *Bromion* alliance in Hungary, however, their data set probably did not contain enough relevés of the transitional types between *Brometalia erecti* and *Arrhenatheretalia* orders. According to Willner et al. (2013a, b), *Onobrychido-Brometum* and the *Bromion* alliance do not occur in the Carpathian Basin, thus such transitional types should not be identified as *Onobrychido-Brometum*. Instead, for the meadows dominated by *Bromus erectus* and containing species of semi-dry and mesic grasslands, they describe a new association: *Cirsio-Brachypodion*, *Filipendulo vulgaris-Brometum erecti* Hundt et Hübl ex Willner 2013. They also think the records of *Onobrychido-Brometum* (sensu Janišová et al. 2007) in Slovakia refer to *Filipendulo-Brometum*. We treat Cluster 31 as belonging to this association. In Hungary this type differs from *Arrhenatherion* associations in the dominance of *Bromus erectus* and the higher frequency of xerophilous species (e.g. *Centaurea scabiosa*, *Festuca rupicola*, *Thesium linophyllon*, *Seseli annuum*) and less nutrient-demanding species of intermittently wet to semi-dry sites (e.g. *Sesleria uliginosa*, *Sanguisorba officinalis*, *Betonica officinalis*). In Austria, there is a continuous transition between *Filipendulo-Brometum* and *Filipendulo-Arrhenatheretum*. In our classification, we identified Cluster 31, which is dominated by *Bromus erectus*, with *Filipendulo-Brometum*, and Cluster 11 that is (co-)dominated by other species, as *Filipendulo-Arrhenatheretum*, therefore their differentiation may be less problematic in Hungary. Besides the dominant species, *Filipendulo-Brometum* usually develops on drier and more calcareous sites than *Filipendulo-Arrhenatheretum*; for that reason, the proportion of xerophilous and calciphilous species is also indicative. *Filipendulo-Brometum* can be separated from other associations of *Cirsio-Brachypodion*, by the high cover of *Bromus erectus* and the presence of moisture-demanding species, while species of rocky habitats are usually absent.

Sanguisorbo minoris-Brometum erecti Illyés, Bauer et Botta-Dukát 2009 (in *Cirsio-Brachypodion*; Clusters 33–36]

Clusters 33 to 36 include dry to semi-dry grasslands dominated by *Bromus erectus* on shallow soils in calcareous mountains and on colline ranges. These clusters were identified as belonging to the association *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer et Botta-Dukát 2009. This syntaxon was described recently by Illyés et al. (2009) as the common, calciphilous semi-dry grassland in the Transdanubian Region with *Bromus erectus* as the dominant grass and many species of *Festuco-Brometea*. The generalist species of calcareous, dry grasslands (e.g. *Teucrium chamaedrys*, *Festuca valesiaca*, *Thymus pannonicus* agg., *Sanguisorba minor*) are common in this association. Several variants can be recognized. In stands on deep soils (mostly Cluster 33) and with a better nutrient- and water-supply, meadow species (e.g. *Lotus corniculatus* agg., *Arrhenatherum elatius*, *Knautia arvensis* agg.) are more frequent, however, they typically do not occur as abundantly as in *Filipendulo-Brometum*. In more open stands with eroded or shallow stony soils and rarely bare rock surfaces (mostly Cluster 34), calcareous species of shallow and dry soils (e.g. *Stipa capillata*, *S. pennata*, *Carex humilis*) are characteristic, although, such stands also contain indicators of grazing due to their past management regime (e.g. *Lepidium campestre*, *Eryngium campestre*). Stands situated mosaically in small clearings in thermophilous oak forests (mostly Cluster 36) are rich in forest edge species (e.g. *Euphorbia angulata*, *Campanula persicifolia*, *Geranium sanguineum*). This association can be separated from *Filipendulo-Brometum* by the lower percentage cover or absence of some rather acidophilous species (e.g. *Luzula campestris, Moenchia mantica, Anthoxanthum odoratum*) and a higher frequency of calciphilous rocky and dry grassland species (e.g. *Acinos arvensis, Anthyllis vulneraria* subsp. *polyphylla, Aster linosyris, Euphorbia seguieriana, Hippocrepis comosa, Stachys recta*) than of mesophilous species. In the Slovak and Czech literature *Scabioso ochroleucae-Brachypodietum pinnati* is reported thriving in similar habitats, which are eventually dominated by *Bromus erectus*. However, *Sanguisorbo-Brometum* lacks many of the diagnostic species of *Scabioso-Brachypodietum*, e.g. *Cirsium acaule*, *Carlina acaulis*, *Ononis spinosa* and *Linum catharticum*. Moreover, *Brachypodium pinnatum* is rather rare in *Sanguisorbo-Brometum* (see also Illyés et al. 2009), while it is the most typical dominant species in *Scabioso-Brachypodietum*. For its separation from other associations of *Cirsio-Brachypodion*, see therein.

