

Influence of Variability of Ryegrass Meadow Soil Conditions on their Natural and Utilization Values

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Abstract

The study presents the findings of research into the effect of the variability of site conditions on their floristic composition providing a basis for the identification of lower phytosociological units. Patches of *Arrhenatheretum elatioris* described with the assistance of phytosociological surveys conducted using the Braun-Blanquet method were subjected to multi-criteria evaluation. On their basis, the following parameters were determined: ecological and botanical structure, geographic-historical distribution, the structure of the life-groups of the floristic types identified, as well as natural values by the Oświt method and sward fodder value according to Filipek. In order to determine the causes of the floristic variability observed, the following soil conditions were assessed: moisture content, soil reaction and nitrogen content by Ellenberg's indicator method, as well as potassium, magnesium and phosphorus content by the appropriate laboratory methods. Typical forms of *Arrhenatheretum elatioris* phytocenoses were found to develop on mucky soils in moderately moist sites. Patches of ryegrass occurring in sites with a periodically higher moisture content on organic soils refer to the *Alopecuretum pratensis* association. On the other hand, the sward of ryegrass meadows developed on dryer, mineral soils was characterised by increased numbers of species characteristic for xerothermic swards from the *Festuco-Brometea* class and sandy plant communities from the *Koelerio glauca-Corynephoretea canescentis*. More intensive utilization, primarily-fertilisation, was among the causes of the development of species-poor phytocenoses of low natural value but sward of a good fodder value.

Keywords: *Arrhenatheretum elatioris*, floristic diversity, natural value, soil conditions, utilization value

Introduction

Arrhenatheretum elatioris are among the most widespread plant communities in Poland and in Central Europe as a whole (Dierschke, 1994, 1999a; Duchoslav, 1997; Kojić *et al.*, 2005; Kucharski and Michalska-Hejduk, 1994; Mucina *et al.*, 1993; Rozbrojová *et al.*, 2010; Valev *et al.*, 2011; Zarzycki *et al.*, 2011; Żyszkowska, 2007). This can be attributed mainly to the wide ecological scale of species making up this phytocenosis. This is reflected in the recorded sub-associations (Kryszak, 2001; Kucharski, 1999; Sykora *et al.*, 1990). Typically developed patches of *Arrhenatheretum elatioris* possess a characteristic multilayer structure with a majority of tall grasses, including dominant oat grass (*Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl and C. Presl), as well as numerous legumes and other dicotyledonous perennials. This is a community which, on typical sites found on moderately moist and relatively fertile soils and at extensive utilization, is characterized by exceptionally high biological diversity, which is expressed in the high landscape value of these meadows. In the course of the last 20 years, however, the gradual disappearance of meadows developed in a typical form has been observed (Vintu *et al.*, 2011; Weigelt *et al.*, 2009). The current structure of *Arrhenatheretum elatioris* patches was affected, first

and foremost, by changes in utilization: on one hand, intensification, where the demand for forages was high and, in other places, the decline in the utilization of meadows which were sometimes left idle for some years, and on the other hand, the floristic structure of ryegrass meadows is associated with site conditions (Zarzycki *et al.*, 2011). The significant drying out of river valleys and flooding, which had previously not been observed, were quickly reflected in the structure of the plant cover.

The aim of this study was to assess the impact of soil conditions on the diversity of *Arrhenatheretum elatioris* in: floristic compositions, which formed the basis for division of lower syntaxonomic units (1) and in natural and utilizations values (2).

Material and methods

Multifaceted analysis was carried out on 300 phytosociological relèves of the *Arrhenatheretum elatioris* association recorded using the Braun-Blanquet scale (Szafer and Zarzycki, 1977) on lowland areas of Wielkopolska Region (Poland) (Fig.1) between 2008-2010 and uploaded to the TURBOVEG database, where they were subjected to edition and initial numerical classification.



