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Vegetation and Fauna of Tisza River Basin III.

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Introduction

Alkali grasslands and marshes are typical in continental climate, at sites with at least moderate soil salt content and dynamic changes in water regime (Deák *et al.* 2014a, Eliáš *et al.* 2013, Valkó *et al.* 2014). Alkali landscapes of the Pannonian biogeographical region are considered as the westernmost occurences of the Eurasian steppes (Dengler *et al.* 2014, Wesche *et al.* 2016). With an extension of more than 210,000 hectares they represent the most continuous salt-affected landscape in continental Europe (Deák *et al.* 2014a). These landscapes hold an extremely high habitat diversity with numerous associations which form a complex mosaic structure even at a very fine-scale (Deák *et al.* 2014a,b,c, Eliáš *et al.* 2013, Török *et al.* 2012).

Alkali meadows are typical elements of the alkali landscapes. There are two major types of alkali meadows characterised by marked differences in the soil properties of the habitat (Borhidi *et al.* 2012). On solonetz soil the order of Beckmannion eruciformis Soó 1933, on solonchak soil the order of Scorzonero-Juncion gerardii (Wendelberg. 1943) Vicherek 1973 is typical. In this chapter we discuss the solonetz type, because this type is typical along the river Tisza and its tributary streams. Solonetz meadows are widespread on the alkali soils of the Great Plain (Deák *et al.* 2014a). They can be found in a great extent in Borsod, Heves, Hortobágy, Nagykunság, Jászság and Körös-vidék regions. The order Beckmannion eruciformis Soó 1933 is related to Festuco–Puccinetalia Soó 1968, Bolboschoenetalia maritimi Hejny 1967, Molinietalia Koch 1926 and to the Peucedano officinalis–Asterion sedifolii Borhidi 1996 orders regarding site characteristics and species composition (Borhidi *et al.* 2012, Deák *et al.* 2014b,c, 2015). The three most widespread associations of solonetz meadows are *Agrostio stoloniferae–Alopecuretum pratensis* Soó 1933 corr. Borhidi 2003, *Agrostio stoloniferae–Beckmannietum eruciformis* Rapaics ex Soó 1930 and *Agrostio stoloniferae–Glycerietum pedicellatae* Magyar ex Soó 1933 corr. Borhidi 2003.

The solonetz meadows are tall grass meadows, which are covered by shallow water from early spring even to midsummer. From June or July they get dry and do to the desiccation polygonal splits often appear on the soil surface. For the development of alkali soils, a high groundwater level rich in salts and also a

continental climate is needed (Molnár & Borhidi 2003, Tóth 2010). In the dry period, intensive evaporation elevates the salts to the surface through the capillary zone. The solonetz meadows are formed on meadow soils, with moderate salt accumulation in the deeper horizons (usually in B horizon). The humus content of the A horizon is high. That is why the pH of the surface is near to neutral even the soil is alkaline in the deep.

In alkali landscapes, the solonetz meadows are typically located between the salt marshes and alkali steppes (Bodrogközy 1980, Deák *et al.* 2014b). Solonetz meadows form either a narrow transition zone between dry alkali steppes and marshes or they can form large stands of several hectares extension. They usually form a habitat mosaic with loess grasslands, alkali steppes, smaller patches of alkali and non-alkali marshes and with other alkali associations, like *Puccinellietum limosae* Magyar ex Soó 1933, *Plantagini tenuiflorae–Pholiuretum pannonici* Wendelberg 1943, *Camphorosmetum annuae* Rapaics ex Soó 1933.

Besides the prisine alkali meadows, there are several thousand hectares of meadows of secondary origin along the river Tisza. Some of the extended alkali areas in Hungary are ancient formations, which were present before human interventions (Molnár & Borhidi 2003, Sümegi *et al.* 2000, 2013). Most of the secondary alkali meadows developed after the regulation of the Tisza and its tributary streams. This process is well documented by the maps of the 1st (1763-87), 2nd (1819-1869) and 3rd (1869-1887) Military Surveys of Hungary. Due to the altered water balance after the landscape-scale river regulation campaigns, alkali meadows developed at the location of former marshes by secondary salinisation and some meadows that were not alkali in the past also became salt-affected. The species pool of secondary meadows is generally less diverse than that of the ancient alkali meadows (Molnár & Borhidi 2003).

Characteristic species of the solonetz meadows

Solonetz meadows usually have two herb layers. In the upper layer the dominant tall grass species are *Alopecurus pratensis*, *Agrostis stolonifera*, *Beckmannia eruciformis*, *Glyceria fluitans* and *Elymus repens*. In the lower layer typical species are *Cerastium dubium*, *Galium palustre*, *Inula britannica*, *Juncus compressus*, *Juncus gerardi*, *Leonurus marrubiastrum*, *Lotus glaber*, *Lycopus* spp., *Lysimachia nummularia*, *Lythrum virgatum*, *Mentha aquatica*, *Mentha pulegium*, *Oenanthe silaifolia*, *Ranunculus lateriflorus*, *Ranunculus repens*, *Ranunculus sardous*, *Rorippa sylvestris* ssp. *kerneri*, *Rumex stenophyllus* and *Veronica scutellata*. Species typical to salt marshes (*Bolboschoenus maritimus*), non-alkali meadows (*Phalaris arundinacea*) and dry alkali grasslands (*Achillea collina*, *Centaurea pannonica*, *Limonium gmellini* ssp. *hungarica*) also occur in solonetz meadows. There are some species that indicate silt accumulation processes, such as *Alopecurus geniculatus*, *Eleocharis uniglumis*, *Eleocharis palustris*, *Myosurus*

minimus, *Pholiurus pannonicus* and *Plantago tenuiflora*. These species are common in Puccinellenion limosae Soó 1933 em. Varga & V. Sípos ex Borhidi 2003 hoc loco too. There are some endemic species in solonetz meadows; the most widespread one is the *Cirsium brachycephalum*, which can form stands of even several hectares extension. Other endemic species is *Limonium gmelinii* ssp. *hungaricum*.

Solonetz meadows are sensitive to the water support. After a longer period with precipitation over or under average they can transform into other associations within the class; even they can transform to a dry grassland or marsh. If the water supply is not sufficient, the constant species (*Agrostis stolonifera*) of the association decreases in cover, and a few grass species become dominant. In some cases the cover of dry grassland species (*Festuca pseudovina, Poa angustifolia, Podospermum canum, Trifolium* spp.) and occasionally weedy species (e.g. *Cirsium arvense, Cirsium vulgare, Myosotis arvensis*) increases due to severe drought. Inadequate water supply or the lack of trampling by grazers leads to the desintegration of the tussock sturcture of the solonetz meadows.

Solonetz meadows are generally inadequate for ploughing, because of the moist soil conditions and the salt accumulation in the deeper horizon. The productivity of the meadows considerably depends on the precipitation of the actual year. If they are not managed, litter can accumulate, which causes decrease in the diversity of annuals and biennials (Kelemen *et al.* 2013). Solonetz meadows, like other natural associations on solonetz soils, are usually not invaded by invasive species, because of the special environmental conditions caused by the high salt content of the soil.

Material and methods

Studied associations and the relevés

We followed Borhidi (2003) for syntaxa and Simon (2000) for taxa. The following associations, affected by Tisza River are discussed in this paper:

Agrostio stoloniferae–Alopecuretum pratensis Soó 1933 corr. Borhidi 2003
Agrostio stoloniferae–Beckmannietum eruciformis Rapaics ex Soó 1930
Agrostio stoloniferae–Glycerietum pedicellatae Magyar ex Soó 1933 corr. Borhidi 2003
Agrostio–Caricetum distantis Rapaics ex Soó 1938
Eleochari–Alopecuretum geniculati (Ujvárosi 1937) Soó 1947
Rorippo kerneri–Ranunculetum lateriflori (Soó 1947) Borhidi 1996

The relevés used in the paper are summarized in Table 1. Most of the relevés were recorded on percentage scale except for old relevés.

Table 1. Summary of relevés used for studying solonetz meadows. Abbreviation of the associations: AgrAlo – *Agrostio stoloniferae–Alopecuretum pratensis*; AgrBeck – *Agrostio stoloniferae–Beckmannietum eruciformis*; AgrGly – *Agrostio stoloniferae–Glycerietum pedicellatae*; AgrCar – *Agrostio–Caricetum distantis*; EleoAlo – *Eleochari–Alopecuretum geniculati*.

