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GRASSLAND COMMUNITIES OF STOL MOUNTAIN (EASTERN SERBIA): VEGETATION AND ENVIRONMENTAL RELATIONSHIPS

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Abstract - The systematic survey of grassland communities was performed on Mt. Stol (eastern Serbia). The main aims of the research were to: (1) determine grassland vegetation types of the researched area; (2) correlate the impacts of the soil and environmental conditions on the occurrence of certain plant communities, and (3) comment on the conservational value of the grasslands in the researched area. The data set included 60 phytosociological relevés of grasslands recorded between 2001 and 2004. The main environmental gradients of species composition were analyzed by Detrended Correspondence Analysis (DCA). For the ecological interpretation of ordination axes, ecological indicator values were used. Three associations were distinguished: *Danthonietum calycinae*, *Asperulo-Agrostietum vulgaris* and *Ranunculo bulbosi-Arrhenatheretum elatioris* belonging to two alliances and two classes: *Chrysopogono-Danthonion - Festuco-Brometea* and *Arrhenatherion - Molinio-Arrhenatheretea.* The results of the DCA support our assumption that the main environmental gradient in the species composition of the grasslands is related to nutrients and moisture. The conservational value of grasslands in the researched area is discussed.

Key words: Grassland vegetation, classification, *Danthonietum calycinae*, *Asperulo-Agrostietum vulgaris*, *Ranunculo bulbosi-Arrhenatheretum elatioris*, ordination, Mt. Stol

INTRODUCTION

Grassland habitats are an integral part of the agricultural landscapes of Europe, providing a wide range of habitats supporting a high biological diversity (Eriksson et al., 1995, Wallis De Vries et al., 2002). The decline of grassland areas throughout Europe in the last decades threatens biological diversity and is a major conservation problem. There is an urgent need to determine the underlying factors that control vascular plant species richness and composition in managed grasslands (Klimek et al., 2007). Most grasslands are composed of semi-natural vegetation as a consequence of a long history of human use. Different types of historical and current grassland use have created different plant and vegetation diversity patterns. Traditionally managed semi-natural grasslands (hay meadows and pastures) are known to support a rich flora and are recognized by high species diversity in different regions of Europe (Norderhaug et al., 2000; Kojić et al., 2004; Matevski et al., 2008). Their further existence depends upon correct management, such as mowing or grazing. However, many grassland communities are now being threatened by rapid changes in agricultural practices, especially related either to the effects of land abandonment (Pykälä et al., 2005; Dajić Stevanović et al., 2008a) or to eu-

trophication (Stevens et al., 2004) as opposite management practices.

The natural and semi-natural grasslands of Serbia represent an important resource for agriculture, occupying about 1.4 million hectares. Intensive research of grassland biodiversity in Serbia started in fifties of the last century and was based on the Braun-Blanquet methodological approach, resulting in many papers on the floristic and vegetation diversity of different geographic areas of the country, as summarized by Kojić et al. (2004). Simultaneously, several studies focused on the relations between management practices and grassland biodiversity (e.g. Mrfat-Vukelić, 1991; Lazarević, 1995; Djordjević-Milosević, 1997; Peeters and Dajić, 2006), as well as ecophysiological features of particular grassland flora (Dajić et al., 1997, 2000a)

Grassland semi-natural communities are listed as a priority habitat for biodiversity conservation in European Union Habitats Directive (92/43/CEE). Many communities of meadows and pastures are identified in the Republic of Serbia as areas of high biodiversity and are included in IPA (Important Plant Areas) (Stevanović, 2005) and PBA (Prime Butterfly Areas) (Jakšić, 2008). In addition, most of the semi-natural grasslands in the country were identified as farming areas of high natural value (HNVF-High Nature Value Farmland) (Cooper et al., 2010).