Polygalo majoris-Brachypodietum pinnati Wagner 1941 [in *Cirsio-Brachypodion*; Clusters 41–43]

This association includes species-rich, semi-dry grasslands in the colline region in which *Brachypodium pinnatum* and sometimes *Bromus erectus* or *Inula ensifolia* are dominant, with a wide pool of termophilous and calciphilous species, e.g. *Adonis vernalis*, *Polygala major*, *Carex halleriana*, *Onobrychis arenaria*, *Pulsatilla grandis*. According to Borhidi et al's (2012) interpretation, there are two variants of this syntaxon in Hungary: a western one containing sub-Mediterranean and Pontic-Pannonian elements, and an eastern one with montane and continental species. Illyés et al. (2009) identifies a small cluster with a distinct distribution in the Bükk Mts with many montane species (e.g. *Carlina acaulis*, *Dracocephalum ruyschiana*, *Primula elatior*) as the eastern variant, but does not support the existence of the western type. We could not confirm this montane type in our classification as a variant of *Polygalo-Brachypodietum*, but according to the descriptions and evaluations of Illyés et al. (2009), it is probably more similar to our Cluster 26, i.e. to *Brachypodio-Molinietum* and should be placed in this association or in transition to it. It is notable that according to Škodová & Ujházy (2014) *Brachypodio-Molinietum* in Slovakia is in transition to *Polygalo-Brachypodietum*. Such transitional subtypes contain many of the diagnostic species of *Polygalo-Brachypodietum*, but also mesophilous species. In our classification, *Polygalo-Brachypodietum* differs from *Sanguisorbo-Brometum* in the higher cover of *Brachypodium pinnatum* and higher frequency and cover of forbs (e.g. *Inula ensifolia*, *Chamaecytisus austriacus* agg., *Pulsatilla grandis*, *Polygala major, Onobrychis arenaria, Scorzonera hispanica, Cirsium pannonicum, Peucedanum cervaria*), among which there is a high proportion of Pontic-Pannonian species. *Polygalo-Brachypodietum* harbours fewer montane, mesophilous and *Molinion*-species than *Brachypodio-Molinietum*.

Euphorbio pannonicae-Brachypodietum pinnati Horváth 2010 [in *Cirsio-Brachypodion*; Clusters 44–48]

This association is a semi-dry grassland dominated by *Brachypodium pinnatum*, which occurs in the Pannonian loess-covered lowlands and foothills. Similarly to *Polygalo-*

Brachypodietum, it is also rich in forbs but mostly those preferring deep soils on loess (e.g. *Euphorbia glareosa*, *Filipendula vulgaris*, *Thalictrum minus*, *Inula hirta*, *Ranunculus polyanthemos*). It has a few loess specialist species (e.g. *Nepeta parviflora*, *Ajuga laxmannii*, *Viola ambigua*, *Taraxacum serotinum*), which are very distinctive elements, however, since they are rare even within this type, their fidelity values were low. This community differs from *Polygalo-Brachypodietum* in the lower proportion of Pontic and sub-Mediterranean species (e.g. *Aster amellus*, *Polygala major*, *Inula ensifolia*, *Pulsatilla grandis, Carex halleriana*). As a subtype of *Euphorbio-Brachypodietum* is dominated by *Bromus erectus*, it is likely to be confused with *Sanguisorbo-Brometum.* However, in *Euphorbio-Brachypodietum* species that occur in shallow, dry soils (e.g. *Acinos arvensis*, *Sanguisorba minor*, *Dianthus pontederae*, *Hippocrepis comosa*, *Petrorhagia saxifraga*) are least frequent.

Trifolio medii-Brachypodietum pinnati Illyés, Bauer et Botta-Dukát 2009 [in *Cirsio-Brachypodion*; Clusters 57–59]

Clusters 57 to 59 include grasslands dominated by *Danthonia alpina*, *Brachypodium pinnatum*, or *Helictotrichon adsurgens* in the North Hungarian Mountains. They contain many forest edge species (e.g. *Pulmonaria mollissima*, *Trifolium medium*, *Aconitum anthora*, *Dictamnus albus*), species which are shared with mesic meadows (e.g. *Briza media*, *Filipendula vulgaris*, *Salvia pratensis*) and acidotolerant species (e.g. *Potentilla alba*, *Luzula campestris* agg.). This association was described under the name *Trifolio medii-Brachypodietum pinnati* by Illyés et al. (2009). It differs from *Polygalo-Brachypodietum* and *Euphorbio-Brachypodietum* in higher frequencies of forest edge species, mesophilous and acidophilous grassland plants and lower proportion of Pontic and Pannonian species. It can be separated from *Brachypodio-Molinietum* by the lower proportion of montane and wet meadow species (e.g. *Cruciata glabra*, *Potentilla erecta*, *Carex pallescens*, *Viola canina*, *Succisa pratensis*, *Molinia caerulea*), although some generalist species that are frequent also in *Molinion* meadows (e.g. *Betonica officinalis*, *Serratula tinctoria*, *Potentilla alba*) can occur in *Trifolio-Brachypodietum*. Considering the definitions and descriptions of *Brachypodio-Molinietum* (Chytrý 2007, Janišová et al. 2007, Škodová & Ujházy 2014), relevés fulfilling our criteria of *Trifolio-Brachypodietum* were probably previously assigned to *Brachypodio-Molinietum* in Slovakia. The relationship between these two associations needs to be clarified in the future.

