PHYTON

ANNALES REI BOTANICAE

VOL. 52, FASC. 2

HORN (AUSTRIA)

APUD FERDINANDUM BERGER & FIL.

2012

PHYTON 52 (2): 177–320

19. 12. 2012

ISSN 0079-2047

PHYTON

ANNALES REI BOTANICAE

VOL. 52, FASC. 2 PAG. 177–320 19. 12. 2012

Phyton (Horn, Austria)	**Vol. 52**	Fasc. 2	177–194	19. 12. 2012

Beckmannia eruciformis Vegetation in the Pannonian Basin (Central and South-Eastern Europe)

By

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With 3 Figures

Received July 4, 2011

Key words: Beckmannion eruciformis, *Beckmannia eruciformis, Poaceae, Poeae*. – Ecology, phytosociology, saline vegetation. – Flora of the Pannonian Basin, Hungary, Romania, Slovakia.

Summary

DÍTĚ D., HRIVNÁK R., MELEČKOVÁ Z., ELIÁŠ P. jun. & DAJIĆ-STEVANOVIĆ Z. 2012. *Beckmannia eruciformis* vegetation in the Pannonian Basin (Central and South-Eastern Europe) – Phyton (Horn, Austria) 52 (2): 177–194, with 3 figures.

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Vegetation with the presence of *Beckmannia eruciformis* (L.) Host (*Poaceae-Poeae*) was studied using both published and authors' field data for the territory of the Pannonian Basin (Slovakia, Hungary and Romania). The analysis of the total of 95 phytosociological relevés enabled distinguishing seven different *B. eruciformis* vegetation types, belonging to four vegetation classes: the Isoëto-Nanojuncetea (Cluster 1), Phragmito-Magnocaricetea (Clusters 2–3), Molinio-Arrhenatheretea (Cluster 4) and Festuco-Puccinellietea (Clusters 5–7). The results indicate that the ecological optimum of *B. eruciformis* has been found for slightly saline and periodically flooded soils in stands of the class Festuco-Puccinellietea, alliance Beckmannion eruciformis Soó 1933 (Cluster 5), where the species exhibited the highest values of the coverage (cover value 3). Based on the Borhidi indicator values, it was found that moisture was the most significant ecological factor influencing the variability of *B. eruciformis* vegetation (Spearman correlation coefficient with the first DCA axis was –0.811, $P < 0.001$), followed by the nutrient content in the soil (–0.559, $P < 0.001$). In addition to the relevance and review of use in the botanical literature of the syntaxa, the Agrostio stoloniferae-Beckmannietum eruciformis Rapaics ex Soó 1930 was discussed. Short comments concerning *Beckmannia eruciformis*-dominated stands in other parts of Eastern and Southeastern Europe are also provided.

Zusammenfassung

Dítě D., Hrivnák R., Melečková Z., Eliáš P. jun. & Dajić-Stevanović Z. 2012. *Beckmannia eruciformis* vegetation in the Pannonian Basin (Central and South-Eastern Europe). [*Beckmannia eruciformis*-Vegetation in der Pannonischen Tiefebene (Zentral- und Südosteuropa)]. – Phyton (Horn, Austria) 52(2): 177–194, mit 3 Abbildungen.

Vegetationsaufnahmen aus der Literatur sowie eigene Aufnahmen mit Vorkommen von *Beckmannia eruciformis* (L.) Host (*Poaceae-Poeae*) aus der pannonischen Tiefebene (Slowakei, Ungarn und Rumänien) wurden zusammen mit Literaturdaten analysiert. Die Analyse von 95 Vegetationsaufnahmen ermöglichte die Unterscheidung von sieben unterschiedlichen Vegetationstypen (Clustern) mit *B. eruciformis*, die den vier Vegetationsklassen Isoëto-Nanojuncetea (Cluster 1), Phragmito-Magnocaricetea (Cluster 2–3), Molinio-Arrhenatheretea (Cluster 4) und Festuco-Puccinellietea (Cluster 5–7) zugeordnet werden. Die Ergebnisse deuten auf ein ökologisches Optimum für *B. eruciformis* auf periodisch überfluteten, leicht salinen Standorten der Klasse Festuco-Puccinellietea, Verband Beckmannion eruciformis Soó 1933 (Cluster 5) hin, wo die Art die höchsten Deckungsrade erreicht (>3). Aus den Borhidi-Zeigerwerten ist ersichtlich, daß Feuchtigkeit den ausschlaggebenden ökologischen Faktor für die Variabilität der *B. eruciformis*-Bestände darstellt (die Spearman-Korrelationskoeffizienten mit der ersten DCA-Achse betragen –0.811, $P > 0.001$), gefolgt vom Nährstoffgehalt im Boden (–0.559, $P > 0.001$). Ferner wurde der Gebrauch und der Inhalt des Syntaxonnamens Agrostio stoloniferae-Beckmannietum eruciformis Rapaics ex Soó 1930 in der botanischen Literatur bewertet. Bemerkungen zu weiteren (süd)osteuropäischen *B. eruciformis*-dominierten Standorten runden den Beitrag ab.

1. Introduction

Beckmannia eruciformis (L.) Host (*Poaceae-Poeae*) is a diploid hemicryptophyte forming sparse tussocks with creeping extravaginal shoots.

The species is anemophilous; the fruits (caryopsides) are spread by endozoochory (HOLUB 1999). Its distribution range extends across a large part of Eurasia. In Southeastern Europe, it ranges from Italy in the west, through the former countries of Yugoslavia, to Albania, Greece, Romania and Bulgaria in the east. In Central Europe, it is found in the Czech Republic, Slovakia and Hungary, from where it continues eastwards to Ukraine and Moldova, the European part of Russia and northwards as far as Lithuania. In Asia it occurs in Turkey, Armenia, Georgia, Kazakhstan and the Caucasus, as well as in western and eastern Siberia of the Russian Federation (TZVELEV 1983, HOLUB 1999).