Fig. 1 Location of study area

Using JUICE software (Tichý, 2002), an initial TWINSpan (Hill, 1979) hierarchical classification analysis was performed, which provided a preliminary picture of the similarities and differences between relevés. The data on these relevés were transcribed from the seven-point Braun-Blanquet scale into following values: r-0.1, +-0.5, 1-5, 2-18, 3-38, 4-63, 5-88. NCLAS software from the SYNTAX 5.0 package (Podani, 1993) conducted a dual classification: with respect to the presence of particular species and with respect to quantitiveness. Vegetation similarities in individual phytosociological relevés were determined with the aid of the Jaccard formula and the Ružičkova formula (Dzwonko, 1977). This was the basis for selecting four groups of relevés (each represented by 30 records). Every group had its own differential species which are used for valorisation of habitat, nature and utilization. The collection of 120 relevés was analysed using the CANOCO 4.5 software (Braak and Šmilauer, 2002). Data were processed with the assistance of PCA analysis, which makes it possible to determine major variability directions of the communities examined in accordance with the habitat gradient.

Site conditions of ryegrass meadows were determined by the phytosociological method (Ellenberg *et al.*, 1992) which evaluated the following for each phytosociological relevé: moisture (F), reaction (R) and nitrogen content (N). Moreover, for each plot the following parameters were determined using common laboratory methods:

- Soil moisture content-by the drier-gravimetric method,
- Soil organic content-the gravimetric method involving sample roasting at a temperature of 600°C and calculation of weight losses,

- Soil pH in 1 mol KCl dm⁻³-by the potentiometric method: in mineral soils-by the Egner-Riehm method and in organic soils in 0.5 mol HCl dm⁻³,

- Content of available magnesium in mineral soils-by the Schachtschabel method and in organic soils in 0.5 mol HCl dm⁻³.

Trophism was described as combining the trophic factors (Mg-, P₂O₅-, K₂O-content, pH, the content of organic matter) and also one of Ellenberg's index-N-content.

Multifaceted natural valorisation concerned:

- diversity evaluation-the mean number of species in the relevé, botanical structure,
- natural evaluation-geographic-historical spectrum (Jackowiak, 1990), the proportion of life-groups (Zarzycki *et al.*, 2002), ecological structure, natural value by the Oświt (2000) method,
- threatened evaluation-the proportion of species exhibiting the strongest expansiveness (Zarzycki *et al.*, 2002).

Natural values were assessed by the Oświt method (2000), which was applied to assess the value of plant communities of wet areas and hydrogenic sites. It consists in ascribing each taxon a numerical value from 1 to 10, depending on the species natural value. In this method, the most valuable species, protected and threatened are awarded the highest values, whereas common species not appearing at the hydromorphic site are given a value of 1. The result was an arithmetical mean of the numerical value of the species which were recorded in relevé.

When performing utilization valorisation, the share of utilization groups as well as sward fodder value calculated according to Filipek (1973) were taken into account. The method developed by Filipek (1973) assigns each species an allotted number of fodder value from 3 to 10. Negative numbers refer to poisonous species, numbers 0 and 1 are assigned to taxons characterised by the lowest fodder value and number 10-corresponds to the best species, such as *Lolium perenne* L. or *Trifolium repens* L.

The species were assessed in accordance with the Braun-Blanquet method with regard to the number of occurrences in relation to the total number of relevés of a given association, i.e. the constancy degree was determined and the mean area cover by the species in the community, i.e. the covering coefficient.

Results and discussion

The structure of ryegrass meadows situated in river valleys of lowland regions depends mainly on the site-its moisture conditions and trophism and, consequently, also on the utilization, i.e. the frequency of cutting and fertilisation. These aspects are also mentioned by Kojić *et al.* (2005), Kucharski (1999), and Rozbrojová *et al.* (2010). This led to variability in the internal structure of the floristic composition of the *Arrhenatheretum elatioris* phytocen-

nosis and was applied as the basis for the identification of the following three sub-associations and one variant:

- Arrhenatheretum elatioris typicum*
- Arrhenatheretum elatioris alopecuretosum pratensis*
- Arrhenatheretum elatioris dactylietosum glomeratae*
- Arrhenatheretum elatioris* var. with *Armeria maritima*

ssp. *elongata*.

Similar examples (sub-associations) which were an effect of ecological variability and vegetation dynamism also in the *Molinio-Arrhenatheretea* class as a whole are noted, e.g. *Cirsietum rivularis*, *Angelico-Cirsietum oleracei*, *Filipendulo-Geranium palustris* (Balátová-Tuláčeková et al., 1987), *Polygono-Cirsietum palustris* (Balátová-Tuláčeková, 1974), *Lolio-Cynosuretum*, *Trisetetum flavescens*, *Alopecuretum pratensis*, *Molinietum medioeuropaeum* communities (Kucharski and Michalska-Hejduk, 1994).