Description of types assigned to alliances without identification at the association level

Sanguisorba officinalis-type [in *Arrhenatherion*; Cluster 27]: Cluster 27 includes a type that occurs in the most humid, western part of Transdanubia on slightly acidic soils. The most common dominant species is *Sanguisorba officinalis*, which is accompanied by elements of *Arrhenatherion* (e.g. *Trisetum flavescens*, *Tragopogon orientalis*, *Festuca rubra*), *Polygono-Trisetion* (e.g. *Hypericum maculatum* agg., *Pimpinella major*) and *Violion caninae* (e.g. *Viola canina*, *Danthonia decumbens*). The co-occurrence of these species groups points to the *Poo-Trisetetum flavescentis* association in *Arrhenatherion*. However, *Poo-Trisetetum* is known to be very variable and usually occurs in intensively mown meadows in humid areas, mostly dominated by *Trisetum flavescens*, *Poa trivialis*, *P. pratensis*, *Festuca rubra*, and other medium-tall grasses (Dierschke 1997, Chytrý

2007, Uhliarová et al. 2014). In contrast, the stands in Cluster 27 are managed extensively by infrequent mowing (maximum once a year), resulting in a high cover of forbs (e.g. *Sanguisorba officinalis*, *Betonica officinalis*, *Hieracium umbellatum*) rather than graminoids. Despite its distinctness, we could not identify Cluster 27 as either *Poo-Trisetetum* or other associations previously known from Hungary and neighbouring countries. Further analyses that include Austrian and Slovenian data of montane meadows may help clarify its syntaxonomical position.

Agrostis capillaris-Trifolium pratense-type [in *Cynosurion*; Cluster 21]: Cluster 21 includes relevés from mesic pastures and nutrient-poor meadows in colline and montane sites. The dominant species (*Agrostis capillaris*, *Trifolium pratense*, *Holcus lanatus*), and also the constant, and diagnostic species (e.g. *Anthoxanthum odoratum*, *Festuca rubra*, *Trisetum flavescens*, *Clinopodium vulgare*) are generalists, therefore, it is difficult to delimit its variation along environmental and land-use gradients, or identify the association to which it belongs. However, there are some typical elements of pastures among the diagnostic species, e.g. *Plantago major*, *Cynosurus cristatus*, *Trifolium dubium* and *Phleum pratense* agg. (mostly *Phleum bertolonii*), thus we consider this type to belong to *Cynosurion*. Although *Festuco commutatae-Cynosuretum* is mentioned as the mesic pasture association in colline and montane regions (e.g. Soó 1973, Borhidi et al. 2012), its descriptions often highlight the presence of montane species, e.g. *Alchemilla* spp., *Danthonia decumbens*, *Carlina acaulis*, *Rhinanthus alectorolophus*, *Rh. wagneri*, which are rare or absent in this cluster. According to Ellmauer & Mucina (1993), there are several elements of nutrient-poor grasslands among the diagnostic species of *Festuco-Cynosuretum*, e.g. *Thymus pulegioides* and *Potentilla erecta*, which are also not typically in Cluster 21. Therefore, we assign this cluster to *Cynosurion*, and note that the identification at the association level needs further study.

Vulpia-Festuca rubra-grasslands [in *Cynosurion*; Cluster 29]: Cluster 29 includes relevés from overgrazed pastures and old-fields on eroded soils. It is characterized by species of disturbed, open, nutrient-poor vegetation, like *Sherardia arvensis*, *Vulpia* spp., *Aphanes arvensis* agg. and *Trifolium striatum*, while the dominant species is *Festuca rubra*. This type is likely to be a disturbed variant of other associations in the *Cynosurion* alliance. It is probably more widespread on leached soils in the more humid regions of Hungary than indicated by our database, because such stands are often considered as disturbed, pioneer or transitional types and thus rarely recorded by phytosociologists. Due to the lack of data, we cannot currently evaluate it in more detail.