Associat-ion	Region	Location	Date of survey	Publisher	No. of relevés	No. of species
AgrAlo	Gyöngyös - Heves vidéke	Sarud (Hídvégpuszta); Tarnaszentmiklós (Garabont); Heves (Doktortanya-dűlő) Pély (Tag-dűlő)	2004, 2005	Schmotzer (unpubl.)	5	44
AgrAlo	Körös-vidék	Vésztő	1998	Penksza (1998)	2	21
AgrAlo	Jászság	Rákóczifalva	2002	Gallé (2002)	5	16
AgrAlo	Nagykunság	Nagyiván	2004	Molnár (NBmR)	20	10
AgrAlo	Nagykunság	Egyek-Pusztakócs	2004, 2007	Deák (unpubl.)	10	26
AgrAlo	Hortobágy	Nyírőlapos	2006	Deák (unpubl.)	10	12
AgrAlo	Hortobágy	Nyírőlapos	2006	Deák (unpubl.)	10	8
AgrAlo	Maros-szög	Deszki-puszta	2006	Aradi (unpubl.)	9	28
AgrAlo	Hortobágy	É-Hortobágy	1963	Bodrogközy (1965)	15	41
AgrAlo	Hortobágy	NA	1934	Soó (1933)	1	45
AgrBeck	Hortobágy	Nyírőlapos	2001	Deák (unpubl.)	6	10
AgrBeck	Nagykunság	Nagyiván	2004	Molnár (NBmR)	20	17
AgrBeck	Nagykunság	Egyek-Pusztakócs	2004, 2007	Deák (unpubl.)	10	33
AgrBeck	Maros-szög	Deszki-puszta	2006	Aradi (unpubl.)	4	18
AgrBeck	Hortobágy	É-Hortobágy	1963	Bodrogközy (1965)	10	25
AgrBeck	Hortobágy	NA	1934	Soó (1933)	1	30
AgrCar	Maros-szög	Deszki-puszta	2006	Aradi (unpubl.)	4	15
AgrGly	Hortobágy	É-Hortobágy	1963	Bodrogközy (1965)	10	30
AgrGly	Hortobágy	NA	1934	Soó (1933)	1	29
AgrGly	Nagykunság	Egyek-Pusztakócs	2007	Deák (unpubl.)	5	10
AgrGly	Hortobágy	Nyírőlapos	2001	Deák (unpubl.)	5	8
EleoAlo	Nagykunság	Egyek-Pusztakócs	2004	Deák (unpubl.)	5	22

Statistical analysis, life forms, and social behaviour types

Our goal was to describe the solonetz meadow associations which have been affected by the Tisza River in present days or in the past. The studied regions were Gyöngyös-Heves-vidéke, Hortobágy, Nagykunság, Jászság, Maros-szög and Körös-vidék. First, we provided a literature review on the solonetz meadows along river Tisza. Second, we characterized the species composition of the solonetz meadows using the relevés available until 2010 (submission date of this chapter) (Table 1). Non-metric multidimensional scaling (NMDS), based on Bray-Curtis dissimilarity was used to explore the differences among associations and regions. For the NMDS we used all of the published relevés except the pooled relevés of Soó (1933). Finally, we compared the three most widespread associations (*Agrostio stoloniferae–Alopecuretum pratensis, Agrostio stoloniferae–Beckmannietum eruciformis* and *Agrostio stoloniferae–Glycerietum pedicellatae*) based on their Relative Ecological Indicator Values (SB, WB), Raunkiaer's life forms, Social Behaviour Types, Phytosociologycal groups and Flora elements of their species pool. The A-D values of the relevés were transformed to percentage cover when it was necessary.

Result and discussion

Literature on the solonetz meadows along the Tisza River

Systematic research on the solonetz meadows was initated by Magyar and Rapaics at the beginning of the 20th century. Rapaics (1916, 1918) described the physiognomy, environmental parameters and species pool of the alkali associations of Hortobágy; among them, he also discussed the solonetz meadows. Later he described the alkali associations of the Middle-Tisza Region, and of Szeged (Rapaics 1927a, 1927b). Magyar (1928) was the first who made the classification of the main solonetz meadow associations. He gave a comprehensive description of the plant associations of the Hortobágy. Soó (1931) evaluated the origin of the flora of Hortobágy. He suggested that Hortobágy was a secondary formation of degraded grasslands, which resulted from human disturbances (regulation of Tisza River, establishing of Árkus-channel, cutting of forests, herding). In a latter article (Soó 1933) he described the associations of the Hortobágy in detail. He categorized the solonetz meadows of the Beckmannion eruciformis association group. Máthé (1941) described the flora elements and the most widespread solonetz meadows of the Hortobágy.

Bodrogközy published several articles about solonetz meadows along the Tisza and its tributary streams. In his paper „Ecology of the Halophilic Vegetation of the Pannonicum" (Bodrogközy 1963) he described vegetation and soil conditions of the Northern-Hortobágy, Árkus-puszta and Máta-puszta. He published coenologi-

cal data of *Agrostio stoloniferae–Alopecuretum pratensis, Agrostio stoloniferae–Beckmannietum eruciformis, Agrostio stoloniferae–Glycerietum pedicellatae* and described the soil of them. He described several variants of the associations. He studied the productivity of the *Agrostio stoloniferae–Alopecuretum pratensis* associations along the River Maros near Nagylak (Bodrogközy 1972). He also reviewed the vegetation of Körös-region and Maros-basin (Bodrogközy 1980). Jakucs (1976) gave a comprehensive general review of solonetz meadows of Hortobágy. The occurrences of typical plants of Hortobágy were listed in the flora monograph of Szujkó-Lacza (1982). Varga-Sípos *et al.* (1982) described the vegetation, animal assemblages and soil of the solonetz meadows of eastern Hortobágy in their nature protection guide about Nyári-járás. Varga-Sípos (1984) reviewed the papers of Magyar, Soó and Bodrogközy and made a synthetic coenological table of *Agrostio stoloniferae–Alopecuretum pratensis, Agrostio stoloniferae–Beckmannietum eruciformis* and *Agrostio stoloniferae–Glycerietum pedicellatae* associations. There is a similar detailed description in the paper of Varga-Sípos & Varga (1993). Tóth & Kertész (1996) analysed the relationship between vegetation and soil in an *Agrostio stoloniferae–Alopecuretum pratensis* in Hortobágy. Zalatnai & Körmöczi (2004) studied the fine-scale pattern of the boundary zones in alkaline grassland communities. Molnár & Borhidi (2003) discussed the origin, landscape history and syntaxonomy of the Hungarian alkali vegetation. Eliaš *et al.* (2013) provided a comprehensive classification of the continental alkali vegetation of Europe. Ladányi *et al.* (2016) studied the soil and vegetation changes due to hydrologically driven desalinization process in an alkaline wetland near Szeged. Erdős *et al.* (2011) studied the effect of land use on the vegetation of alkali grasslands. Lukács *et al.* (2017) published a comprehensive summary on new floristic data in the Hortobágy region.

In the recent decades, researchers at the University of Debrecen, Department of Ecology and the MTA-DE Biodiversity and Ecosystem Services Research Group studied the mechanisms shaping the species composition of alkali vegetation of the Hortobágy and the conservation, management of alkali vegetation of these unique habitats. Deák *et al.* (2014a) provided evidence for the relationship between micro-topography and vegetation zonation in alkali habitats using remotely sensed data. They developed a new methodology for large-scale habitat mapping in alkali landscapes based on hyperspectral (Burai *et al.* 2015) and laser-scanned data (Alexander *et al.* 2015, 2016, Zlinszky *et al.* 2015). They evaluated the diversity-productivity relationships (Kelemen *et al.* 2013, 2015) and also the role of soil seed bank in the vegetation dynamics in alkali habitats (Valkó *et al.* 2014). The effects of rainfall fluctuations on the fine-scale vegetation dynamics of alkali grasslands and wetlands is discussed by Lukács *et al.* (2015).

A synthesis on the solonetz meadow vegetation, regarding species composition and conservation challenges was published by Deák *et al.* (2014b). They synthesised the conservation and management prospects of alkali grasslands (Török

et al. 2012) and alkali marshes (Deák *et al.* 2014c) of Central-Europe. Deák & Tóthmérész (2006, 2007) studied the effect of mowing on *Agrostio stoloniferae–Alopecuretum pratensis* in Hortobágy (Nyírőlapos). They studied effect of reed harvesting on the diversity and productivity of alkali wetlands (Deák *et al.* 2015a) and the role of grazing (Godó *et al.* 2017, Godó 2018, Kovácsné Koncz *et al.* 2018, Török *et al.* 2014, 2016, 2018, Tóth *et al.* 2018) and fire (Valkó *et al.* 2016) in shaping alkali habitats. Spontaneous regeneration of *Agrostio stoloniferae–Alopecuretum pratensis* on soil-filled drainage channels was evaluated by Deák *et al.* (2015b) and Valkó *et al.* (2015, 2017).