Typical, species-rich patches of *Arrhenatheretum elatioris* (A.e.) can be found relatively seldom. They occupy dry meadow sites or habitats which are moderately moist and utilised extensively. In the Wielkopolska Region, they develop primarily on mucky soils with sand frequently underlying at a depth of 0.4 to 0.6 m and with the water table situated at a level of 0.9 m in July. Soils are poor in the available forms of Mg, K and P (Tab. 1). The highest constancy, apart from *Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl and C. Presl is achieved here by *Taraxacum officinale* F. H. Wigg., *Achillea millefolium* L., *Galium mollugo* L. and *Holcus lanatus* L. (Tab. 2). The gradual disappearance from the agricultural landscape of semi-natural patches of *Arrhenatheretum elatioris* and their replacement by more productive monocultures of such grasses as *Dactylis glomerata* L. or *Festuca pratensis* Huds. was also reported by Brzeg and Wojterska (1996) and Dubiel et al. (1999).

Patches reminiscent of foxtail meadows, *Arrhenatheretum elatioris alopecuretosum pratensis*, begin to appear in places which are characterised by higher moisture and are richer in nutrients (Tab. 1). Their structure was found to contain increased proportions of species both from the *Molinietalia* order and the *Phragmitetea* class (Tab. 3) and the most constant components included: *Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl and C. Presl, *Alopecurus pratensis* L., *Rumex acetosa* L. and *Holcus lanatus* L.

In the case of slightly elevated sites, on mineral soils and lower reaction as well as very low trophicity, patches with high proportions of *Armeria maritima* ssp. *elongata* Mill. Willd were recorded (Tab. 1). In their composition, increased proportions of species from the *Festuco-Brometea* and *Koelerio glaucae-Corynephoretea canescentis* classes were observed alongside numerous species characteristic for the *Arrhenatheretalia* order (Tab. 3).

On the other hand, *Arrhenatheretum elatioris dactylietosum glomeratae* phytocenoses were found to develop in the vicinity of large cattle farms, on strongly decomposed peats and mucks of moderate moisture content and a considerably higher site trophy (Tab. 1) caused by regular fertilisation. In comparison with the rest of the sub-associations, a slightly higher total number of species was recorded in their sward accompanied by a simultaneously higher proportion of fodder grasses.

The PCA analysis of ecological indices performed here (Fig. 2) enabled illustration of the general site preferences of those sub-associations identified assigning phytosociological reléves with respect to Ellenberg's (1992) indicator numbers (F, R, N). The basic edaphic factor affecting the heterogeneity of ryegrass meadows might be moisture content (by Ellenberg's index). This factor differentiates firstly into *Arrhenatheretum elatioris* (A.e.) *alopecuretosum*

Tab. 1. Differentiation of site conditions of the *Arrhenatheretum elatioris*

Syntaxon of <i>Arrhenatheretum elatioris</i>	F	R	N	Actual moisture [%weight]	Soil pH [1 mol KCl]	The content of organic matter [%]	Mg	K ₂ O	P ₂ O ₅
							[mg kg ⁻¹]		
<i>typicum</i>	5.6	6.6	5.9	37.6	5.6	18.3	16.5	54.9	68.5
<i>dactylietosum glomeratae</i>	5.5	6.6	6.0	58.8	6.1	27.9	134.1	399.3	2005.5
<i>alopecuretosum pratensis</i>	5.8	6.5	5.8	71.3	5.6	31.9	40.1	85.8	114.5
with <i>Armeria maritima</i> ssp. <i>elongata</i>	5.3	6.2	5.4	15.1	4.8	4.2	9.2	22.8	26.5