In Central Europe, the occurrence of *Beckmannia eruciformis* is primarily associated with wetlands, saline marshy meadows and pastures, and with the banks of stagnant water bodies. It also grows in ditches along roadsides. It requires moist or wet, muddy, clayey, alkaline and moderately saline soils, which are damp or flooded at the beginning of the vegetation season and dry out during the summer (TUTIN 1980, HOLUB 1999, POPESCU 2005).

In general, the occurrence of this species is associated with several vegetation types, including wetlands of the class Phragmito-Magnocaricetea, and moderately wet meadows with different, even extreme, levels of salinisation of the class Festuco-Puccinellietea (FEKETE & al. 1997, MOLNÁR & BORHIDI 2003). There are specific ecological conditions found in the Pannonian Basin (mainly in the area of Hungary), where *B. eruciformis* is considered to be a diagnostic species of the alliance Beckmannion eruciformis SOÓ 1933 of the class Festuco-Puccinellietea (cf. MOLNÁR & BORHIDI 2003). The alliance was particularly described for Hungary by SOÓ 1933, and this part of the Pannonian Basin is its primary habitat (cf. HOLUB 1999). The alliance Beckmannion eruciformis includes grasslands which are flooded in spring and later fall dry, with slightly saline alkaline solonetz soils. The floristic composition of the stands developing on less salinised soils is comparable to the vegetation of flooded wet meadows of the alliance Cnidion venosi (class Molinio-Arrhenatheretea). In contrast, vegetation growing on soils containing a higher salt concentration is similar to the communities of the alliance Puccinellion limosae (class Festuco-Puccinellietea, cf. BORHIDI 2003). Coenological and ecological relations of *B. eruciformis* from the Pannonian Basin were well reported (RAPAICS 1916, SOÓ 1930, 1933, BODROGKÖZY 1965a, 1965b). Nevertheless, these studies are mostly only of a local or regional significance which is related to their generally limited geographical area (e.g. SOÓ 1933, SLAVNIĆ 1948, 1953, BODROGKÖZY 1965a, VICHEREK 1973, KNEŽEVIĆ 1980). Thus, the ecological features of the study species have been described up to date only due to locally-based knowledge. Comparison among available phytosociological studies related to *B. eruciformis* has shown that coenological and ecological variability of *B. erucifomis* is relatively high. Due to this fact, it could be recommended that the study area should be extended beyond the Pannonian Basin to use the obtained information on the species distribution and ecological requirements to draw conclusions for a larger scale context.

The main objectives of this paper are:

a) To classify and subsequently characterise the vegetation where the species *Beckmannia eruciformis* occurs,

b) To define the ecological niche and habitat characteristics of the species within the Pannonian Basin based on the existing vegetation and ecological data.

In general, this study aimed at completing and summarising the information as regards coenological and ecological affinity of *B. eruciformis* in the studied area.

2. Material and Methods

Analyses of the coenological and ecological affinity of *Beckmannia eruciformis* were performed based on results of traditional phytosociological research. The total of 19 phytosociological relevés was sampled during the vegetation seasons in 2009 and 2010, using the Braun-Blanquet approach. In addition to these hitherto unpublished relevés, already published data from the Slovak (Hegedüšová 2007) and Hungarian (Lájer & al. 2007) national phytosociological databases were acquired. All phytosociological records obtained from Hungary (71%), Slovakia (17%) and Romania (12%) (in total, 95 relevés) were stored in the Turboveg database (Hennekens & Schaminée 2001) and after export to the JUICE program (Tichý 2002) used for further analysis (see legend of Tab. 1, Fig. 1). Some narrowly defined species or subspecies were combined: *Glyceria fluitans* agg. (*G. fluitans*, *G. notata*), *Plantago major* (*P. major* subsp. *major, P. major* subsp. *intermedia*), *Puccinellia distans* agg. (*P. distans, P. limosa*), *Trifolium fragiferum* subsp. *bonannii* (*T. fragiferum, T. fragiferum* subsp. *bonannii*).

The data were processed using TWINSPAN analysis (Hill 1979), modified according to Roleček & al. 2009 with two pseudo-species cut levels (0% and 5%), the Sørensen dissimilarity was applied as a measure of cluster heterogeneity. Congruence of the classification procedure available in the JUICE program was used to determine the optimal number of clusters (Botta-Dukát & al. 2005). Detrended correspondence analysis (DCA) was applied to explain the major environmental gradients in the species composition using the CANOCO 4.5 package (ter Braak & Šmilauer 2002). The percentage cover degrees of the species were logarithmically transformed and the rare species were downweighted. The unweighted Borhidi indicator values (BIV) were used as indicators of environmental factors (Borhidi 1993) and applied for each species and each relevé to be plotted onto the DCA ordination diagram as supplementary variables. These values were correlated with the position of the relevés on the first two ordination axes using the STATISTICA software (StatSoft 2001).

The nomenclature of taxa follows the checklist of non-vascular and vascular plants of Slovakia (Marhold & Hindák 1998), and the names of syntaxa follow Borhidi 2003. The vascular plant species considered as halophytes follow the list of Krist 1940.

3. Results

Based on the analysis of 95 phytosociological relevés with the occurrence of *Beckmannia eruciformis* in the Pannonian Basin, 7 clusters have been identified representing different vegetation types (Fig. 1, Tab. 1).

Fig. 1. Distribution of the analysed *Beckmannia eruciformis* relevés from the Pannonian Basin. The alliance Beckmannion eruciformis (Cluster 5) is marked by □, other syntaxa are marked by ●.