Linum tenuifolium-Brachypodium pinnatum-type [in *Cirsio-Brachypodion*; Clusters 55–56]: Cluster 55 and 56 are grasslands on calcareous, shallow soils, dominated by *Brachypodium pinnatum*. Accompanying species are xerophilous and calciphilous, e.g. *Linum tenuifolium*, *Carex liparicarpos*, *Seseli hippomarathrum*, *Teucrium montanum*. This type is similar to *Lino tenuifolii-Brachypodietum pinnati* (Dostál 1933) Soó 1971 according to the description of Borhidi et al. (2012). According to Soó (1971) this name includes *Polygalo-Brachypodietum* from Austria (Wagner 1941), while Škodová (2014) considers it as a syntaxonomical synonym of *Scabioso-Brachypodietum* Klika 1933. Since the nomenclature of *Scabioso-Brachypodietum* and its delimitation from other associations is unclear, we avoid using this name. In this cluster, Pontic and Pannonian elements (e.g. *Aster amellus*, *Polygala major*, *Inula ensifolia*) and shared species of semi-dry and mesic grasslands (e.g. *Campanula glomerata*, *Filipendula vulgaris*, *Ranunculus polyanthemos*, *Salvia pratensis*) are rarer, while some species of drier grasslands (e.g. *Festuca valesiaca*, *Carex liparicarpos, Teucrium montanum*) are more frequent. The occurrence of grazing tolerant species (e.g. *Ononis spinosa*, *Eryngium campestre*, *Carlina vulgaris*) may be an indicator of former pasturing that may have resulted in the lower species richness. Despite the dominant species, its environmental background and species pool are similar to *Sanguisorbo-Brometum* on deep soils.

Description of out-of-scope types with nomenclatural relations to Arrhenatheretalia or Brometalia erecti

Festuca rubra-type [in *Violion caninae*; Cluster 22]: Cluster 22 comprises nutrient-poor, montane, mesic grasslands that are either grazed or recently abandoned. The dominant species are *Festuca rubra*, *Agrostis capillaris*, *Galium verum* and *Anthoxanthum odoratum*, and the differential species are *Thymus pulegioides*, *Viola canina*, *Solidago virgaurea* and *Veronica officinalis*. Previously mesic grasslands at nutrient-poor sites dominated by *Festuca rubra* and *Agrostis capillaris* were traditionally assigned to *Anthyllido-Festucetum rubrae* (in *Arrhenatherion*) in Hungary; however, the species composition of Cluster 22 does not match its descriptions (Soó 1971, Borhidi 2003). Moreover, there are issues concerning the separation of this association from other nutrient-poor grasslands. According to Borhidi et al. (2012), *Anthyllido-Festucetum* includes three subassociations: *typicum*, *agrostidetosum* and *arrhenatheretosum*; each of them relying on nomenclatural tables originally published by Máthé & Kovács (1960) as subassociations of *Festuco-Cynosuretum* (but see *Diantho-Arrhenatheretum* for our concept of the *Arrhenatherum*-dominated type). However, Jurko (1974) assigns these tables to *Anthoxantho-Agrostietum tenuis* Sillinger 1930. The differentiation between *Anthyllido-Festucetum rubrae* and *Anthoxantho-Agrostietum tenuis* is never explicitly made by any authors, and it is very likely that they should be considered synonyms (or *pro parte* synonyms). However, there is also a disagreement among experts in other countries on the interpretation of *Anthoxantho-Agrostietum*. Jurko (1974) classifies many nutrient-poor grassland types in this association within *Cynosurion*, including variants that are now treated under *Violion caninae*. More recently authors tend to use this syntaxon name in a narrow sense, although, in slightly different ways, which is also mirrored by its assignment to different alliances. Chytrý (2007) assigns *Anthoxantho-Agrostietum* to *Cynosurion*, Janišová et al. (2007), Rozbrojová et al. (2010), and Uhliarová et al. (2014) to *Arrhenatherion*, while Willner et al. (2013a) consider it as a part of *Violion caninae*. The species composition of Cluster 22 is also very similar to *Campanulo rotundifoliae-Dianthetum deltoidis* (in *Violion caninae*) in the Czech Republic according to Chytrý (2007). However, according to Ujházy & Kliment (2014), an important feature of this association is the constant occurrence and significant (over 5%) cover of *Nardus stricta*, which is absent in Cluster 22. The delimitation between *Campanulo-Dianthetum* and *Anthoxantho-Agrostietum* is also unclear, therefore, Willner et al. (2013a) treats the former as a part of *"Anthoxantho-Agrostietum s. lat."*. The syntaxonomy of nutrient-poor, mesic grasslands obviously needs a supra-national revision, therefore, we cannot identify Cluster 22 at the level of association. Since in this type the proportion of mesotrophic species of *Arrhenatherion* and *Cynosurion* is rather low, similarly to Willner et al. (2013a) we place it in *Violion caninae*, which is outside the scope of this paper.