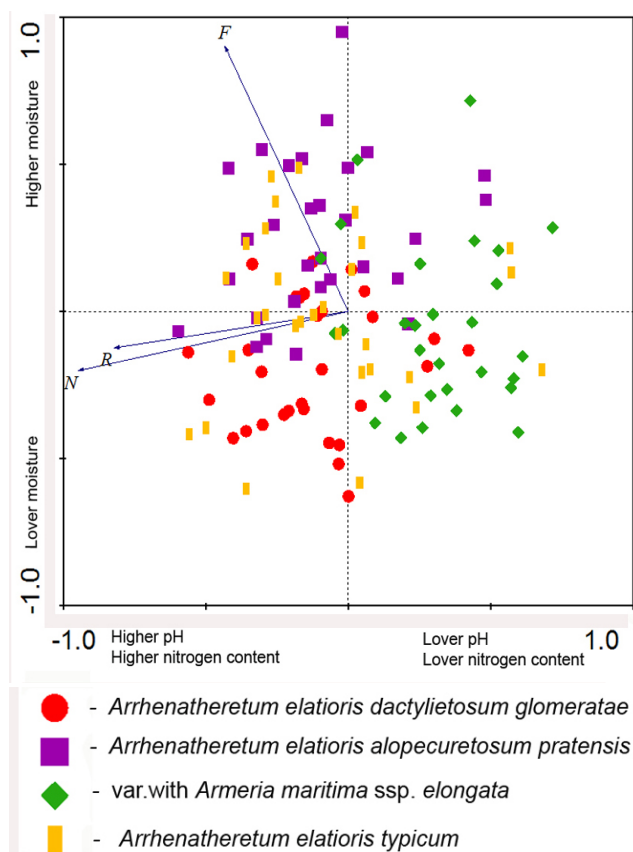
Tab. 2. Participation of characteristic species and number of species in reléve in *Arrhenatheretum elatioris* syntaxon

Syntaxon of <i>Arrhenatheretum elatioris</i>	Species characteristics for: (in %)									Number of species in relevé (mean, range)
	M-A			Phr.	Artem.	Stell.	K-C	F-B	Other	
	Arrh.	Mol.	Other with M-A							
<i>typicum</i>	14.1	9.2	20.9	9.9	11.7	8.1	1.8	2.7	21.6	23 (15-43)
<i>dactylietosum glomeratae</i>	15.7	8.3	24.2	3.7	10.2	15.6	1.9	1.9	18.5	18 (11-30)
<i>alopecuretosum pratensis</i>	12.4	9.5	22.9	10.5	8.6	9.5	1.9	1.9	22.9	21 (12-37)
with <i>Armeria maritima</i> ssp. <i>elongata</i>	16.7	7.8	23.5	5.9	7.8	6.9	5.9	2.9	22.5	22 (13-35)

Note: M-A-*Molinio-Arrhenatheretea*; Arrh.-*Arrhenatheretalia*; Mol.-*Molinietalia*; Phr.-*Phragmitetea*; Artem.-*Artemisietea vulgaris*; Stell.-*Stellarietea mediae*; K-C-*Koelerio glaucae-Corynephoretea canescentis*; F-B-*Festuco-Brometea*.

Tab. 3. Species with the highest constancy and cover index

Syntaxon of <i>Arrhenatheretum elatoris</i>	Species with the highest constancy and cover index
<i>typicum</i>	<i>Arrhenatherum elatius</i> V ^{3783.3} ; <i>Taraxacum officinale</i> V ^{282.0} ; <i>Achillea millefolium</i> V ^{238.7} ; <i>Galium mollugo</i> V ^{680.0} ; <i>Holcus lanatus</i> V ^{433.3} ; <i>Festuca arundinacea</i> IV ^{152.6} ; <i>Rumex acetosa</i> IV ^{150.3} ; <i>Plantago lanceolata</i> IV ^{122.0} ; <i>Deschampsia caespitosa</i> IV ^{248.6} ; <i>Ranunculus acris</i> IV ^{42.6}
<i>dactylietosum glomeratae</i>	<i>Arrhenatherum elatius</i> V ^{3233.3} ; <i>Rumex acetosa</i> V ^{276.0} ; <i>Achillea millefolium</i> V ^{280.0} ; <i>Plantago lanceolata</i> V ^{95.0} ; <i>Poa pratensis</i> IV ^{455.3} ; <i>Lolium perenne</i> IV ^{330.3} ; <i>Dactylis glomerata</i> IV ^{288.6} ; <i>Taraxacum officinale</i> IV ^{249.0}
<i>alopecuretosum pratensis</i>	<i>Arrhenatherum elatius</i> V ^{3050.0} ; <i>Alopecurus pratensis</i> V ^{606.6} ; <i>Rumex acetosa</i> V ^{258.0} ; <i>Holcus lanatus</i> V ^{360.3} ; <i>Plantago lanceolata</i> IV ^{211.3} ; <i>Galium mollugo</i> IV ^{348.3} ; <i>Phalaris arundinacea</i> IV ^{241.6} ; <i>Deschampsia caespitosa</i> IV ^{166.0}
with <i>Armeria maritima</i> ssp. <i>elongata</i>	<i>Arrhenatherum elatius</i> V ^{2525.0} ; <i>Rumex acetosa</i> V ^{420.3} ; <i>Armeria maritima</i> V ^{290.6} ; <i>Galium mollugo</i> V ^{306.6} ; <i>Plantago lanceolata</i> V ^{287.3} ; <i>Anthoxanthum odoratum</i> IV ^{560.3} ; <i>Linaria vulgaris</i> IV ^{119.0} ; <i>Poa pratensis</i> IV ^{286.6} ; <i>Holcus lanatus</i> IV ^{288.3} ; <i>Achillea millefolium</i> IV ^{95.6}