The first four clusters include vegetation dominated by helophytes typical for wetlands with shallow, occasionally flooded sites and exposed bottoms (Tab. 1, Fig. 3). Flooding mainly in the first half of the vegetation season is characteristic for these communities. This is documented by the highest average indicator value for the moisture (Fig. 2). Flooding can last even longer, which was shown for vegetation grouped within cluster 2 in locations where water often stagnates during the entire vegetation season. This is signalled by the presence of many hygrophilous species and obligate hydrophytes (Tab. 1). At the same time, regarding the absence of halophytes and minimal presence of the sub-halophytes, this group represents the vegetation of the least saline soils. This fact is confirmed by the position of these relevés on the opposite side upon applied BIV for the soil reaction gradient on the DCA diagram (Fig. 2). These relevés were considered to belong to the classes Isoëto-Nanojuncetea, Phragmito-Magnocaricetea and Molinio-Arrhenatheretea, known to develop at very wet and moderately wet non-saline sites. The next three clusters (clusters 5–7) comprise the vegetation growing on rarely or never flooded areas with a higher rate of salinity compared to the previous group (Fig. 2). Hygrophilous species are present in a much lower degree as compared to the vegetation of the first four clusters. In contrast, the presence of some obligate halophytes increases (e. g. *Pholiurus pannonicus, Plantago tenuiflora,*

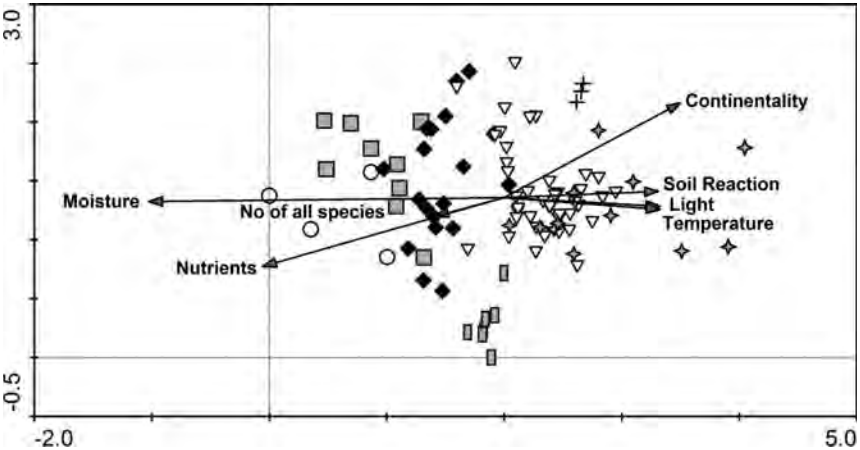

Fig. 2. Detrended correspondence analysis (DCA) ordination diagram of relevés (eigenvalues of the first two axes are 0.380 and 0.231; total inertia 4.419). The average Borhidi indicator values and the number of all species were plotted onto a DCA diagram as supplementary variables. The cumulative percentage variances of the species-environment relation for the first two axes are 26.1 and 30.2%. Spearman correlation coefficients with the first DCA axis (***P < 0.001, **P < 0.01, *P ≤ 0.05): No. of all species (–0.181ns), Light (0.338***), Temperature (0.361***), Continentality (0.408***), Moisture (–0.811***), Soil reaction (0.405***), Nutrients (–0.559***). Empty circles – Cluster 1, shaded squares – Cluster 2, black diamonds – Cluster 3, shaded boxes – Cluster 4, down-triangles – Cluster 5, crosses – Cluster 6, shaded stars – Cluster 7.

Puccinellia distans agg.; Tab. 1, Fig. 3). This vegetation is included in the class Festuco-Puccinellietea.

Within the first group of relevés of cluster 1, the characteristic species occurring on flooded (and later exposed soils) should be stressed: *Elatine* spec. div., *Eleocharis acicularis, Lindernia procumbens* and *Schoenoplectus supinus*. The typical species of periodically flooded habitats could be also found (e. g. *Alisma plantago-aquatica, Eleocharis palustris*). This cluster belongs to the class Isoëto-Nanojuncetea, alliance Eleocharition ovatae. The cover values of *B. eruciformis* in this group of relevés are usually low, not higher than 5%. The stands are relatively rich in species and show the highest indicator values for moisture and nutrients (Fig. 2). This vegetation type was recorded only in Hungary (Tab. 1).

In clusters 2 and 3, the occurrence of several typical wetland species was recorded, indicating regular flooding and stagnation of the water level during certain periods of the year. Species, such as *Alisma lanceolatum, A. plantago-aquatica, Eleocharis palustris* and *Glyceria fluitans* agg. were highly abundant, which is a result of periodic flooding and subsequent drying up of the ground. The vegetation of these clusters can be classified

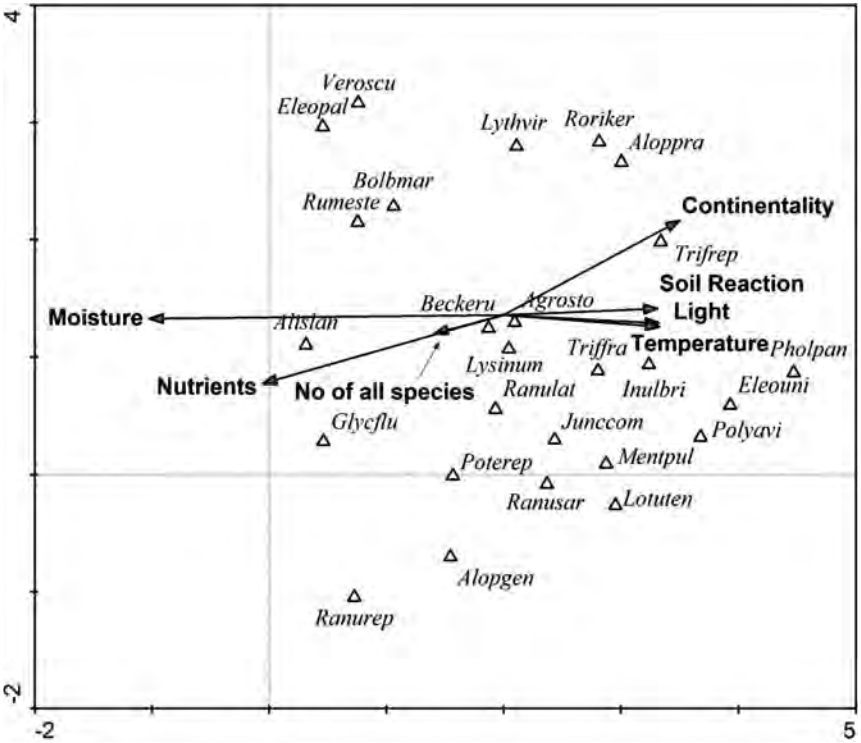

Fig. 3. Detrended correspondence analysis (DCA) ordination diagram of species with Borhidi indicator values and Number of all species plotted onto a DCA diagram as supplementary variables.