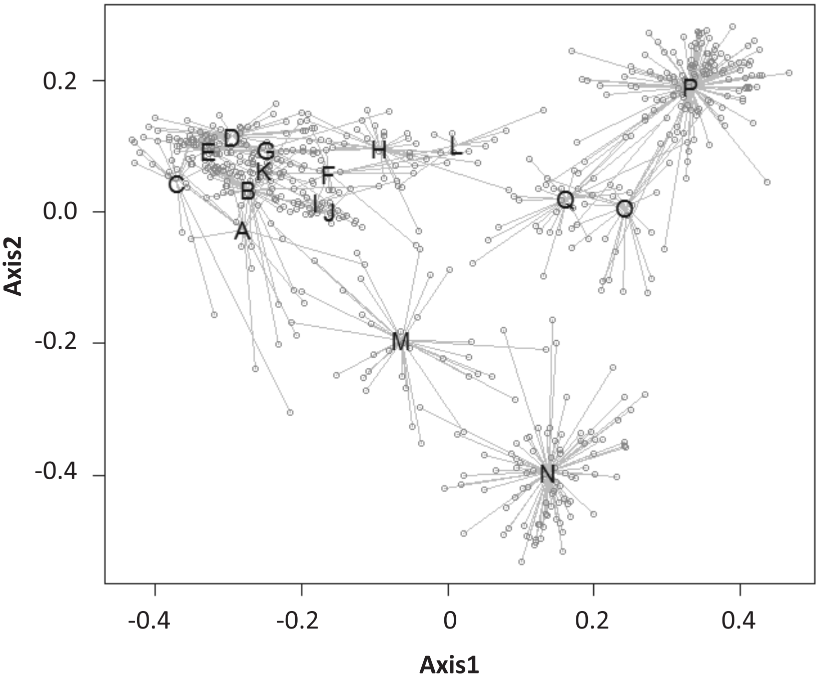

Fig. 3. – Principal coordinates analysis of all the associations distinguished. A – *Ranunculo-Arrhenatheretum*; B – *Tanaceto-Arrhenatheretum*; C – *Pastinaco-Arrhenatheretum*; D – *Filipendulo-Arrhenatheretum*; E – *Ranunculo-Alopecuretum*; F – *Diantho-Arrhenatheretum*; G – *Anthoxantho-Festucetum pratensis*; H – *Colchico-Festucetum*; I – *Anthoxantho-Festucetum pseudovinae*; J – *Alopecuro-Festucetum pseudovinae*; K – *Cynosuro-Lolietum*; L – *Brachypodio-Molinietum*; M – *Filipendulo-Brometum*; N – *Sanguisorbo-Brometum*; O – *Polygalo-Brachypodietum*; P – *Euphorbio-Brachypodietum*; Q – *Trifolio-Brachypodietum*.

Stipenion tirsae Borhidi 2012 [in *Festucion valesiacae*; Cluster 60]: Cluster 60 includes a type dominated by *Stipa tirsa*, and this is also not within the scope of this paper. Although, similar grasslands (with the name *Stipetum tirsae* Meusel 1938) are included in *Cirsio-Brachypodion* by Dengler et al. (2012), we follow a more common viewpoint that considers *Stipenion tirsae* as a separate suballiance in *Festucion valesiacae* (Borhidi et al. 2012; see also Chytrý 2007, Hegedüšová Vantarová & Škodová 2014).

Ordinations

In the principal coordinates analysis of all the associations identified, 9.6% and 6.2% of the total variation were explained by the first two axes, respectively. *Arrhenatheretalia* and *Brometalia erecti* were separated along Axis 1 (Fig. 3), with more mesic associations on the left and semi-dry associations on the right side of the diagram. Associations of *Brometalia* containing a high proportion of mesophilous species (*Brachypodio-Molinietum*, *Filipendulo-Brometum*) were placed in intermediate positions. The two driest associations, *Sanguisorbo-Brometum* and *Euphorbio-Brachypodietum* are well separated from all the other associations, while *Polygalo-Brachypodietum* and *Trifolio-*