General description of the studied associations

VIII.1 *Agrostio stoloniferae–Alopecuretum pratensis* Soó 1933 corr. Borhidi 2003

This widespread association is situated on the least alkali soils (1st class). Stands of *Agrostio stoloniferae–Alopecuretum pratensis* are formed on slightly solonetized meadow soil. A and B horizons are leached, calcium carbonate and soda occurs in deeper horizons. The soil is poor in water-soluble salts (Bodrogközy 1963). This is the driest type of alkali meadows. *Alopecurus pratensis* can tolerate a wide range of soil moisture; thus it is present even under relatively dry soil conditions (Bodrogközy 1965). After the temporal water cover in spring and early summer stands of this association usually dry out and have a polygonally split soil. This association often located between dry steppes and wet alkali meadows like *Agrostio stoloniferae–Beckmannietum eruciformis* or *Agrostio stoloniferae–Glycerietum pedicellatae* (Deák *et al.* 2014a). Depending on the water supply (precipitation, water from snowmelt), this association can have dry grassland or marsh characteristics and it can even turn into these associations. Due to this phenomenon, the *Agrostio stoloniferae–Alopecuretum pratensis* stands are rich in species and are rather variable (Deák *et al.* 2014b).

Its dominant tall grass species are *Alopecurus pratensis*, *Elymus repens* and *Agrostis stolonifera*. The association has an *Elymus repens* facies (Varga 1982), where *Elymus repens* replaces *Alopecurus pratensis* and becomes a dominant or at least subdominant species. In solonetz meadows *Elymus repens* does not behave like a ruderal competitor; it may be regarded as a competitor regarding the Social Behaviour Types (Borhidi 1995). Formation of this *Elymus repens* facies generally occurs due to regional level desiccation or changes in management. We found this facies in the coenological data of the Nagykunság, Hortobágy and in Deszki-puszta. In case of continuous and sufficient water supply and presence of grazing, tussocks formed by *Agrostis stolonifera* can be present. If the habitat gets dry, steppe species establish there, such as *Festuca pseudovina*, *Poa angustifolia*, *Trifolium* spp., *Achillea collina* and *Plantago lanceolata*. In stands where salt accumulation is high

Limonium gmelinii ssp. *hungaricum* may occur, occasionally together with the protected and regionally rare *Prospero paratheticum* (Deák *et al.* 2015c). This process usually takes place on the boundaries of the habitats (Bodrogközy 1965). *Carex praecox* as a subordinate species appear in the relevés of the Middle-Tisza and Maros regions. In every relevés *Juncus* species (*Juncus effusus, J. conglomeratus, J. compressus, J. gerardi*) occur with high frequency and cover. *J. gerardi* is the only species, which is present only in relevés of the Deszki-puszta. Due to heavy grazing and trampling *Trifolium fragiferum* and *Lotus tenuis* might appear.

In the relevés of Soó (1933), there are several species that are not typical to the alkali meadows of the Hortobágy. There are many dry (alkali and loess) grassland species, even ruderal ones (*Achillea collina*, *Centaurea pannonica*, *Festuca pseudovina*, *Salvia austriaca, Silene viscosa*, *Verbascum phoeniceum*). The presence of *Artemisia pontica, Aster sedifolius* ssp. *sedifolius, Odontites rubra* and *Peucedanum officinale* is not common in the meadows of the region. The reason for this difference is that Soó made a pooled "typical" relevé from several surveys of the region. That is why the species of other habitats are also included in the list. They may originate from the surveys that were made in the one of the two *Galatello–Quercetum roboris* Zólyomi Tallós 1967 (Ohat, Újszentmargita) forests, and/or other *Peucedano–Asteretum sedifolii* Soó 1947 corr. Borhidi 1996 stands.

Bodrogközy (1965) described four variants of *Agrostio stoloniferae–Alopecuretum pratensis* from the Northern-Hortobágy. These variants can be considered as facies. The four variants are *beckmannietosum*, *juncetosum conglomerati*, normale, normale *trifoliosum fragiferi*. The *beckmannietosum* is considerably salt affected. It is very close to the *Agrostio stoloniferae–Beckmannietum eruciformis* regarding its species composition. The *juncetosum conglomerati* is rarely mentioned as an alkali meadow association. As Bodrogközy described it, it is a wet and less alkali meadow with the dominance of *Juncus conglomeratus*, which is not a typical alkali plant species. In this association several hygrophilous species occur (*Ranunculus* spp.). It often appears in disturbed, grazed areas. The normale *trifoliosum fragiferi* type develops if the meadow dries out and if intensive grazing and trampling occurs. Here the cover of dry steppe species, such as *Leontodon autumnalis*, *Trifolium fragiferum*, *Lotus tenuis*, *Festuca pseudovina* and *Podospermum canum* increases considerably, while the cover of *Agrostis stolonifera* and *Alopecurus pratensis* decreases. This subtype is susceptible to weed encroachment (*Artemisia vulgaris, Cirsium arvense, Pulicaria vulgaris*). These subtypes show that the *Agrostio stoloniferae–Alopecuretum pratensis* changes dynamically related to the environmental factors. *Agrostio stoloniferae-Alopecuretum pratensis* stands are usually utilized as hay meadow or grazed by cattle.

VIII.2 *Agrostio stoloniferae–Beckmannietum eruciformis* Rapaics ex Soó 1930

Agrostio stoloniferae–Beckmannietum eruciformis is formed on soils with the highest salt content (2nd and 3rd class alkali soils) amongst alkali meadows. The highest salt content is present in stands, which dry out in midsummer. Soil of *Agrostio stoloniferae–Beckmannietum eruciformis* has a loose structure. Thick columnar structure may be found in the B horizon (Bodrogközy 1963). Surface water cover is typical in spring and early summer, but the habitat dries out frequently in midsummer. The dominant grass species are *Alopecurus pratensis*, *Agrostis stolonifera*, and *Beckmannia eruciformis*, which form tussocks in case of proper water supply. Like the *Agrostio stoloniferae–Glycerietum pedicellatae*, it has several hygrophyte species. It has more halophyte species (like *Aster tripolium* ssp. *pannonicum* and *Puccinellia limosa*) than the other meadow associations. In this association due to high salt content and good water balance, species of salt marshes like *Bolboschoenus maritimus* are often found. *Agrostio stoloniferae–Beckmannietum eruciformis* is a more stable association than *Agrostio stoloniferae–Alopecuretum pratensis* as it has more permanent water supply. The high salt content inhibits the establishment of several species, which are present in the *Agrostio stoloniferae–Alopecuretum pratensis* association, but not salt-tolerant enough to survive here. The *Agrostio stoloniferae–Beckmannietum eruciformis* stands are usually not utilized for hay making because their wet soil is not suitable for the machinery, but used as pastures for cattle.

VIII.3 *Agrostio stoloniferae–Glycerietum pedicellatae* Magyar ex Soó 1933 corr. Borhidi 2003

The association occurs on 1st class alkali soils similarly to *Agrostio stoloniferae–Alopecuretum pratensis*, but in lower depressions; that is why it has a more permanent water cover. It is the wettest alkali meadow association. The soil surface dries out only in extreme dry summers (Bodrogközy 1965). Its soil is eluviated, thus its solonetz character is poor. It has little salt content in both horizons. Due to the effect of permanent water cover, columnar structure is generally absent (Bodrogközy 1965). This association often forms a transition zone between the drier alkali meadows and marshes, especially *Schoenoplectetum tabernaemontani* Soó 1947 (Deák *et al.* 2014c, 2015a). The species pool is very similar to the associations mentioned above, but it has a more homogenous species composition, because it is characterised by more balanced water conditions. The dominant grass species are *Glyceria fluitans* and *Agrostis stolonifera.* As subordinate species *Beckmannia eruciformis, Eleocharis* spp., *Epilobium tetragonum* and *Lycopus europaeus* are present. Several marsh species occur there, such as *Bolboschoenus maritimus*, *Schoenoplectus lacustris* ssp. *lacustris* and *Schoenoplectus lacustris* ssp. *tabernaemontani*. In this association tussock formation is not typical.

Bodrogközy (1965) differentiated three variants based on their water regime. The wettest subtype is *baldingerosum*; and there is a typicum, and a *beckmanniosum* variant, the latter showing a transition towards the *Agrostio stoloniferae–Beckmannietum eruciformis*. That is why the relevés of Bodrogközy (1965) have a high species number. Soó's relevé has high species number because it is a pooled survey like in case of the *Agrostio stoloniferae–Alopecuretum pratensis*. Stands of this association are often unmanaged; they generally cannot be mown by machine because of the permanently wet soil. If the surroundings of the stand are grazed, cattle may feed here.

VIII.4 *Agrostio–Caricetum distantis* Rapaics ex Soó 1938

Formerly it was treated as a subassociation, and was described as *Agrostidetum stoloniferae* Soó (1940) 1968 in the Red Data Book (Borhidi, 1999). This association is formed on 2nd class alkali soils. Its dominant species are *Agrostis stolonifera* and *Carex distans*. Subordinate species like *Alopecurus geniculatus*, *Aster tripolium* ssp. *pannonicus*, *Beckmannia eruciformis*, *Cirsium brachycephalum* and *Plantago maritima* are present in areas that are affected by silt deposition. *Agrostio–Caricetum distantis* shows a transition to *Puccinellietum limosae*. Tussock forming is typical in this association. Stands of this association are usually mowed or grazed.