The study site of our research was chosen due to the fact that the Stol mountain has already been appreciated for its high biodiversity and has been appointed as a Prime Butterfly Area (PBA) due to the presence of many important butterfly species on national and European levels (Jakšić, 2008) and HNVF (Cooper et al., 2010). Ornithological research was also conducted on Stol, and together with area of Veliki Krš, it was officially listed as an area of special national importance for bird fauna (Puzović and Grubač, 2000), and the biodiversity of predator birds is highlighted. Moreover, this wider area is important as one of the centers for vertebrate diversity in Serbia (Savić et al., 1999). Special attention should be drawn to the fact that this area is one of 61 areas from the IPA list (Stevanović, 2005). Important Plant Areas are the most important places in the world for wild plant diversity. They are identified at a national level using internationally standardized criteria, the presence of threatened species, threatened habitats and species richness.

Nevertheless, former reports on this area have not addressed either the floristic and vegetation diversity, or relations between environmental factors, primarily soil features and distribution of grassland communities. Moreover, to the best of our knowledge, multivariate statistical analysis matching vegetation data with soil performances was conducted for the first time for Serbia.

The aims of this study were to: (1) evaluate the grassland vegetation diversity and types of grassland communities present on the researched area; (2) identify the impacts of the soil and environmental conditions on the occurrence of certain plant communities, and (3) to comment on the conservational value of the grasslands in the study area.

MATERIALS AND METHODS

Study area

The study was carried out in Mt. Stol (1156 m. a.s.l.), which is located in the eastern part of the Serbia, 15 km north of the city of Bor (Fig. 1).

The study area is in the form of a narrow belt (1-1.5 km), 33 km long in a SE-NW direction. The belt is not continuous and is divided into three units (Zeremski, 1991). The area belongs to Balkan-Carpathian mountain system; the main bedrock is limestone, but andesite and silicate are locally found as well. The climate is transitional between steppic and Mediterranean, with some influence of Central European and mountain climates (Diklić, 1965), that give the vegetation a certain xeromorphic character.

The natural vegetation is dominated by beech forest (ass. *Fagetum montanum serbicum* B. Jovanović

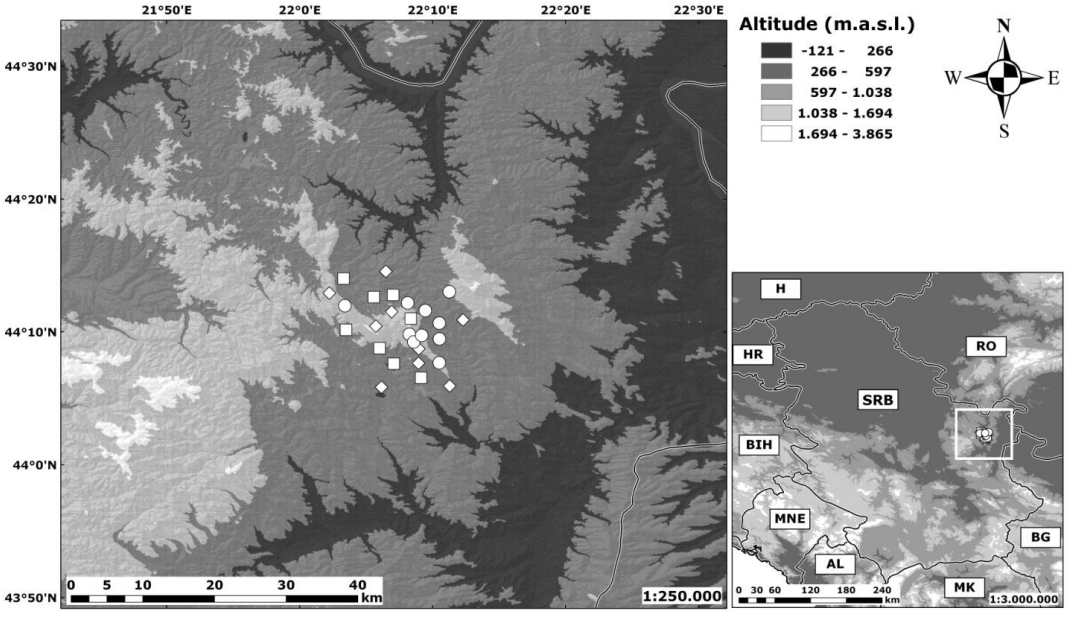

Fig. 1. Study area with indicated locations of relevés (○ - ass. *Danthonietum calycinae;* ◇ - ass. *Asperulo-Agrostietum vulgaris*; □ - ass. *Ranunculo bulbosi-Arrhenatheretum elatioris.*