Only species with weight of analysis more than 5% are presented: *Agrosto – Agrostis stolonifera, Alislan – Alisma lanceolatum, Alopgen – Alopecurus geniculatus, Aloppra – A. pratensis, Beckeru – Beckmannia eruciformis, Bolbmar – Bolboschoenus maritimus* agg., *Eleopal – Eleocharis palustris, Eleouni – E. uniglumis, Glycflu – Glyceria fluitans* agg., *Inulbri – Inula britannica, Junccom – Juncus compressus, Lotuten – Lotus tenuis, Lysinum – Lysimachia nummularia, Lythvir – Lythrum virgatum, Mentpul – Pulegium vulgare, Pholpan – Pholiurus pannonicus, Polyavi – Polygonum aviculare* agg., *Poterep – Potentilla reptans, Ranulat – Ranunculus lateriflorus, Ranurep – R. repens, Roriker – Rorippa kerneri, Rumeste – Rumex stenophyllus, Triffra – Trifolium fragiferum, Trifrep – T. repens, Veroscu – Veronica scutellata*. Other information is presented in Fig. 2.

into the class Phragmito-Magnocaricetea, alliance Oenanthion aquaticae. The vegetation grouped in cluster 2 is also typified by the occurrence of hydrophytes (e. g. *Salvinia natans, Hydrocharis morsus-ranae*), marshy (e. g. *Glyceria maxima*) and ruderal species (e. g. *Cirsium arvense*). Several species capable to grow on slightly salinised wet meadows were recorded within cluster 3 (e. g. *Lythrum virgatum, Ranunculus lateriflorus*). The cover values of *B. eruciformis* vary significantly from 1% to 50%. All relevés of cluster 2 were sampled on the Potiská Nížina Lowland, Slovakia (Tab. 1). The vegetation presented in cluster 3 was primarily found in Hungary (74% of relevés), and to a smaller extent in Slovakia (16%) and Romania (10%; Tab. 1).

Many species of cluster 4 are grassland species and species known to occur in trampled habitats (e. g. *Leontodon autumnalis, Plantago major, Potentilla anserina*), as well as on moderately salinised soils, considered as facultative halophytes, including *Mentha pulegium, Lotus tenuis, Ranunculus lateriflorus, Rumex stenophyllus* and *Trifolium fragiferum* subsp. *bonannii*. The relevés of this cluster belong to the Potentillion anserinae (class Molinio-Arrhenatheretea). The cover values of *B. eruciformis* are higher than those observed in previous clusters, and average between 25% and 50%. This type of vegetation is present in all three countries, especially in Slovakia (72%; Tab. 1).

In the second group of relevés, cluster 5 comprises meadow-like vegetation. Almost all of the species which are considered by many authors as diagnostic species of the alliance Beckmannion eruciformis (Tab. 1) are highly abundant here (cf. SOÓ 1933, BORHIDI 2003). The relatively high average cover values of *B. eruciformis* (between 25% and 50%) in the relevés are characteristic for the vegetation of this cluster. The relatively high indicator values for soil reaction, temperature and light, and low indicator values for moisture and nutrients are main characteristics for this vegetation (Fig. 2). 90% of the relevés were sampled in Hungary, while the rest originate from Romania (Tab. 1).

Cluster 6 partially groups facultative halophytes. Apart from common halophytes of cluster 4, salt tolerant species like *Festuca pseudovina* and/or *Podospermum canum* are highly abundant, coexisting with many other typical species of meadows and pastures of drier habitats (*Carex caryophyllea, Tithymalus cyparissias, Plantago lanceolata* etc.). This vegetation could be placed into the order Festuco-Puccinellietea, alliance Festucion pseudovinae. Within the analysed stands, several sub-halophytes (e. g., *Mentha pulegium, Trifolium fragiferum* subsp. *bonannii*) find their optimal growing conditions within such type of vegetation. The vegetation is under a moderate influence of surface water, which is indicated by the position of those relevés along the humidity gradient in the ordination diagram (Fig. 2). This cluster represents the relevés of the marginal distribution of *B. eruciformis* within the study area, which is also indicated by the low cover values of the species in these relevés. Relevés of this cluster are recorded from Romania only (Tab. 1).

In cluster 7, species-poor stands with high constancy of obligate halophytes restricted to periodically flooded habitats are typical (e. g., *Plantago tenuiflora* and *Pholiurus pannonicus*). At the same time, species typical for wetlands are absent. The vegetation can be included in the class

Festuco-Puccinellietea, alliance Puccinellion limosae. Stands of this vegetation type are restricted to soils with the highest salt content and are more dependent on a continental climate (Fig. 2). The vegetation of this group occurs in shallow field depressions which are flooded only for a short time at the beginning of the growing season. The vast majority of relevés (92%) was sampled in Hungary, the rest in Romania (8%, Tab. 1). As in the previous cluster, the constancy of the characteristic species of the alliance Beckmannion eruciformis (see Tab. 1) is lower, whereas the cover values of *B. eruciformis* vary between 15% and 25%.

The results of the Detrended Correspondence Analysis (DCA) with application of the Borhidi indicator values (BIV) as supplementary variables show that the main ecological factor determining the species composition of the studied vegetation is moisture (Fig. 2). Along the first axis of the DCA ordination diagram, the relevés are located in the direction of decreasing moisture levels, which is confirmed by the results of the TWINSPAN classification (cf. Tab. 1). The stronger negatively correlating factor with axis 1 is the indicator value for moisture, followed by the indicator value for nutrients, and the most positive factor was the BIV for continentality, closely followed by the indicator for soil reaction (Fig. 2). This gradient corresponds with the position of the species in the ordination space (Fig. 3). The wetland species (e. g., *Alisma lanceolatum, Eleocharis palustris, Glyceria fluitans* agg.) are located in the left part of the ordination scale, and several (sub)halophytes or species of disturbed habitats (e. g., *Eleocharis uniglumis, Pholiurus pannonicus, Polygonum aviculare, Trifolium repens*) are presented on the right side of the diagram. The central positions along the moisture gradient are occupied by mainly hygrophilous species of meadows and periodically flooded non-forest vegetation (e. g., *Agrostis stolonifera, Alopecurus geniculatus, Ranunculus repens*).