VIII.5 *Eleochari–Alopecuretum geniculati* (Ujvárosi 1937) Soó 1947

This association shows relationship with *Plantagini tenuiflorae–Pholiuretum pannonici* but it remains wet until midsummer while *Plantagini tenuiflorae–Pholiuretum pannonici* gets dry earlier.. Silt deposition is typical similarly to *Agrostio–Caricetum distantis*. Some of its species are common with *Plantagini tenuiflorae–Pholiuretum pannonici* and *Agrostio stoloniferae–Alopecuretum pratensis.* Usually the stands of *Eleochari–Alopecuretum geniculati* are species-poor. Constant species are *Alopecurus geniculatus*, *Eleocharis palustris* and *E. uniglumis*.

VIII.6 *Rorippo kerneri–Ranunculetum lateriflori* (Soó 1947) Borhidi 1996

This association generally occurs in the matrix of *Agrostio stoloniferae–Beckmannietum eruciformis*. It is formed on the permanently wet areas, which are rich in silt. It is rich in dicotyledonous species which favour soils affected by silt deposition. Typical species are *Agrostis stolonifera*, *Eleocharis palustris*, *Beckmannia eruciformis*, *Elatine alsinastrum*, *Peplis portula*, *Ranunculus aquatilis*, *R. lateriflorus* and *Rorippa sylvestris* ssp. *kerneri*.

Ordination of the studied associations

The species composition of all studied associations are plotted on Figure 1.

Agrostio stoloniferae–Alopecuretum pratensis

Relevés from Gyöngyös-Heves-vidéke, Nagykunság, Jászság and Maros-szög compose a considerably compact group (Figure 1). The relevés from Gyöngyös-Heves-vidéke does not have a typical species pool, as they contain many species of dry grasslands (Figure 2). Their species number is high (Heves 5 relevés 44 species). Relevés from Körös-vidék shows the same pattern (2 relevés 21 species). Relevés from Nagykunság are more heterogeneous. The reason for this is that the certain relevés were carried out in a vegetation mapping project, thus they are far from each other. One of the relevés was made in an extremely weedy (*Cirsium arvense*) stand, thus it is further away from the other relevés of the association on the scatter plot of the ordination. In spite of being weedy (which usually indicates pure water supply and high level of disturbance), this area is fairly wet which is indicated by the high cover of *Agrostis stolonifera*. Thus, this relevé is located near the group of *Agrostio–Caricetum distantis* (Figure 1). Relevés from Maros-szög overlap with the relevés from Nagykunság. The relevé No.118 is a facies of *Elymus repens*. It does not contain *Alopecurus pratensis*, but many dry grassland species.

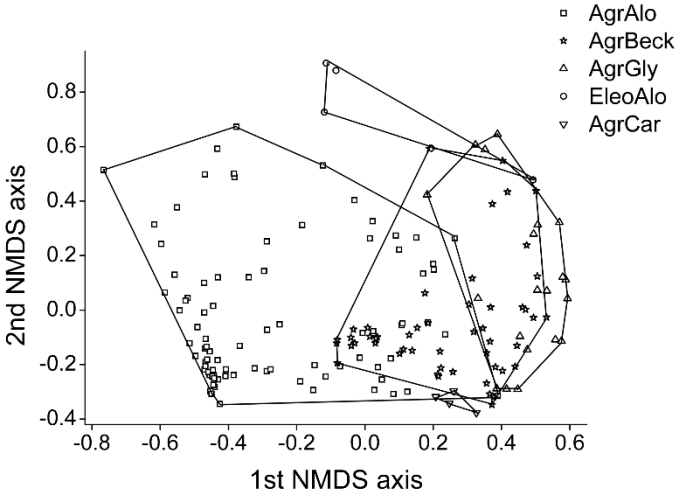

Figure 1. NMDS ordination of the relevés based on the percentage cover scores using Bray-Curtis similarity . Abbreviation of associations: AgrAlo - *Agrostio stoloniferae - Alopecuretum pratensis;* AgrBeck - *Agrostio stoloniferae - Beckmannietum eruciformis;* AgrGly - *Agrostio stoloniferae - Glycerietum pedicellatae;* AgrCar - *Agrostio-Caricetum distantis; EleoAgr - Eleochari - Alopecuretum geniculati.*

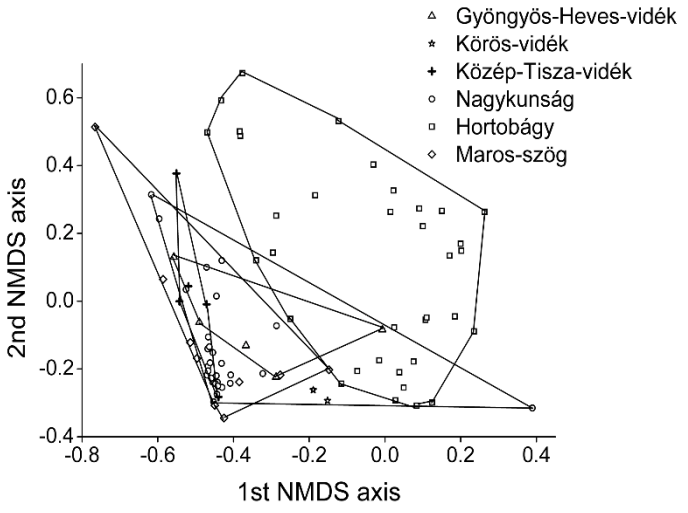

Figure 2. NMDS ordination of the relevés from *Agrostio stoloniferae - Alopecuretum pratensis* stands based on percentage cover scores using Bray-Curtis similarity.

The relevés of Hortobágy are the most heterogeneous. They overlap with all of the groups mentioned before. We have the largest number of relevés from there, which is well-justified by the heterogeneity of associations and habitats. The relevés No.93-102 are placed next to the groups of *Agrostio stoloniferae–Beckmannietum eruciformis* on the ordination (Figure 1). The reason for this is that this stand contains *Beckmannia eruciformis* and *Glyceria fluitans* as subordinate species in a high cover. It is interesting, that even the relevés 83-92 were located only 30-40 meters away from the relevés 93-102. The only difference is that the relevés 93-102 are grazed, the relevés 83-92 are not. This example from Hortobágy (Nyírőlapos) shows that management type can cause considerable differences in the species composition of associations.

The relevés of Bodrogköz overlap with the *Agrostio stoloniferae–Beckmannietum* group (Figure 1). This is due to the fact that his relevés come from four subtypes. Two of these subtypes (*beckmannietosum* and *juncetosum conglomerati*) show a great similarity with the stand of *Agrostio stoloniferae–Beckmannietum eruciformis* in Nagykunság (Kunmadarasi-puszta) in which there were many *Juncus conglomeratus* tussocks. The total species number of the relevés is high (44 species) because the relevés were scattered across four variants of the association. Relevés from Nagykunság (Kunmadarasi-puszta) are considerably more compact (Figure 2). They were recorded in a small homogenously managed area (50×50m).

Agrostio stoloniferae–Beckmannietum eruciformis

We have data from three regions (Nagykunság, Hortobágy, Maros-szög, see Figure 3). The two groups from Hortobágy are not separeted from the relevés of the Maros-szög. Relevés recorded in Nagykunság are very heterogeneous. Stands from Nagykunság (Kunmadarasi-puszta) are similar to the relevés of Bodrogközy's *Agrostio stoloniferae–Alopecuretum pratensis* (Figure 1). The reason for similarity is that the relevés of Bodrogközy from *Agrostio stoloniferae–Alopecuretum pratensis* association contain *Beckmannia eruciformis* with considerable frequency and cover values. The relevés of Bodrogközy are more species rich than any other relevés in the region.

Agrostio stoloniferae–Glycerietum pedicellatae

The group of *Agrostio stoloniferae–Glycerietum pedicellatae* overlaps with the *Agrostio stoloniferae–Beckmannietum eruciformis* (Figure 1). These two associations show considerable similarity as their species composition and attributes of habitat (salt content, water balance) are more similar to each other than to the *Agrostio stoloniferae–Alopecuretum pratensis*.