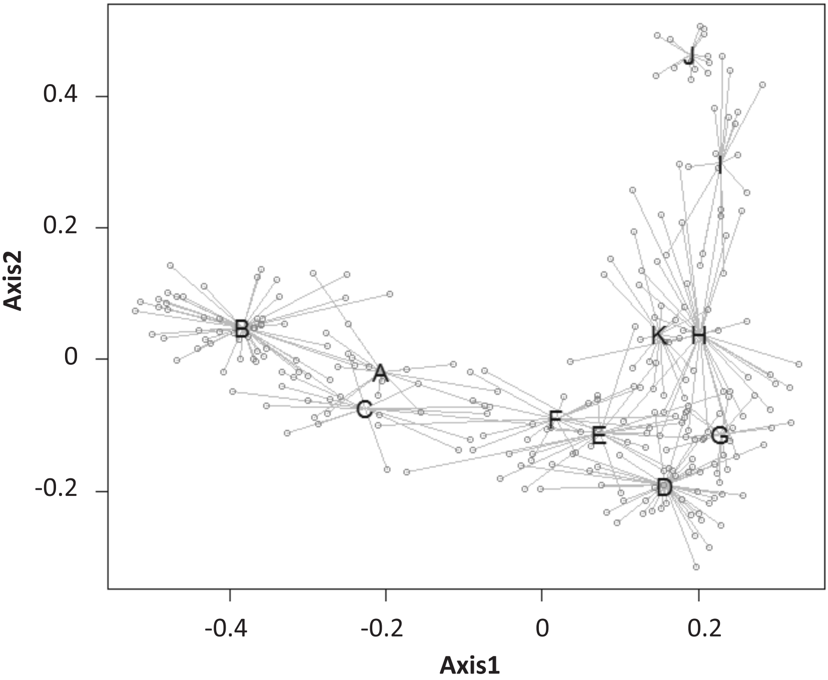

Fig. 4. Principal coordinates analysis of the associations in *Arrhenatheretalia* order. A – *Ranunculo-Arrhenatheretum*; B – *Tanaceto-Arrhenatheretum*; C – *Pastinaco-Arrhenatheretum*; D – *Filipendulo-Arrhenatheretum*; E – *Ranunculo-Alopecuretum*; F – *Diantho-Arrhenatheretum*; G – *Anthoxantho-Festucetum pratensis*; H – *Colchico-Festucetum*; I – *Anthoxantho-Festucetum pseudovinae*; J – *Alopecuro-Festucetum pseudovinae*; K – *Cynosuro-Lolietum*.

Brachypodietum are in a central position in the range in variation of *Cirsio-Brachypodion*. Fig. 4 shows the ordination of *Arrhenatheretalia* associations. The first two axes accounted for 11.04% and 5.74% of the total variation, respectively. Along Axis 1 the types dominated by *Arrhenatherum elatius* (*Tanaceto-Arrhenatheretum*, *Ranunculo-Arrhenatheretum*, *Pastinaco-Arrhenatheretum*) are on the left. *Cynosurion* communities are separated along Axis 2, with *Anthoxantho-Festucetum pseudovinae* and *Alopecuro-Festucetum pseudovinae* in the most extreme position along this gradient, while *Colchico-Festucetum* and *Cynosuro-Lolietum* are closer to *Arrhenatherion* communities. The species-rich meadow associations with various management and environmental backgrounds (i.e. *Filipendulo-Arrhenatheretum*, *Anthoxantho-Festucetum pratensis*, *Diantho-Arrhenatheretum*, *Ranunculo-Alopecuretum*) are close to each other in the bottom right-hand corner of the diagram.

Syntaxonomical summary

On the basis of our classification, we suggest the following system for the mesic and semi-dry grasslands in Hungary:

Order: *Arrhenatheretalia* Tx. 1931 (in *Molinio-Arrhenatheretea*)
1. Alliance: *Arrhenatherion elatioris* Koch 1926
    - 1.1. Association: *Ranunculo bulbosi-Arrhenatheretum* Ellmauer 1993
    - 1.2. Association: *Tanaceto vulgaris-Arrhenatheretum* Fischer ex Ellmauer 1993
    - 1.3. Association: *Pastinaco sativae-Arrhenatheretum* (Knapp 1954) Passarge 1964
    - 1.4. Association: *Filipendulo vulgaris-Arrhenatheretum* Hundt et Hübl ex Ellmauer 1995
    - 1.5. Association: *Diantho deltoidis-Arrhenatheretum* (Máthé et Kovács 1960) Lengyel nom. nov.
    - 1.6. Association: *Anthoxantho odorati-Festucetum pratensis* Borhidi 2012
    - 1.7. Association: *Ranunculo repentis-Alopecuretum pratensis* Ellmauer 1993
2. Alliance: *Cynosurion cristati* Tüxen 1947
    - 2.1. Association: *Colchico autumnalis-Festucetum rupicolae* Lengyel, Csiky, Dénes et Király ass. nov.
    - 2.2. Association: *Anthoxantho odorati-Festucetum pseudovinae* Juhász-Nagy 1959
    - 2.3. Association: *Alopecuro pratensis-Festucetum pseudovinae* Juhász-Nagy 1959
    - 2.4. Association: *Cynosuro cristati-Lolietum perennis* Br.-Bl. et De Leeuw 1936

Order: *Brometalia erecti* Br.-Bl. 1936 (in *Festuco-Brometea*)
1. Alliance: *Cirsio pannonici-Brachypodion pinnati* Hadač et Klika 1944
    - 1.1. Association: *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939
    - 1.2. Association: *Filipendulo vulgaris-Brometum erecti* Hundt et Hübl ex Willner 2013
    - 1.3. Association: *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer et Botta-Dukát 2009
    - 1.4. Association: *Polygalo majoris-Brachypodietum pinnati* Wagner 1941
    - 1.5. Association: *Euphorbio pannonicae-Brachypodietum pinnati* Horváth 2010
    - 1.6. Association: *Trifolio medii-Brachypodietum pinnati* Illyés, Bauer et Botta-Dukát 2009