4. Discussion

4.1. Vegetation with *Beckmannia eruciformis* in the Pannonian Basin

Through the evaluation of the accessible phytosociological data from the Pannonian Basin, a wide coenological and ecological affinity of *Beckmannia eruciformis* was confirmed. According to our results, the species occurs in several habitat types, ranging from permanently flooded through periodically dry to not flooded areas, and from not salinised to moderately salinised habitats. The studied vegetation belongs to four classes and the following list of the syntaxa:

Isoëto-Nanojuncetea, Eleocharition ovatae (cluster 1),
Phragmito-Magnocaricetea, Oenanthion aquaticae (clusters 2–3),
Molinio-Arrhenatheretea, Potentillion anserinae (cluster 4),
Festuco-Puccinellietea, Beckmannion eruciformis (cluster 5),
Festucion pseudovinae (cluster 6),
Puccinellion limosae (cluster 7).

Table 1. – A shortened synoptic table of communities with the occurrence of *Beckmannia eruciformis* from the Pannonian Basin. The average coverage rate is presented in the upper index.

Cluster	1	2	3	4	5	6	7
No. of relevés	4	9	19	7	41	3	12
Average of species number per relevé	22	15	11	20	12	30	10
Relative proportion of relevés according to individual countries:							
Hungary	100	0	74	14	90	0	92
Slovakia	0	100	16	72	0	0	0
Romania	0	0	10	14	10	100	8
Diagnostic species of groups							
Elatine hungarica	100^{+}	.	.	.	.	.	.
Marsilea quadrifolia	75^{3}	.	.	.	.	.	.
Oryza sativa	75^{a}	.	.	.	.	.	.
Schoenoplectus supinus	75^{1}	.	.	.	.	.	.
Eleocharis acicularis	75^{3}	.	.	.	.	.	.
Lindernia procumbens	50^{+}	.	.	.	.	.	.
Elatine alsinastrum	75^{1}	11^{+}	16^{+}	.	2^{+}	.	8^{+}
Glyceria maxima	.	78^{1}	.	.	.	.	.
Salvinia natans	.	67^{a}	.	.	.	.	.
Oenanthe aquatica	.	56^{1}	5^{1}	.	.	.	.
Cirsium arvense	.	56^{+}	5^{+}	.	.	.	.
Lycopus europaeus	.	44^{+}	5^{1}	.	.	.	.
Hydrocharis morsus-ranae	.	33^{1}	.	.	.	.	.
Sparganium erectum	.	33^{1}	.	.	.	.	.
Carex riparia	.	33^{1}	.	.	.	.	.
Veronica scutellata	.	22^{+}	42^{1}	.	12^{1}	.	.
Lythrum salicaria	.	33^{+}	21^{+}	14^{+}	.	.	.
Leontodon autumnalis	.	.	.	86^{1}	.	.	.
Gnaphalium uliginosum	.	.	.	43^{+}	.	.	.
Potentilla anserina	.	.	.	43^{+}	.	.	.
Bidens tripartitus	25^{+}	.	.	57^{+}	.	.	.
Plantago major	25^{+}	11^{1}	.	86^{+}	10^{+}	33^{+}	.
Inula britannica	.	11^{+}	.	29^{+}	44^{+}	.	.
Rorippa kerneri	.	.	37^{1}	.	63^{1}	100^{1}	25^{+}
Eleocharis uniglumis	.	.	5^{+}	.	46^{1}	.	58^{a}
Lotus corniculatus	.	.	.	.	.	100^{+}	.
Veronica arvensis	.	.	.	.	.	100^{+}	.
Ornithogalum kochii	.	.	.	.	.	100^{+}	.
Holosteum umbellatum	.	.	.	.	.	100^{+}	.
Euphorbia cyparissias	.	.	.	.	.	100^{+}	.
Plantago lanceolata	.	.	.	.	.	100^{1}	.
Ranunculus acris	.	.	.	.	.	100^{+}	.
Cerastium fontanum agg.	.	.	.	14^{+}	.	100^{1}	.
Ranunculus pedatus	.	.	.	.	.	67^{+}	.
Thymus chamaedrys agg.	.	.	.	.	.	67^{+}	.
Poa angustifolia	.	.	.	.	.	67^{1}	.
Carex praecox	.	.	.	.	.	67^{1}	.
Veronica prostrata	.	.	.	.	.	67^{+}	.
Carex caryophyllea	.	.	.	.	.	67^{1}	.
Thlaspi perfoliatum	.	.	.	.	.	67^{+}	.
Festuca pseudovina	.	.	.	.	10^{+}	67^{+}	8^{+}
Pholiurus pannonicus	.	.	5^{+}	.	2^{1}	.	100^{1}
Plantago tenuiflora	.	.	.	14^{+}	5^{+}	.	58^{+}
Puccinellia distans agg.	.	.	.	.	5^{+}	.	33^{a}