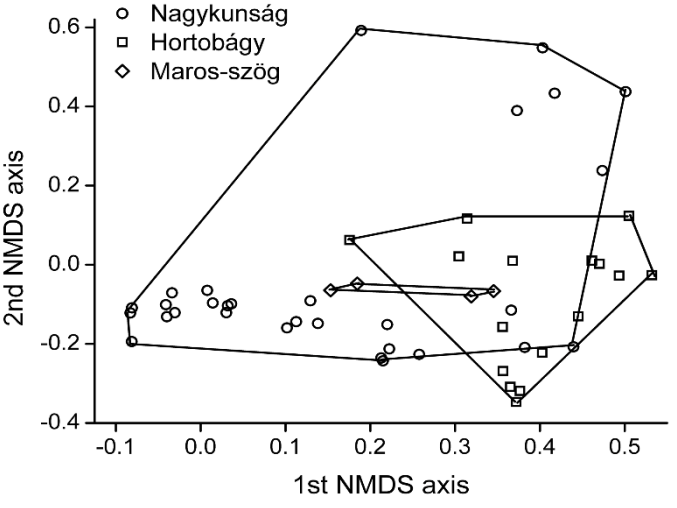

Figure 3. NMDS ordination of the relevés from *Agrostio stoloniferae - Beckmannietum eruciformis* stands based on percentage cover scores using Bray-Curtis similarity.

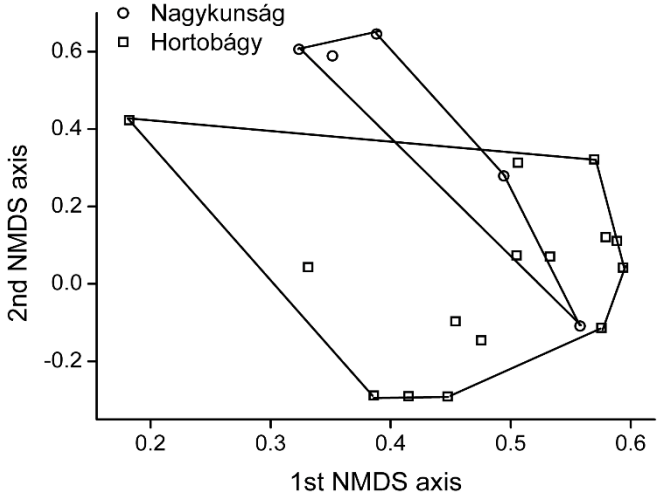

Figure 4. NMDS ordination of the relevés from *Agrostio stoloniferae - Glycerietum pedicellatae* stands based on percentage cover scores using Bray-Curtis similarity.

Groups of Hortobágy and Nagykunság overlap, but not completely (Figure 4). In this case, the subtypes of Bodrogközy (Hortobágy) are very similar to the *Agrostio stoloniferae–Beckmannietum eruciformis* (Figure 1).

Agrostio-Caricetum distantis

Relevés of this association (from Maros-szög) are situated between the *Agrostio stoloniferae–Alopecuretum pratensis* and *Agrostio stoloniferae–Beckmannietum eruciformis* (Figure 1). The *Agrostio–Caricetum distantis* has better water supply and its soil has higher salt content than that of *Agrostio stoloniferae–Alopecuretum pratensis*, but its soil gets dry earlier than that of *Agrostio stoloniferae–Beckmannietum eruciformis*, therefore *Agrostio-Caricetum distantis* stands harbour fewer halophyte species.

Eleochari–Alopecuretum geniculati

Relevés of this association (Nagykunság) are apart from the others (Figure 1). This association is not a typical tall grass alkali meadow.

Vegetation characteristics of the solonetz meadow associations

We studied the characteristics of the three most widespread associations, namely *Agrostio stoloniferae–Alopecuretum pratensis*, *Agrostio stoloniferae–Beckmannietum eruciformis* and *Agrostio stoloniferae–Glycerietum pedicellatae*,

from which we had enough relevés for the analyses. Studied characteristics were Relative Ecological Indicator Values (SB, WB), Raunkiaer's life form, Social Behaviour Types, Phytosociologycal groups and Flora elements (Borhidi 1995).

Relative Ecological Indicator Values for Salt content (SB)

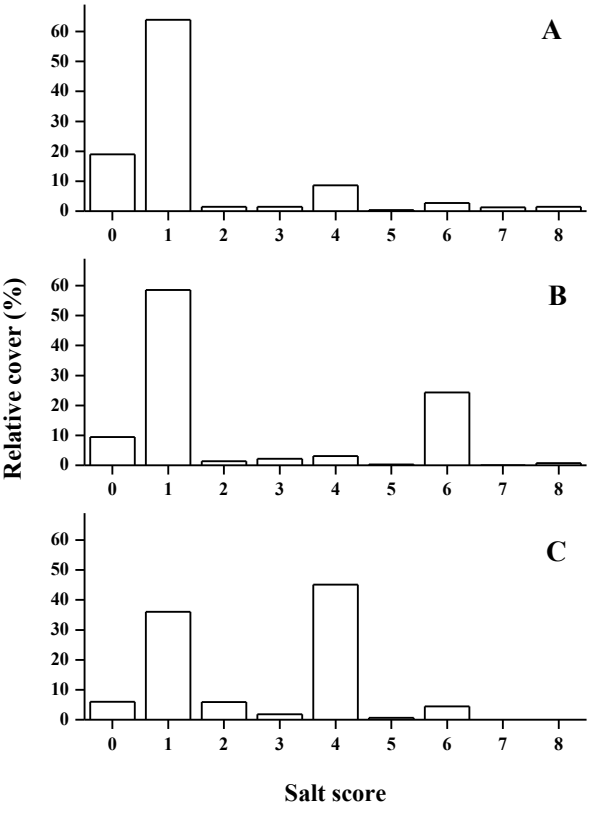

Figure 5. Distribution of Salt scores (SB) in the three studied solonetz meadow associations: A – *Agrostio stoloniferae–Alopecuretum pratensis;* B – *Agrostio stoloniferae–Beckmannietum eruciformis;* C – *Agrostio stoloniferae–Glycerietum pedicellatae*.

In *Agrostio stoloniferae–Alopecuretum pratensis* association the species with 0 and 1 values – which have little tolerance against salt are the dominant (Figure 5). Their ratio is 18.9% and 63.9%, respectively. Beside them, species with the value 4 are present (8.6%) which have a medium salt tolerance. Some of them are

dry grassland plants (*Silene viscosa, Trifolium* spp.) that are present in drying stands. Some of them are meadow species which can be found in wetter stands, such as *Eleocharis uniglumis*, which is a typical species of *Agrostio stoloniferae–Alopecuretum pratensis* stands. The largest number of salt-tolerant species are present in *Agrostio stoloniferae–Beckmannietum eruciformis* (Figure 5). Here the only species with high salt-tolerance (group 6) is *Beckmannia eruciformis* which is the dominant species of the association. In case of *Agrostio stoloniferae–Glycerietum pedicellatae* species with moderate salt-tolerance (category 4) form the most abundant group (45.2%). The reason for the high ratio of this group is that the dominant plant of the association (*Glyceria fluitans*) belongs here. In this association *Beckmannia eruciformis* with score 6 also occurs.

Relative Ecological Indicator Values for Soil Moisture (WB)

Agrostio stoloniferae–Alopecuretum pratensis is the association located on the driest habitats. Here the group with 6 WB score dominates (47.7%) and also group 4 (13%) and group 7 (15.7%) have considerable proportion (Figure 6). This association occurs typically in wet areas, which can get dried occasionally. Thus, there are several dry grassland species, such as *Achillea collina, Centaurea pannonica, Cruciata pedemontana, Festuca pseudovina, Podospermum canum, Trifolium* spp. in these meadows. These species are generally typical species of the surrounding dry grasslands (alkali-, loess steppes). Depending on the weather conditions, these associations can transform to each other. A dry grassland species with high frequency is *Elymus repens*. This species is frequently present with high cover in drying stands forming a facies. Usually it appears in those dry stands, which are managed improperly. *Cirsium arvense* is present in dry, heavily disturbed stands. Majority of group 6 is composed by *Alopecurus pratensis*, but the ratio of *Limonium gmelinii* ssp. *hungaricum* is considerable too. High cover of *L. gmelinii* ssp. *hungaricum* is typical in drying meadows with high salt content. Other subordinate species of group 6 are *Rumex* spp. which can form facies of the *Agrostio stoloniferae–Alopecuretum pratensis* association. *Rumex stenophyllus* is typical in undisturbed stands, *R. crispus* is typical in disturbed stands. *Agrostis stolonifera* is the species with the highest cover in group 7. Dominant species of group 8 are *Beckmannia eruciformis* and *Juncus* spp. In lower-lying patches *Eleocharis uniglumis* is frequent, its moisture score is high (9). Other species in the group 9 are: *Lycopus* spp. and *Carex melanostachya* which are species of an alkali sedge association (*Caricetum melanostachyae* Balázs 1943).