Fig. 2. Principal Components Analysis diagram (PCA) showing the main axes of variability in phytocenoses of the association *Arrhenatheretum elatoris* (Br.-Bl. 1925) Koch 1926

pratense and *A.e.* (variant with *Armeria maritima* ssp. *elongata*) sub-association, which clearly differ from each other, and secondly, the set of *A.e. typicum* and *A.e. dactylietosum glomeratae* relieves failed to form a distinct grouping. The group of *A.e. alopecuretosum pratense* relieves is distinctly visible as separate in the quarter for high F index values, whereas the *A.e.* variant with *Armeria maritima* ssp. *elongata* is distinct in the area of the diagram in which both the values of the F index as well as R and N indices are the lowest. These indices reflect site-plant community relationships, as confirmed by soil investigations (Tab. 1), i.e., including the higher moisture of soils occupied by the *A.e. alopecuretosum pratense* sub-association or low reaction and nitrogen availability of soils taken up by the variant with *Armeria maritima* ssp. *elongata*. The development of *A.e. dactylietosum glomeratae*, on the other hand, is most affected by soil reaction and nutrient availability, as evidenced by the grouping of the phytosociological relieves of this sub-association in the area of the diagram with the highest values of R and N indexes.

Therefore, the significant floristic variability of the *Arrhenatheretum elatoris* association observed is the outcome of both the diversification of sites occupied by this phytocenosis, but also reflected the method and intensity of utilization. In the case of fertilised and more frequently cut meadows (usually three times), the proportion of cultivated grasses increases, hence the *A.e. dactylietosum glomeratae* and *A.e. alopecuretosum pratensis* sward is characterised by the best fodder value. The variant with *Armeria maritima* ssp. *elongata* and *Anthoxanthum odoratum* that occupies the poorest sites contains many uncultivated grasses in its floristic composition as well as legumes which reduce sward fodder value (Tab. 4). Therefore, the species structure of ryegrass meadows depends greatly on human activity.

The considerable capability of the phytocenoses to adapt to various site conditions is further corroborated by distinct taxon dynamism as expressed by more than a 40% share of species of high expansion capability. This becomes particularly apparent in sites where the floristic composition is modified to a lesser degree by utilization-*A.e.* variant with *Armeria maritima* ssp. *elongata*. In the biological spectrum, hemicryptophytes characteristic for the temperate zone are dominant and the increased proportion of therophytes in the sward of the *A.e. dactylietosum glomeratae* sub-association can probably be attributed to intensively utilization and the possibility to spread species from neighbouring fields (Tab. 5).

On study plots, ruderal and segetal species which were frequently alien to hydrogenic sites were found. At the present time, this is reflected in the very low value of the valorisation index calculated according to Oświt (2000), classifying patches of ryegrass meadows as naturally poor.