Cluster	1	2	3	4	5	6	7
No. of relevés	4	9	19	7	41	3	12
Aquatic and marsh species diagnostic for the first three groups							
Lemna minor	75^{1}	33^{+}	11^{+}	.	2^{1}	.	.
Alisma plantago-aquatica	75^{1}	67^{+}	5^{1}	14^{+}	.	.	.
Meadow species diagnostic for the last four groups							
Mentha pulegium	50^{+}	.	.	86^{+}	44^{1}	100^{+}	42^{1}
Lotus tenuis	.	.	.	86^{+}	17^{+}	33^{+}	17^{+}
Trifolium fragiferum subsp. *bonannii*	.	.	.	71^{+}	17^{+}	100^{1}	.
Trifolium repens	.	11^{+}	.	29^{+}	15^{+}	100^{a}	17^{+}
Trifolium angulatum	.	.	.	.	12^{1}	33^{+}	17^{+}
Podospermum canum	.	.	.	.	12^{+}	33^{+}	8^{r}
Carex stenophylla	.	.	.	.	2^{+}	33^{+}	25^{a}
Other species with frequency more than 10%							
Beckmannia eruciformis	100^{1}	100^{b}	100^{a}	100^{3}	100^{3}	100^{1}	100^{b}
Agrostis stolonifera	.	67^{b}	95^{a}	100^{1}	88^{a}	67^{1}	75^{a}
Alopecurus pratensis	25^{+}	22^{1}	47^{1}	.	76^{a}	100^{3}	33^{1}
Eleocharis palustris	100^{1}	89^{a}	84^{1}	.	24^{a}	100^{1}	8^{1}
Ranunculus lateriflorus	.	.	47^{1}	71^{a}	46^{1}	.	33^{+}
Glyceria fluitans agg.	75^{+}	56^{1}	68^{a}	71^{1}	17^{1}	.	.
Rumex stenophyllus	25^{+}	67^{+}	21^{1}	14^{+}	29^{1}	.	.
Alopecurus geniculatus	.	11^{a}	32^{1}	71^{1}	17^{1}	.	17^{1}
Lythrum virgatum	.	.	26^{1}	.	24^{1}	.	42^{+}
Alisma lanceolatum	75^{1}	22^{r}	47^{1}	14^{+}	10^{+}	.	.
Lysimachia nummularia	.	11^{a}	21^{1}	29^{+}	17^{1}	100^{1}	17^{+}
Polygonum aviculare	25^{+}	.	.	14^{1}	24^{+}	.	50^{+}
Juncus compressus	25^{+}	.	21^{+}	57^{+}	17^{1}	.	17^{1}
Bolboschoenus maritimus agg.	50^{+}	.	32^{1}	.	10^{1}	.	42^{1}
Ranunculus sardous	.	11^{r}	11^{+}	57^{+}	20^{+}	.	8^{r}
Potentilla reptans	.	11^{+}	16^{+}	29^{+}	20^{+}	.	.
Ranunculus repens	.	44^{1}	11^{1}	100^{1}	.	.	.
Mentha aquatica	.	.	32^{1}	.	2^{+}	.	33^{+}
Oenanthe silaifolia	.	.	11^{+}	.	20^{+}	.	8^{1}
Galium palustre	.	33^{+}	16^{+}	.	2^{+}	100^{+}	.
Carex vulpina	.	11^{1}	16^{+}	.	7^{1}	33^{+}	17^{+}
Rumex crispus	.	.	16^{1}	.	10^{1}	100^{+}	.

Source of data:

Cluster 1 (4 relevés): (4) UBRIZSY 1961, tab. 1, relevés 2, 4, 6, 9.

Cluster 2 (9 relevés): (8) DÍTĚ & al. (unpubl.); (1) ZLACKÁ 2005, page 27, relevé at the top of the page.

Cluster 3 (19 relevés): (4) DÍTĚ & al. (unpubl.); (6) unpublished relevés sampled by Schmotzer: Hungarian Phytosociological Database; (8) BODROGKÖZY 1965a, table in page 7, relevés 4, 5, 6, 7, 9, 10 and table in page 9, relevés 1–2; (1) ZLACKÁ 2005, page 27, relevé in the bottom of the page.

Cluster 4 (7 relevés): (1) CSIKY 1999, relevé in page 41; (5) VICHEREK 1973, tab. 21, relevés 1–5; (1) POP 1962, table 10, relevé 4.

Cluster 5 (41 relevés): (3) DÍTĚ & al. (unpubl.); (10) BODROGKÖZY 1965a, table in page 7, relevé 7, table in page 9, relevé 8, table in page 9, relevés 5, 7, 9, table in page 15, relevés 1–3, 5–7; (17) BODROGKÖZY 1965b, table II, relevé 1, table III, relevés 1–16; (1) POP 1968, tab. 42, relevé 6; (8) unpublished relevés sampled by Schmotzer: Hungarian Phytosociological Database; (1) TIMAR 1954, table 6, relevé 3.

Cluster 6 (3 relevés): (2) POP 1959, table 6, relevés 1–2; (1) POP 1968, table 42, rel. 1.

Cluster 7 (12 relevés): (6) DÍTĚ & al. (unpubl.); (5) BODROGKÖZY 1965a, table in page 9, relevés 3–4, 6, 8, 10; (1) BODROGKÖZY 1965b, table 2, relevé 8.

Therefore, the phytocoenological affiliation of *B. eruciformis* seems to be quite broad. This statement is supported by historical and recent studies (e. g. Soó 1930, 1933, Bodrogközy 1965a, 1965b, 1970, Borhidi 2003). The optimal conditions for the growth of *B. eruciformis* are linked to occassionally flooded to moderately dry habitats. In addition, there is no significant presence of typical wetland species at the sites of the highest abundance of the species, whereas species requiring drier substrate ("asteno-xerophytes") are missing, as already reported by Bodrogközy 1987. At the same time, the species is most abundant in low to moderately saline soils, growing together with sub-halophytes or even together with some obligate halophytes in minimal presence. This particularly refers to cluster 5 (Tab. 1) which, in our opinion, can be considered as vegetation of the alliance Beckmannion eruciformis (class Festuco-Puccinellietea).