In case of *Agrostio stoloniferae–Beckmannietum eruciformis* the histogram shifts towards higher values (Figure 6). This indicates that this association needs wetter habitat than *Agrostio stoloniferae–Alopecuretum pratensis*. The first group with high participation is group 6 (13.5%). Its species are *Alopecurus pratensis* and *Rumex stenophyllus* which are present with a high cover. The largest group is group

7 (44.7%), which is composed by *Agrostis stolonifera*, a constant species of the association and *Mentha* spp. as a subordinate species. Other constant species is *Beckmannia eruciformis*. This species constitutes the majority of group 8 (30.6%). *Lythrum virgatum* and *Glyceria fluitans* are present with high frequency and cover values. In group 9 the endemic *Cirsium brachycephalum* is present. Beside it *Eleocharis uniglumis* and *Veronica scutellata* are present with high values. Group 10 consists of two species with high frequency but low cover values: *Eleocharis palustris* and *Bolboschoenus maritimus*.

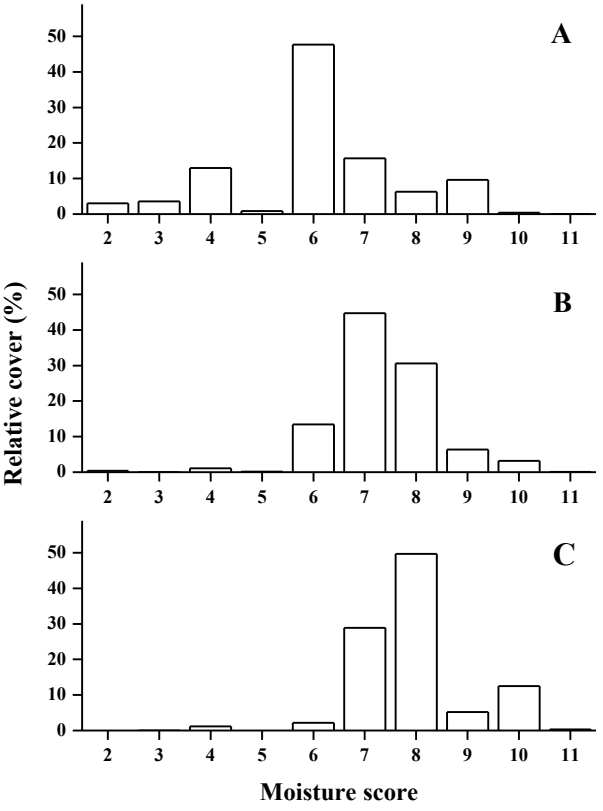

Figure 6. Distribution of Moisture scores in the three studied solonetz meadow associations: A – *Agrostio stoloniferae–Alopecuretum pratensis;* B – *Agrostio stoloniferae–Beckmannietum eruciformis;* C – *Agrostio stoloniferae–Glycerietum pedicellatae*.

Agrostio stoloniferae–Glycerietum pedicellatae occurs in habitats with the best water supply and has a histogram shifted to the highest values (Fig. 6). Group 7 (28.9%) consist almost exclusively of *Agrostis stolonifera*. Two constant species (*Beckmannia eruciformis, Glyceria fluitans*) give the majority of group 8 (49.7%). Group 9 is almost absent. The reason for this is the permanent water cover that is not favourable for *Eleocharis uniglumis*, which was present in the other two associations. *Carex melanostachya* and *Phalaris arundinacea* are present with low cover values thus they contribute to a transition to alkali sedge associations and marshes. The members of group 10 (*Alisma lanceolatum*, *Bolboschoenus maritimus*, *Phragmites australis*, *Schoenoplectus lacustris* and *Typha* spp.) are common species with alkali and non-alkali marshes (Deák *et al.* 2014c).

Raunkiaer's life form categories

Hemicryptophytes (H), geophytes (G) and helo- and hydrophytes (HH) are the most typical life forms in the three associations (Table 2). In *Agrostio stoloniferae–Alopecuretum pratensis*, hemicryptophytes are the dominant group (72.6%) comprised by the dominant graminoid (*Alopecurus pratensis*, *Agrostis stolonifera*, *Juncus conglomeratus*, *J. effusus*) and typical dicotyledonous species (*Galium palustre*, *Lythrum* spp., *Mentha* spp., *Rumex* spp). The most abundant species of the group of geophytes (16.8%) are *Eleocharis* spp. and *Elymus repens* and also the small *Juncus* species (*Juncus compressus, J. gerardii*) belong to this group.

Table 2. Proportions of Raunkiaer's life forms in the three studied solonetz meadow associations. Abbreviation of associations: AgrAlo – *Agrostio stoloniferae–Alopecuretum pratensis;* AgrBeck – *Agrostio stoloniferae–Beckmannietum eruciformis;* AgrGly – *Agrostio stoloniferae–Glycerietum pedicellatae*. Abbreviation of Raunkiaer's life forms: Ch – Chamaephytes; H – Hemicryptophytes; G – Geophytes; HH – Helo- and hydrophytes; Th – Therophytes; TH – Hemitherophytes.

	AgrAlo	**AgrBeck**	**AgrGly**
Ch	0.6	0.1	0.2
H	72.6	90.1	38.9
G	16.8	3.6	4.5
HH	4.8	3.5	54.9
Th	4.4	2.3	1.5
TH	0.8	0.5	0.1

In *Agrostio stoloniferae–Beckmannietum eruciformis* the ratio of geophytes is low (3.6%). The frequent geophyte species are *Eleocharis* spp. *Elymus repens*, which gives the majority of this group in case of *Agrostio stoloniferae–Alopecuretum pratensis*, is not typical in this association because of the high salt content and better water supply. The group of hemicryptophytes (90.1%) is mainly

composed by constant grass species, such as *Alopecurus pratensis*, *Agrostis stolonifera*, *Beckmannia eruciformis* and *Glyceria fluitans*. Further species of this group are *Juncus conglomeratus*, *J. effusus*, *Lythrum* spp., *Rumex stenophyllus* and *Veronica scutellata*.

In *Agrostio stoloniferae–Glycerietum pedicellatae* association the group of helophytes and hydrophytes has the highest value (54.9%) indicating the moist habitat conditions of the association. Typical species of this group are the common species with sedge associations and marshes, such as *Alisma lanceolatum*, *Bolboschoenus maritimus*, *Carex melanostachya*, *Lycopus* spp., *Phragmites australis*, *Schoenoplectus tabernaemontani* and *Typha* spp. In the group of hemicryptophytes (38.9%) *Agrostis stolonifera, Beckmannia eruciformis, Glyceria fluitans* and *Rorippa sylvestris* subsp. *kerneri* are present. The group of geophytes (4.5%) is composed only by *Eleocharis* spp.; mainly *Eleocharis palustris* is present.

Social Behaviour Types

Agrostio stoloniferae–Alopecuretum pratensis association is the most heterogeneous regarding social behaviour types (Table 3). The reason for this is partly the many weed species that are present in drying stands. This association is the most unstable because of its place in the zonation (Deák *et al.* 2014a). *Agrostio stoloniferae–Alopecuretum pratensis* can dry out the easiest way that can lead to degradation. Here is the lowest the soil salt content that allows the establishment of a wider range of species. The group of disturbance-tolerants (11.6%) consists of *Juncus* spp. (except *J. gerardi*), *Lycopus* spp., *Mentha* spp.; with lower cover *Pulicaria vulgaris* and *Leontodon autumnalis* also occur. *Elymus repens* is the most frequent species of the group of ruderal competitors (12%). In our opinion, this species is not a ruderal competitor in alkali meadows but a competitor. If we recalculate the data accordingly, the proportion of the competitors is higher as it is shown in Table 3 (59.8%). The dominant grass species of the association and *Eleocharis palustris* also belong to the group of competitors. *Eleocharis uniglumis*, *Lythrum* spp. and *Rumex stenophyllus* belong to the group of generalists (11.6%). Proportion of specialists is low (4.5%). Specialist species typical to meadows (*Rorippa sylvestris* ssp. *kerneri* and *Ranunculus lateriflorus*) and alkali dry grasslands (*Limonium gmelini* ssp. *hungaricum*, *Lotus tenuis*, *Ranunculus pedatus* and *Trifolium* spp.) both occur in this association.

In *Agrostio stoloniferae–Beckmannietum eruciformis* the proportion of species of disturbed, secondary and artificial habitats is low. Disturbance-tolerant species have a small ratio (4.8%), with similar wetland species mentioned at *Agrostio stoloniferae–Alopecuretum pratensis*. The group of competitors (81.7%) is composed by the dominant grass species of the association and *Eleocharis palustris*. The group of geophytes (10.7%) is composed by *Carex* spp., *Eleocharis uniglumis*, *Lythrum* spp., *Rumex stenophyllus* and *Veronica scutellata*. Specialist

species (1.1%) include *Aster tripolium* ssp. *pannonicus, Cirsium brachycephalum, Limonium gmelini* ssp. *hungaricum, Lotus tenuis, Pholiurus pannonicus, Ranunculus lateriflorus* and *Rorippa sylvestris* ssp. *kerneri*.