With the above suggestions, we introduce significant changes in the syntaxonomy of the *Arrhenatheretalia* and *Brometalia erecti* orders in Hungary. Five new associations are included in the order *Arrhenatherion*. Four of them (*Ranunculo bulbosi-Arrhenatheretum*, *Filipendulo-Arrhenatheretum*, *Tanaceto-Arrhenatheretum*, *Ranunculo-Alopecuretum*) are adopted from the Austrian and Slovak literature, and it is proposed that a former subassociation be raised to the association level with the name *Diantho-Arrhenatheretum*. We exclude *Anthyllido-Festucetum rubrae* from the *Arrhenatherion* communities in Hungary. *Anthoxantho-Festucetum pseudovinae*, which was assigned to *Arrhenatherion* by Borhidi et al. (2012), is moved to *Cynosurion*. *Alopecuro-Festucetum pseudovinae* as a separate association appeared in synthetic reviews for the first time in literature on Hungarian vegetation after its original publication. *Colchico-Festucetum rupicolae* is described as a new association. According to Willner et al. (2013a), the name *Cynosuro-Lolietum* was adopted in order to replace the invalid name *Lolio-Cynosuretum*. Neither our analyses nor our field experience support the presence of the *Phyteumo-Trisetion* alliance in Hungary. In *Brometalia erecti*, there are the most fundamental changes regarding the treatment of *Bromion erecti*. *Carlino acaulis-Brometum* is not recognized as a separate cluster in our analysis. The type that is mentioned as *Onobychido-Brometum* by Borhidi et al. (2012) is identified with *Filipendulo-Brometum* (belonging to *Cirsio-Brachypodion*), which is a new element in the list of Hungarian syntaxa. Therefore, we suggest rejecting *Carlino-Brometum* and *Onobrychido-Brometum,* which are both included in *Bromion*, in Hungary. We detected *Brachypodio-Molinietum* for the first time in Hungary and assigned it to *Cirsio-Brachypodion*. Apart from detecting *Filipendulo-Brometum* and *Brachypodio-Molinietum* as associations new to this country, our findings on *Cirsio-Brachypodion* are similar to those of Illyés et al. (2009). We confirm the presence of *Polygalo-Brachypodietum*, *Euphorbio-Brachypodietum*, *Trifolio-Brachypodietum* and *Sanguisorbo-Brometum* in Hungary. We did not recognize and interpret *Poo badensis-Caricetum montanae* (see Varga 1997) and *Lino-Brachypodietum* unambiguously; therefore, we suggest removing the latter two from the list of Hungarian syntaxa. We separate four vegetation types belonging to *Arrhenatheretalia* or *Brometalia* but are unable to identify them at the level of associations. Further studies should focus on the clarification of their position.

Possible biases and open questions

Present study is currently the most comprehensive synthesis of mesic and semi-dry grasslands in Hungary that is based on the statistical analysis of a large data set of phytosociological relevés. The size of the data set used is smaller than that used in certain national syntheses (Chytrý 2007, Hegedüšová Vantarová & Škodová 2014), however, we still consider it sufficient for detecting the most significant types in Hungary. Although, we paid particular attention to fully including all the compositional variation in the target syntaxa, there are differences among regions in the degree of representativeness. Clearly, areas that were subject to more detailed, recent regional studies (e.g. Bakony Region: Bauer 2012; South Transdanubia: Lengyel et al. 2012b) are better represented than others, and it is possible that not all such inequalities were corrected by using geographically stratified HCR resampling. Moreover, geographical biases may have interacted with the uneven temporal coverage. Relevés by Juhász-Nagy (1959) from the Bereg Plain played a big role in the recognition of *Anthoxantho-Festucetum pseudovinae* and *Alopecuro-Festucetum pseudovinae*, since Cluster 17 and 18 include almost only these relevés. At the time of sampling, in the 1950s, the management of meadows and pastures may have been different from currently, not only on the Bereg Plain, but across the country (Molnár et al. 2012). Moreover, the Bereg Plain is a rather special and marginal part of the distribution of mesic grasslands due to its continental climate. In addition, comparison of old and recent phytosociological data is always biased due to differences in the concept of sampling and taxonomy (Podani 2006). In addition, the relevés of Juhász-Nagy (1959) lack information on plot size and percentage covers of rare species, however, it is likely that these shortcomings had an insignificant influence on the classification. Unfortunately, we have no more recent data from the Bereg Plain. For these reasons, we admit that biogeographical patterns, temporal changes in management and conceptual differences in the methodology may have both equally contributed to the separation of these two clusters, and therefore, the information on these types presented here should be interpreted with caution. Nevertheless, the *Festuca rupicola*-dominated relevés of Juhász-Nagy (1959) are classified together with many relevés from Transdanubia with clearly similar habitat conditions, which can be interpreted as a positive example of the applicability of old data for current investigations.

During the evaluation of types (i.e. one or more clusters assigned to the same low syntaxon) we only considered relevés with positive silhouette values, i.e. those that are more similar to the other relevés in the same type than relevés of the most similar other type. Following this decision, separations between types became clearer, which facilitated their interpretation. However, it is important to bear in mind that our descriptions refer to the most typical forms of each association (or their variants, in some cases). Undoubtedly, transitional stands do exist between several types and many of them cannot be reliably identified syntaxonomically.