The first information about the vegetation with the presence of *B. eruciformis* came from Rapaics 1916. In this report, a list of species from the western part of the Hortobágy puszta (SE Hungary), where *B. eruciformis* is growing in wet hay meadows dominated by *Alopecurus pratensis* and *Agrostis stolonifera*, was presented. Except for an overview of the species, no quantitative characterisation was provided. Based on this report of Rapaics 1916, the community "*Agrostis alba-Beckmannia eruciformis*" was described (Soó 1930). This description can be considered as valid according to the International Code of Phytosociological Nomenclature (Weber & al. 2000), while the combination is the basionym of the valid name Agrostio stoloniferae-Beckmannietum eruciformis Rapaics ex Soó 1930 (cf. Borhidi 2003). SOÓ 1930 characterised the community with the following taxa (ordered according to their constancy rates): *Agrostis stolonifera, Beckmannia eruciformis, Mentha pulegium, Inula britannica, Alopecurus pratensis, Eleocharis palustris* and *E. uniglumis, Trifolium fragiferum, Lotus tenuis, Rorippa kerneri, Polygonum aviculare, Pulicaria vulgaris, Trifolium repens, Alopecurus geniculatus, A. aequalis, Glyceria fluitans* agg. and *Tripolium pannonicum*. Sporadically there were present *Cirsium brachycephalum, Oenanthe silaifolia, Pholiurus pannonicus, Heleochloa alopecuroides, H. schoenoides, Plantago tenuiflora,* and *Dichodon viscidum*. Except for *Tripolium pannonicum*, no additional obligate halophytes are quoted in the list, whereas several species considered as subhalophytes are reported. In an another study performed by Soó 1933, a significantly modified species list of the community from 1930 was reported, and in addition to the term "association", the term "ass.-complex" was used. In this list, the following species were appointed (arranged according to their constancy rates): *Juncus atratus, Rumex stenophyllus, Ranunculus sardous, R. lateriflorus, Lythrum virgatum, Euphorbia palustris, Lysimachia nummularia, Veronica scutellata*. On the other hand, he omitted some species from the list of 1930, such as *Alopecurus pratensis, A. geniculatus, A. aequalis, Trifolium fragiferum, T. repens, Lotus tenuis,* *Polygonum aviculare* and *Pulicaria vulgaris*. *Tripolium pannonicum* is again the only more frequently occurring obligate halophyte; but the occurrence of several facultative halophytes has decreased. These differences found in two works published by the same author within a three-year period, clearly illustrate the changes of the species composition of the association. In both papers (Soó 1930, 1933), however, the occurrence of this vegetation type was shown to be restricted to wet and slightly saline habitats. Nevertheless, Bodrokgözy 1965b defined the typical stands of the association developing on solonetz soils with low salt content and exposed to flooding. In the association, he also included the stands occurring on more salinised soils, typical for the presence of the salt meadow species such as *Podospermum canum, Limonium gmelinii* or *Festuca pseudovina* as well as some other obligate halophytes, such as *Pholiurus pannonicus* and *Plantago tenuiflora* (cf. Bodrokgözy 1963, 1965b, Borhidi 2003). With respect to differences in the species composition, we consider that the original description of the association provided by Soó 1930, was significantly changed, particularly due to the much higher presence of the halophytic species.

According to Borhidi 2003, the association Agrostio stoloniferae-Beckmannietum eruciformis (Beckmannion eruciformis as well) occupies soils with a high content of salts, the stands are characterised as wet solonetz meadows with a mosaic pattern. The author included this association in the group of the most important continental halophytic communities growing in the Great Hungarian Plain (Alföld), especially within the zonation of salt marshes of the Tisza River Basin (Tiszántúl). The species composition is very heterogeneous and many obligate halophytes are considered as constant species of the stands on strongly salt-affected soils (Borhidi 2003). This, however, does not match the original description according to which the stands of the alliance Beckmannion eruciformis develop on slightly saline soils and the occurrence of obligate halophytes is no more than accessory. In our analysis, relevés with a higher frequency of halophytes are presented in clusters 6 (Festucion pseudovinae) and 7 (Puccinellion limosae). They were observed only in Hungary, in the area of Hortobágy and Körös Maros National Parks, as well as in Western Romania. On the contrary, stands with only sporadic occurrence of obligate halophytes (e. g., *Pholiurus pannonicus, Plantago tenuiflora*) and presence of diagnostic species of the Beckmannion eruciformis were grouped into cluster 5. The species composition of cluster 5 corresponds with the original description of Agrostio stoloniferae-Beckmannietum eruciformis (Beckmannion eruciformis) performed by Soó 1930.

Several additional plant communities with the presence of *B. eruciformis* were described within the Pannonian Basin. For example, Slavnić 1948 documented the association Oenanthe-Beckmania erucaeformis Țopa 1930 in Vojvodina, Serbia. This vegetation type is characterised by high constancy values of *Oenanthe silaifolia, Gratiola officinalis, Rumex stenophyllus, Melilotus dentatus, Beckmannia eruciformis, Agrostis stolonifera* and *Glyceria fluitans*. Stands with similar species composition were also mentioned by BODROGKÖZY & GYÖRFFY 1970, but without reporting complete phytosociological relevés. These stands were described as the community "Agrosti-Beckmannietum eruciformis gratioletosum (officinalis)". Regarding the species structure, the non halophytic hydrophytes were dominant, including first of all *Gratiola officinalis, Oenanthe silaifolia, Euphorbia palustris* and *Juncus atratus*. Forming a considerable part of the total vegetation cover of the stands, they may be considered as differential species. Apart from the dominant species *B. eruciformis* and *Agrostis stolonifera*, other species, such as the above mentioned *Gratiola officinalis* and *Oenanthe silaifolia* make up as much as 30–40% of the total cover of the stands, whereas the total cover of the vascular plant species in this subassociation usually reaches 60–70%. The community was recorded in swampy depressions on saline soils with high nitrogen content (cf. BODROGKÖZY & GYÖRFFY l. c.). In our opinion, these stands represent vegetation of the class Molinio-Arrhenatheretea. This opinion is supported by SLAVNIĆ 1948, since a similar species composition was found together with *B. eruciformis* in the region of Northern Serbia (Vojvodina). However, SLAVNIĆ described it as "Alopecurus-Rorippa kerneri SLAVNIĆ 1941 subassociation with *Beckmannia eruciformis*". KNEŽEVIĆ 1980 registered the community in the area of Kruščić (Vojvodina) as well. In addition, BODROGKÖZY 1965a reported the occurrence of *B. eruciformis* in other communities of the alliance Beckmannion eruciformis SOÓ 1933. In the region of Árkuspuszta (Hungary), *B. eruciformis* was recorded in the association Agrosti-Glycerietum poiformis SOÓ (1933) 1947. Moreover, *B. eruciformis* occured here in the subassociation "typicum", particularly in the subassociation "beckmannietosum". The community was found in deeper water of the littoral zone forming transitional stand towards the association Agrostio stoloniferae-Beckmannietum eruciformis. Dominant species are *Glyceria fluitans* and *Agrostis stolonifera*, whereas the absence of halophytes is typical, as well as a high frequency of species of the class Phragmito-Magnocaricetea. In our analysis, this type of vegetation is grouped in cluster 3 (Tab. 1). Another association with the significant presence of *B. eruciformis* (cover values 25–50%) is the Agrosti-Alopecuretum pratensis SOÓ (1933) 1947 subassociation beckmannietosum SLAVNIĆ 1948 (cf. BODROGKÖZY 1965a). The species was occasionally recorded also in the species-poor subassociation juncetosum conglomerati BODROGKÖZY 1965a. Within the stands of this community, the following species were dominant: *Alopecurus pratensis, Agrostis stolonifera* and *Eleocharis uniglumis*, which are known as characteristic for the ass. Agrostio stoloniferae-Beckmannietum eruciformis, as pointed out by SOÓ 1930. In our analysis, these relevés are placed into cluster 5, i. e., they belong to the alliance Beckmannion eruciformis.