In *Agrostio stoloniferae–Glycerietum pedicellatae* the proportion and typical species of the groups of disturbance-tolerants (4.7%) and geophytes (5.7%) is very similar to those in *Agrostio stoloniferae–Beckmannietum eruciformis.* The competitors form the largest group (87.1%) including the dominant grass species of the association (*Agrostis stolonifera, Beckmannia eruciformis* and *Glyceria fluitans*) and *Eleocharis palustris*, accompanied by *Phalaris arundinacea, Phragmites australis, Schoenoplectus lacustris* and *Typha* spp. The proportion of specialists is low (1.8%), and most of them are species of wet habitats (*Ranunculus lateriflorus* and *Rorippa sylvestris* ssp. *kerneri*).

Table 3. Proportions of Social Behaviour Types in the three studied solonetz meadow associations. Abbreviation of associations: AgrAlo – *Agrostio stoloniferae–Alopecuretum pratensis;* AgrBeck – *Agrostio stoloniferae–Beckmannietum eruciformis;* AgrGly – *Agrostio stoloniferae–Glycerietum pedicellatae*. Abbreviation of Social Behaviour Types: AC – Adventive competitors; RC – Ruderal competitors; I – Introduced crops; W – Native weed species; DT – Disturbance-tolerant plants of natural habitats; NP – Natural pioneers; G – Generalists; C – Competitors; S – Specialists.

	AgrAlo	**AgrBeck**	**AgrGly**
AC	0	0.1	0
RC	12	0.5	0
I	0.01	0	0
W	0.2	0.8	0
DT	11.6	4.8	4.7
NP	0.3	0.4	0.7
G	11.6	10.7	5.7
C	59.8	81.7	87.1
S	4.5	1.1	1.8

Phytosociological groups

In *Agrostio stoloniferae–Alopecuretum pratensis* association, the Molinio–Arrhenatheretea (48.6%) species dominate (Table 4). These species are meadow species that have low salt tolerance. The majority of this group is composed by *Alopecurus pratensis* and *Juncus conglomeratus*. Festuco–Puccinellietea (8.9%) species typical to alkali includes species of alkali steppes, alkali meadows and other alkali associations (*Puccinellietum limosae, Plantagini tenuiflorae–Pholiuretum pannonici, Camphorosmetum annuae*). There are also dry and wet grassland species in this group. Dry grassland species (*Festuca pseudovina, Limonium gmelini* ssp. *hungaricum, Trifolium* spp.) can estabish in *Agrostio stoloniferae–*

Alopecuretum pratensis stands when the habitat is getting dry. Frequent and typical wet grassland species are *Alopecurus geniculatus*, *Beckmannia eruciformis* and *Ranunculus lateriflorus*. Two species is present from the group Phragmitetea: *Carex melanostachya* and *Galium palustre*. *Eleocharis uniglumis* is the only representative of group Scheuchzerio–Caricetea nigrae, but it has high cover (4.5%) and frequency values. There are several species in the indifferent group (33.4%), including *Agrostis stolonifera*, *Carex praecox*, *Elymus repens*, *Inula britannica*, *Lycopus* spp., *Lythrum virgatum*, *Mentha* spp. and *Poa* spp.

Table 4. Proportions of the phytosociologycal groups in the three studied solonetz meadow associations. Abbreviation of associations: AgrAlo – *Agrostio stoloniferae–Alopecuretum pratensis;* AgrBeck – *Agrostio stoloniferae–Beckmannietum eruciformis;* AgrGly – *Agrostio stoloniferae–Glycerietum pedicellatae*.

Phytosociologycal group	AgrAlo	AgrBeck	AgrGly
Agropyretea	0.1	0	0
Agrostietea stoloniferae	0.1	0	0
Artemisietalia	0.1	0.1	0
Bidentetea	0	0.4	0
Bolboschoenetea	0.1	1.4	1.6
Chenopodietea	0.1	0.7	0
Festuco - Brometea	0.1	0	0
Festuco - Puccinellietea	8.9	26.5	8.7
indifferent	33.4	52	34.9
Isoëto - Nanojuncetea	0.1	0.1	0.3
Lemnetea	0.1	0	0.3
Molinio - Arrhenatheretea	48.6	14.8	1.7
Phragmitetea	4.2	1.5	52.4
Plantaginetea	0.1	0.1	0
Ruppietea	0	0.1	0.1
Scheuchzerio - Caricetea nigrae	4.5	2.6	0.1
Secalietea	0.1	0	0
Sedo - Scleranthetea	0.1	0	0
Thero - Salicornieta	0	0.1	0

In *Agrostio stoloniferae–Beckmannietum eruciformis* Festuco–Puccinellietea (26.5%) is the largest group (Table 4). This suggests that this association contains typical alkali species and develops in salt-affected habitats. The most typical species are typical species of wet alkali habitats, such as *Alopecurus geniculatus*, *Beckmannia eruciformis*, *Cirsium brachycephalum* and *Rumex stenophyllus*. *Pholiurus pannonicus* is typical in patches with silt accumulation. Molinio–Arrhenatheretea species are similar to those in *Agrostio stoloniferae–Alopecuretum pratensis* (*Alopecurus pratensis*, *Juncus conglomeratus*) and have a lower

proportion (14.8%). The group Scheuchzerio–Caricetea nigrae is represented only by *Eleocharis uniglumis.* The group Phragmitetea is present with a lower value (1.5%) than in *Agrostio stoloniferae–Alopecuretum pratensis*. Typical Phragmitetea species are *Alisma lanceolatum*, *Glyceria fluitans*, *Veronica scutellata* and occasionally*Typha angustifolia*. *Bolboschoenus maritimus* is the only representative of the group Bolboschoenetea. Indifferent species form a large group (52%), including *Agrostis stolonifera*, *Eleocharis palustris*, *Inula britannica*, *Juncus effusus*, *Lycopus europaeus*, *Lysimachia nummularia*, *Lythrum virgatum* and *Mentha* spp.

The proportion of the phytosociologycal groups shows that *Agrostio stoloniferae–Glycerietum pedicellatae* can be found in habitats with good water supply (Table 4). Accordingly, the group Phragmitetea has the greatest proportion (52.4%). Species that need continuous water supply are more frequent in this association, such as *Alisma lanceolatum*, *Carex melanostachya*, *Glyceria fluitans*, *Lythrum salicaria*, *Phalaroides arundinacea*, *Phragmites communis*, *Schoenoplectus lacustris* and *Typha angustifolia*. The proportion of the species typical to alkali habitats (Festuco–Puccinellietea) is lower (8.7%) than in the other two associations. Species typical to dry steppes are absent, rather typical alkali meadow species are present (*Alopecurus geniculatus*, *Beckmannia eruciformis*, *Ranunculus lateriflorus*, *Rorippa sylvestris* ssp. *kerneri*). Molinio–Arrhenatheretea which is a well-represented group in other two associations is represented here by only a few species with low cover (1.7%). *Alopecurus pratensis* and *Juncus conglomeratus* are present in only a few relevés with small cover. shows the same pattern. From group Bolboschoenetea there is only one species present (*Bolboschoenus maritimus*). The cover of the Scheuchzerio–Caricetea nigrae group is very low (0.1%), as its typical species *Eleocharis uniglumis* cannot tolerate the continuous water cover. The group Isoëto–Nanojuncetea (0.3%). is represented by *Elatine alsinastrum* and *Peplis portula*. The indifferent group contains few species, such as *Agrostis stolonifera*, *Eleocharis palustris* and *Lycopus europaeus.*

Flora elements

The flora elements typical to continental steppes (continental, ponthic-mediterranean, ponthic) are present in *Agrostio stoloniferae–Alopecuretum pratensis* with high scores, as this is the driest solonetz meadow association (Table 5). In the group of continental flora elements (5%) there are alkali steppe species with low cover and frequency (*Achillea collina*, *Festuca pseudovina*, *Hordeum hystrix*, *Plantago tenuiflora*, *Ranunculus pedatus*), and several alkali meadow and sedge species (*Carex melanostachya*, *Lythrum virgatum*, *Ranunculus pedatus*, *Rumex stenophyllus*). The group of ponthic-mediterranean flora elements (1.5%) contains *Podospermum canum*, *Trifolium retusum* and *Trigonella procum-bens*. The group of Pannonian flora elements contains pannonian endemic species that are typical in alkali habitats, such as

Limonium gmelini subsp. *hungaricum* and *Puccinellia limosa*. Proportion of endemic species is the highest in this association (1.2%). *Ajuga genevensis*, *Ranunculus lateriflorus* and *Rorippa austriaca* are in the ponthic group. The only species in the group of atlantic-submediterranean flora elements is *Trifolium striatum*, a typical species of moderately alkali steppes and loess grasslands. The group of European is represented with low species number and cover and includes *Alopecurus geniculatus* and *Juncus conglomeratus*. The group with the highest species number and cover is the groupd of Eurasian flora elements (55.1%) with several generalist wetland plants (*Alopecurus pratensis*, *Carex praecox*, *Eleocharis palustris*, *Inula britannica*, *Juncus compressus*, *Lycopus europaeus*, *Lysimachia nummularia* and *Ranunculus sardous*) and a few dry grassland species (*Gypsophila muralis* and *Trifolium fragiferum*). Typical species from the circumboreal group (20%), such as *Beckmannia eruciformis*, *Eleocharis uniglumis*, *Elymus repens* and *Galium palustre* occur in natural, undisturbed stands in good condition. Cosmopolitan species (11.4%) are *Agrostis stolonifera*, *Bolboschoenus maritimus*, *Juncus effusus*, *Poa trivialis*, *Rumex crispus* and *Typha angustifolia*. There are some other flora element groups present in low proportion, such as submediterrean (0.7%; *Lotus glaber*, *Mentha pulegium*) and balkanian (0.9%; *Trifolium angulatum*, *Bupleurum tenuissimum*).