1953 (non Rudski 1949), above which shrubby communities of liliac (ass. *Eryngio-Syringetum vulgarae* Diklić 1965 and ass. *Syringo-Carpinetum orientalis* (Grebenščikov 1950) Mišić 1967) occur, as well as herbaceous communities on rocky grounds (ass. *Potentillo-Caricetum humilis* R. Jovanović 1955, ass. *Humileto-Stipetum grafianae* R. Jov. 1955 and ass. *Sempervivo-Seslerietum argentae* R. Jovanović 1955). On woodless areas, there are fragmentary developed semi-natural grasslands that are classified into ass. *Agrostietum vulgare* Z. Pavlović 1955, ass. *Danthonietum calycinae* Cincović et Kojić 1958, and ass. *Arrhenatheretum elatioris* sensu lato.

Vegetation sampling

The grassland vegetation was studied in 2001-2004, and 60 phytosociological relevés were collected in total. The sampling plots were selected so as to cover uniformly the entire study area and ranged from 800-900 m. a.s.l. The relevé sampling followed the Braun-Blanquet approach (Braun-Blanquet, 1964; van der Maarel, 2005).

The nomenclature of the vascular plants followed Flora of R. Serbia (Josifović, 1970-1977) and Flora Europaea (Tutin et al. 1964-1993). Life forms are according to the classification of life forms of the flora in Serbia (Stevanović, 1992).

Phytosociological units comply with the syntaxonomic nomenclature of the vegetation of Serbia (Kojić et. al., 1998; Mucina et al., 1993).

Soil sampling and laboratory methods

The soil samples were taken from a depth ranging from 0-20 cm. Analyses of the soil features were done in accordance with standard methods. Soil texture and proportions of clay, silt and sand particles, respectively, were determined with the combined sieving and pipette method with an Na-pyrophosphate preparation. Soil reaction (pH) was measured by potentiometric method (soil-to-water or KCl ratio: 1:2.5). Total C was determined with the dichromate method; H-extractable acidity by Na-acetate; S-exchangeable bases by HCl; T-exchangeable cation