Tab. 4. Influence on useful groups and fodder value score (FVS)

Syntaxon of <i>Arrhenatheretum elatioris</i>	Proportion of cover of useful groups [%]				Proportion of valuable species (fodder grasses + legumes) [%]	FVS (Fodder Value Score)
	Grasses	Legumes	Sedges	Herbs and weeds		
<i>Typicum</i>	71.0	0.7	0.3	28.0	60.4	6.90
<i>Dactylisotum glomeratae</i>	74.8	0.7	0.1	24.4	69.1	7.46
<i>Alopecuretosum pratensis</i>	76.8	0.4	0.9	21.9	66.5	7.16
with <i>Armeria maritima</i>	72.6	0.9	0.4	26.1	51.9	6.37

Tab. 5. Natural values of the *Arrhenatheretum elatioris*

Syntaxon of <i>Arrhenatheretum elatioris</i>	Geographic-historical spectrum [%]				Proportion of species with higher and the highest expansion degree [%]	Raunkiaer's life forms [%]			Natural value	
	Apophytes	Spontaneophytes	Archeophytes	Kenophytes		Hemicryptophytes	Terophytes	Other	Number of valorisation	Values
<i>Typicum</i>	71.2	18.9	8.1	1.8	41.4	69.4	14.4	16.2	2.0	small
<i>Dactylisotum glomeratae</i>	71.3	11.1	14.8	2.8	43.5	59.3	23.1	17.6	1.9	small
<i>Alopecuretosum pratensis</i>	72.4	18.1	7.6	1.9	45.7	63.8	16.2	20.0	2.1	small
with <i>Armeria maritima</i>	78.4	13.7	5.9	2.0	47.1	68.6	17.6	13.7	1.8	under small

However, in the case of typical sites, these are among the most beautiful flowering meadows in this landscape.

The development of meadow communities depends, to a great extent, on human activity as well as on site conditions, which are also frequently modified by man. Hence, the syntaxonomic position of some phytocenosis and their lower units is frequently widely discussed as evidenced by characteristic ryegrass meadows. This wide ecological scale of the association provides a basis for it to be treated as a central unit-*Arrhenatheretum medioeuropaeum* (Iljanič and Šegulja, 1983; Iljanič and Vučković, 1982; Ullman *et al.*, 1990) within the framework of which, a number of lower sub-associations and variants exist. The central units are a result of the higher constancy of characteristic species for alliance than association (Dierschke, 1981; Kopecký and Hejný, 1974).

Similar difficulties with the classification of seminatural communities into the phytosociological system are encountered in the case of the *Alopecuretum pratensis* association (Matuszkiewicz, 2008). In the work of some researchers, this is included in the *Arrhenatheretalia* order as the wettest form of the *Arrhenatheretum elatioris* association (Grynja, 1987), while in the work of others, it is treated as a separate association in the *Arrhenatherion-Alopecuretum pratensis* alliance (Kucharski and Michalska-Hejduk, 1994) or as *Ranunculo repentis-Alopecuretum pratensis* (Valev *et al.*, 2011), sometimes as *Poo-Alopecuretum pratensis* (Kojić *et al.*, 2005). Recently, it has usually been treated as a central association in the *Alopecurion* of the *Molinietalia* order (Alma *et al.*, 2008; Matuszkiewicz, 2008). Meadows dominated by *Holcus lanatus* (Blažková,

1992) cause also serious problems with unequivocal classification. Most researchers include *Holcus lanatus* community in the *Calthion* alliance (Kováč, 1981; Kryszak, 2001), whereas Duchoslav (1997) and Kucharski (1999) place it in *Alopecurion pratensis*. Sometimes velvet grass is also classified into the *Arrhenatherion elatioris* alliance (Kováčová, 1976).

The multiplicity and dynamism of factors affecting the vegetation cover both in Poland as well as in Europe as a whole makes it necessary to widen our knowledge of the structure of plant communities and directions of transformations taking place inside them. At the present time, it is also very important to monitor these changes, primarily in order to undertake appropriate action to maintain the high biodiversity of seminatural meadow phytocenoses (Dierschke, 1999b; Elmore and Mustard, 2003; Ford, 1997; Isselstein *et al.*, 2005; Kopecký and Hejný, 1974; Looy *et al.*, 2006; Peeters and Janssens, 1998; Plantureux *et al.*, 2005).

Conclusions

All factors affecting ryegrass meadows exert an influence on their extraordinary heterogeneity. However, the development of lower phytosociological units in lowland areas depends mainly on site moisture and soil nutrient availability which, in turn, is influenced by fertilization. Both soil aridity and a shortage of nutrients result in the loosening of the sward and the incursion of synanthropic species, as well as short-lived sand and steppe species which are better adapted to altered edaphic conditions.

The abundance of species and the natural value of the *Arrhenatheretum elatioris* association all depend primarily on utilization intensity and are inversely proportional to sward fodder value.

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