4.2. Vegetation with *Beckmannia eruciformis* in Central and South-Eastern Europe

In Central and Southeastern Europe, stands with *Beckmannia eruciformis* have also been observed in localities outside of the Pannonian Basin.

In Serbia, in the Potamisje region, the relevés with *B. eruciformis* have been recorded on reclaimed wetlands (Vučković 1985). The vegetation was described as "Agrostetum albae pannonicum beckmannietosum eruciformis" (Article 34a Code of phytosociological nomenclature; cf. Weber & al. 2000). The stands are characterised by high cover values of *Agrostis stolonifera* (75–100%) and low cover values (up to only 5%) of several typical species of association Agrostio stoloniferae-Beckmannietum eruciformis (Beckmannion eruciformis), including *B. eruciformis, Glyceria fluitans* agg., *Ranunculus lateriflorus, Rorippa kerneri* and *Eleocharis palustris*. This species-poor vegetation is analogous to the vegetation of cluster 3 (Oenanthion aquaticae) in our study, but with lower cover values of *B. eruciformis*. For the area of Niš (southern Serbia), the presence of the vegetation with a very high abundance of *B. eruciformis* (75–100% of coverage) was reported (Ranđelović & al. 2007). The authors classified it as Oenantho fistulosae-Beckmanietum eruciformis, order Phragmitetalia. The total absence of the co-dominant *Agrostis stolonifera* and other typical species of Beckmannion eruciformis was quite apparent. Considering the floristic structure, these stands are not to compare with our dataset recorded for the Pannonian region (see Tab. 1).

At the very south of the Pannonian Basin, in Bulgaria, vegetation dominated by *B. eruciformis* is rare, and it has been recently confirmed only for SE Bulgaria in the vicinity of Stara Zagora, Primorsko, Haskovo and Sredets (Sopotlieva, Hájková, Apostolova & Hájek, unpublished data). The stands of this vegetation occur in depressions within complexes of sub-halophytic grasslands of the Trifolion resupinati K. Micevski 1957 alliance. Fluctuating water regime and disturbance of stands are considered as typical for this type of vegetation. The phytosociological material from the area is rather insufficient because only 4 relevés are available. The stands are very poor in species, whereas the cover values of *B. eruciformis* vary between 1% and 40%. In addition, a low cover value (up to only 5%) is characteristic for the accompanying species *Agrostis stolonifera*, which is even absent in particular stands. *Eleocharis palustris, Juncus effusus* and, in one case, *Carex acutiformis* are more abundant. The species composition indicates slightly saline soils, but a more accurate classification of these stands is not possible.

For the sake of a complete description of the occurrence of *B. eruciformis* in Central and South-Eastern Europe, we have also addressed its occurrence north of the Pannonian Lowland, in North-Eastern Poland. In this area, CIOSEK 2004 reported 22 phytosociological relevés containing *B. eruciformis*. The author included the stands in the order Trifolio fragiferae-Agrostietalia stoloniferae R. TX. 1970 and alliance Agropyro-Rumicion crispi NORDH. 1940 em. R. TX. 1950. *B. eruciformis* was regarded to be a character species, and *Deschampsia caespitosa* and *Phalaris arundinacea* were treated as differential species. CIOSEK 2004 also recorded several common species growing together with *B. eruciformis* as found in the Pannonian Basin, including *Agrostis stolonifera, Alopecurus pratensis* and *Lysimachia nummularia*. Moreover, some species not recorded from *Beckmannia* stands in the Pannonian region have been found, such as *Iris pseudacorus, Viola stagnina* and *Dianthus superbus*. The only sub-halophytic species occurring sporadically in the stands with *B. eruciformis* in North-Eastern Poland is *Trifolium fragiferum*. This finding highlights the fact that *B. eruciformis* is a facultative halophyte and can be abundant even on non-saline soils (SLAVNIĆ 1948, OŤAHELOVÁ & al. 1985, ZLACKÁ 2005).

5. Acknowledgements

We are grateful to D. SOPOTLIEVA, P. HÁJKOVÁ, I. APOSTOLOVA, and M. HÁJEK for providing unpublished data from Bulgaria, to M. BALLA, R. ŠUVADA, A. I. CSATHÓ and to the staff of the Körös-Maros National Park for their assistance during the field work and to Zs. MOLNÁR and D. VUKOV for the provided literature. We are also indebted to D. SENKO for creating the map. The study was supported by grants VEGA No. 2/0030/09, 2/0181/09 and 2/0003/12.

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