Table 5. Proportions of the flora elements in the three studied solonetz meadow association. Abbreviation of associations: AgrAlo – *Agrostio stoloniferae–Alopecuretum pratensis;* AgrBeck – *Agrostio stoloniferae–Beckmannietum eruciformis;* AgrGly – *Agrostio stoloniferae–Glycerietum pedicellatae*. Abbreviation of the flora elements: ADV – Adventive; AsM – Atlantic-submediterranean; BAL – Balkanian; CIR – Circumboreal; CON – Continental; COS – Cosmopolitan; EUA – Eurasian; EUR – European; PAN – Pannonian; PoM – Ponthic-mediterranean; PON – Ponthic; PoP – Ponthic-Pannonian; SME – Submediterranean; TUR – Turanian.

Flora element type	**AgrAlo**	**AgrBeck**	**AgrGly**
ADV	0.1	0.1	0
AsM	0.4	0	0
BAL	0.9	0	0
CIR	20	29.2	9.1
CON	5	5.1	1
COS	11.4	46.2	34.9
EUA	55.1	15.3	50.2
EUR	3.2	1.7	3.6
PAN	1.2	0.2	0
PoM	1.5	0.4	0
PON	0.6	0.2	1.2
PoP	0	0.4	0
SME	0.7	1.4	0
TUR	0.1	0	0

In *Agrostio stoloniferae–Beckmannietum eruciformis* association, the cosmopolitan group (46.2%) has the largest proportion (Table 5) including a few species with high cover scores, such as *Agrostis stolonifera*, *Bolboschoenus maritimus* and *Juncus effusus*. The most frequent species of the circumboreal (29.2%) group are *Beckmannia eruciformis, Eleocharis uniglumis* and *Veronica scutellata*. The group of Eurasian flora elements (15.3%) includes common species of wetlands, such as *Alisma lanceolatum*, *Alopecurus pratensis*, *Eleocharis palustris*, *Glyceria fluitans*, *Inula britannica*, *Lycopus europaeus* and *Lysimachia nummularia.* The group of European flora elements is represented with a small percentage cover (1.7%), including *Alopecurus geniculatus, Juncus conglomeratus* and *Mentha aquatica*. The continental group has the same proportion as in *Agrostio stoloniferae–Alopecuretum pratensis* (5.1%), but since this association has a wetter habitat, dry grassland species are absent. Typical species with continental distribution are *Lythrum virgatum*, *Plantago tenuifolia* and *Rumex stenophyllus*. *Cirsium brachycephalum* and *Limonium gmelini* subsp. *hungarica* are the only representatives of Pannonian group. There are only a few species in the ponthic group, including *Ranunculus lateriflorus* and *Rorippa austriaca*. In the Submediterranean group there is only one species (*Mentha pulegium*). The ponthic-pannonian group is present only in this association with a single species (*Pholiurus pannonicus*).

The Eurasian group has the largest proportion (50.2%) in *Agrostio stoloniferae–Glycerietum pedicellatae* (Table 5) containing *Alisma lanceolatum*, *Eleocharis palustris* and *Glyceria fluitans*. The cosmopolitan group (34.9%) contains species typical also to marshes, such as *Agrostis stolonifera*, *Bolboschoenus maritimus*, *Phalaris arundinacea*, *Phragmites communis* and *Typha angustifolia*. Typical species of the circumboreal group (9.1%) are *Beckmannia eruciformis*, *Schoenoplectus lacustris* and *Veronica scutellata*. The European group is represented by *Alopecurus geniculatus* and *Rorippa sylvestris* subsp. *kerneri*. There is only one species in the continental group (*Carex melanostachya*). *Ranunculus lateriflorus* occurs in this association as the member of ponthic group.

Conclusions

Solonetz meadows are typical associations of the alkali grasslands of the Great Hungarian Plain. Water balance and the salt content of the soil are the main environmental factors driving these associations. Solonetz meadows usually form a transition zone between salt marshes and alkali steppes. Six solonetz meadow associations occur on the floodplain of the Tisza river. Three of them (*Agrostio stoloniferae–Alopecuretum pratensis, Agrostio stoloniferae–Beckmannietum eruciformis and Agrostio stoloniferae–Glycerietum pedicellatae*) cover a large area. There are three other, less widespread associations (*Agrostio–Caricetum*

distantis, Eleochari–Alopecuretum geniculati, Rorippo kerneri–Ranunculetum lateriflori), which are important in maintaining the diversity of the landscape. The three most frequent associations are similar in species pool, structure, and habitat conditions, but there are differences in the ratio of the frequent species controlled by the salt content and the water coverage during the spring and early summer.

Agrostio stoloniferae–Alopecuretum pratensis

This was the most heterogeneous association of the studied solonetz meadows. Salt scores showed that the species with low salt tolerance (0-1) were the most frequent in this association. According to the moisture scores (score 6 dominates) this association is the driest one; therefore, several species typical to surrounding dry grasslands were present here. Competitors and generalists were the most frequent strategies and this association was the most sensitive to the establishment of weed species. Because of the low salt content of the soil the proportion of typical alkali species (Festuco–Puccinellietea) was low. Those species were the most abundant, which were common species of the non-alkali meadows (Molinio–Arrhenatheretea) and those which were habitat generalists. The ratio of continental, ponthic-mediterranean, and ponthic elements was high. The ratio of pannonian endemic species typical in alkali habitats was relatively high. The majority of species belonged to the Eurasian, circumboreal and cosmopolitan groups.

Agrostio stoloniferae-Beckmannietum eruciformis

This association showed more stable meadow and alkali characteristics, than *Agrostio stoloniferae–Alopecuretum pratensis*. *Beckmannia eruciformis* was abundant, indicating the high salt content of the soil. This was a wetter habitat than the *Agrostio stoloniferae–Alopecuretum pratensis*, thus the moisture scores shifted towards the higher scores The most abundant moisture group was 7, and species with low moisture scores were almost absent. There were fewer generalist species there and the most abundant social behaviour type group was the group of competitors. Due to the higher salt content of the soil the species of Festuco–Puccinellietea had the highest proportion in this association. Ratio of the species of non alkali meadows (Molinio–Arrhenatheretea) was considerably lower, but the ratio of indifferent species was the highest in the stands of *Agrostio stoloniferae–Beckmannietum eruciformis*. The majority of the species pool was composed by the Eurasian, circumboreal and cosmopolitan groups as in the *Agrostio stoloniferae–Alopecuretum pratensis* association. The difference was that the ratio of cosmopolitan and continental species was considerably higher, and the Eurasian group was suppressed. There were several endemic Pannonian, Ponthic-Pannonian species with low abundance.

Agrostio stoloniferae–Glycerietum pedicellatae

Agrostio stoloniferae–Glycerietum pedicellatae was the wettest alkali meadow association, it showed common characteristic with sedge meadows and alkali and non-alkali marshes. This association occurred in habitats with moderately deep and permanent water cover; the species preferring wet habitats were typical there having high moisture scores. The good water supply was also indicated by the dominance of helo- and hydrophytes. Spectrum of Social Behaviour Types showed the same pattern as in the case of the *Agrostio stoloniferae–Beckmannietum eruciformis*: group of competitors was the most frequent, generalists and weeds were less frequent. Contrary to the other alkali meadows, the group of Phragmitetea was present with a high ratio. Proportion of species typical to alkali salt-affected habitats (Festuco–Puccinellietea) was the same as in the *Agrostio stoloniferae–Alopecuretum pratensis* association, and the species typical to dry steppes was absent. The ratio of Molinio–Arrhenatheretea species was low. The majority of the species pool was composed by the Eurasian, circumboreal and cosmopolitan groups as in the other alkali meadows. As the habitat had moderate salt content and permanent water cover the ratio of continental and ponthic species was low. There were no endemic species in the relevés ot this association.

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