In our classification we aimed to identify vegetation types at the association level, however, no revisions of associations can avoid questions related to higher-level syntaxa. Despite many arguments about their nomenclature and interpretation, e.g. *Brometalia erecti*, regarding the treatment of orders and alliances we followed the concept of Borhidi et al. (2012).

We clustered the data set using a relatively fine resolution (60 clusters) and then evaluated relationships between clusters using a minimum spanning tree, literature data and field experience. Then, certain clusters were merged, if they were judged as belonging to the same association. For several associations, when it was reasonable, we preferred to adopt names from the literature of neighbouring countries in order to reduce idiosyncrasy in the syntaxonomy of Hungarian grasslands. Such adoptions were done on the basis of informal examination of phytosociological data or textural descriptions of associations in reference literature, but no quantitative approaches were applied for the assignment of unclassified relevés to existing types. Although, several supervised or semi-supervised methods are published with this aim (van Tongeren et al. 2008, Tichý et al. 2014), due to the strong biogeographical pattern in species composition of grasslands, we experienced the limitations of using these methods when the geographical origin of the reference data differed from that of the relevés to be classified. Due to the lack of quantitative support for the adoption of certain names used in the literature of other countries and for rejection of names previously used in Hungary, in the future, the distribution and geographical variation of grassland syntaxa should be revised in a supra-national analysis. Such broader-scale investigations should be supplemented by studies at local and regional scales with the aim of revealing dynamics, local variation and conservation aspects of these threatened vegetation types.

See www.preslia.cz for Electronic Appendices 1–4

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Souhrn

Mezická a mírně suchá travinná společenstva patří mezi nejcennější a druhově nejbohatší antropogenní biotopy v Maďarsku. Přestože jsou ochranářsky velmi ceněné, jejich vegetační diverzita a syntaxonomie byly dlouho přehlíženy. Tento článek proto přináší první syntézu a syntaxonomickou revizi tohoto typu vegetace v Maďarsku, založenou na numerické klasifikaci řádu *Arrhenatheretalia* a aktualizaci klasifikace řádu *Brometalia erecti*. Celkem 1204 snímků bylo klasifikováno do 60 shluků, které byly spojeny do asociací pomocí metody 'minimum spanning tree' a expertního zhodnocení druhového složení. Pro každou asociaci je uvedeno a diskutováno její druhové složení, zeměpisné rozšíření a ekologie. Celkem bylo rozlišeno 11 asociací ve dvou svazech řádu *Arrhenatheretalia*. V rámci svazu *Arrhenatherion* jsme převzali několik jmen asociací z vegetačních přehledů jiných zemí a jedno jméno je navrženo nově. V naší koncepci zahrnuje svaz *Arrhenatherion* mezo-hygrofilní asociaci *Ranunculo-Alopecuretum*, dále *Filipendulo-Arrhenatheretum* a *Anthoxantho-Festucetum pratensis*, což jsou louky s kolísající vodní hladinou, ale odlišným zeměpisným rozšířením, *Pastinaco-Arrhenatheretum*, asociaci mezických luk s výrazným zastoupením generalistů, *Ranunculo bulbosi-Arrhenatheretum*, charakterizovanou přítomností druhů snášejících sucho a méně náročných na obsah živin, *Tanaceto-Arrhenatheretum*, typickou zastoupením ruderálních druhů, a *Diantho-Arrhenatheretum*, ve které roste velký počet druhů horských luk. Mezi čtyři asociace svazu *Cynosurion* patří *Cynosuro-Lolietum*, vyskytující se na intenzivně pasených trávnících na živinami bohatých mezických nebo vlhkých půdách v oblastech s humidním klimatem; intenzivní pastva je typická i pro *Alopecuro-Festucetum pseudovinae*, tuto asociaci však najdeme v oblastech s kontinentálnějším klimatem a na zhutnělých půdách. Poslední dvě asociace svazu *Cynosurion*, *Anthoxantho-Festucetum pseudovinae* a *Colchico-Festucetum rupicolae*, jsou vázány na mezické nížinné pastviny a zahrnují některé xerofilní druhy, navzájem se však liší intenzitou pastvy a regionální zásobou druhů. Poprvé byly v Maďarsku zjištěny dvě asociace svazu *Cirsio-Brachypodion*, jež tvoří přechod k mezičtějším typům travinných společenstev – *Filipendulo-Brometum* se subatlantickým rozšířením a *Brachypodio-Molinietum*, vázané spíše na horské oblasti Karpat. Zjistili jsme, že se v Maďarsku vyskytují též *Sanguisorbo-Brometum*, běžné společenstvo polosuchých trávníků na kamenitých půdách v Podunají, *Polygalo-Brachypodietum*, kolinní typ se zastoupením mnoha pontických druhů, *Trifolio-Brachypodietum*, asociace spíše zalesněných horských oblastí, a *Euphorbio-Brachypodietum*, společenstvo polosuchých trávníků na panonských spraších. Vegetace svazů *Phyteumo-Trisetion* a *Bromion erecti* se naopak v Maďarsku pravděpodobně nevyskytuje.

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