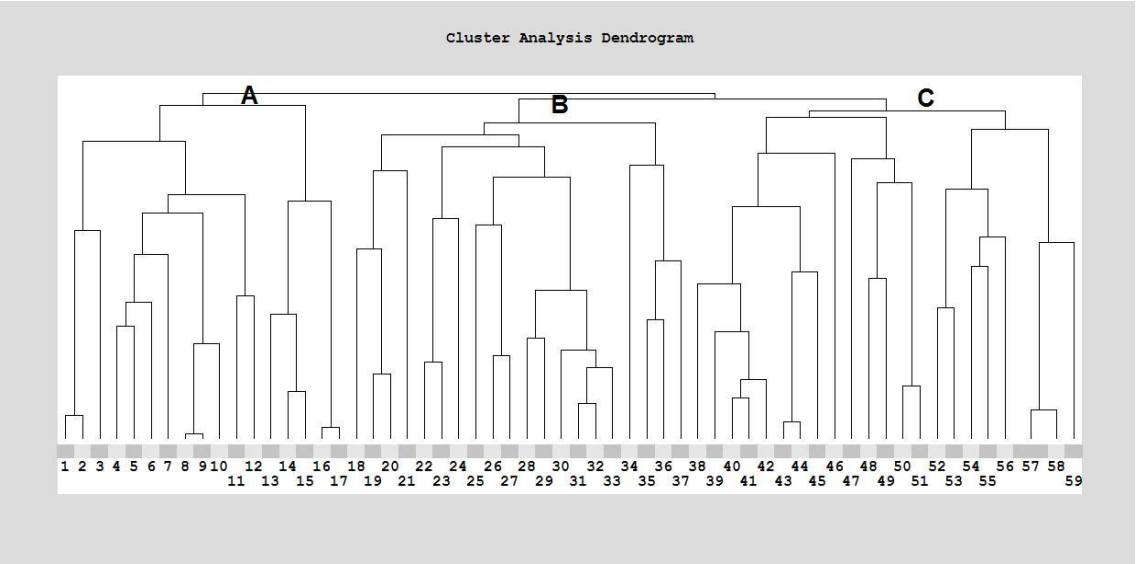

Fig. 2. Classification of three grassland associations. Cluster **A**- ass. *Ranunculo bulbosi-Arrhenatheretum elatioris*, cluster **B**- ass. *Asperulo-Agrostietum vulgaris,* **C**- ass. *Danthonietum calycinae.*

was calculated as H+S and V-base saturation was calculated as (S/T) 100.

Soil was sampled in the representative plots and for further statistical analysis averages were used for missing values (Lepš and Šmilauer, 2003).

Statistical analysis

The data obtained from the field were stored in the database TURBOVEG (Hennekens and Schamineé, 2001). The basic arrangement of the phytosociological table and tabular synthesis were made with JUICE 7.0 software (Tichý, 2002).

We carried out cluster analysis of the dataset in the program PC-ORD 5 (McCune and Mefford, 1999) using Relative Sorensen as a distance measure and Ward's method algorithm for dendrogram construction.

Diagnostic species have been determined using the Phi-coefficient as a fidelity measure (Chytrý et al., 2002). Square-root transformed cover values were used. The size of all groups was standardized to equal size and Fisher's exact test ($p<0.05$) was applied. Species with Phi-coefficient values higher than 0.10 have been considered diagnostic. Species with cover ≥25% in a minimum 5% of the relevés for any association have been accepted as dominant. Species recorded in a minimum of 50% of the relevés for any association were considered constant.

For the estimation of ecological conditions, we used species ecological indicator values (EIV) for light (L), temperature (T), moisture (M), soil reaction (S) and nutrients (N) (Pignatti, 2005). Those indicator values, although proposed for Italy, have been used in various studies on the Balkan Peninsula (Šilc et al., 2009, Kavgaci et al., 2010). Major gradients in the species composition of grasslands were analyzed using Detrended Correspondence Analysis (DCA) from the CANOCO 4.5 package (ter Braak and Šmilauer, 2002). For ecological interpretation of these gradients, average EIV values for each relevé were plotted onto a DCA ordination diagram as supplementary environmental variables.

The relationship between species composition and soil features was also analyzed by DCA with passively projected explanatory variables.

RESULTS AND DISCUSSION

Classification of grassland vegetation

Classification of the selected 60 phytosociological relevés is presented by the dendrogram (Fig. 2) and in the synoptic table (Tab. 2).

Interpretation of the results of cluster analysis clearly indicates two groups of relevés, corresponding with two classes of grassland vegetation, the *Molinio-Arrhenatheretea* and *Festuco-Brometea*, whereas additional division into three groups of clusters indicates the existence of three different plant associations, determined as: ass. *Ranunculo bulbosi-Arrhenatheretum elatioris* Ellmauer in Mucina et al. 1993, *Asperulo-Agrostietum vulgaris* Jovanović-Dunjić 1956 and *Danthonietum calycinae* Cinc. et Kojić 1958. The syntaxonomic position of these associations is as follows:

Class Molinio-Arrhenatheretea Tüxen 1937

Order Arrhenatheretalia elatioris Pawl. 1928

Alliance Arrhenatherion elatioris Koch 1926

Ass. Ranunculo bulbosi-Arrhenatheretum elatioris Ellmauer in Mucina et al. 1993

Class Festuco-Brometea Br.-Bl. et Tüxen ex Soó 1947

Order Brometalia erecti Br.-Bl. 1936

Alliance Chrysopogono-Danthonion calycinae Kojić 1957

Ass. Asperulo-Agrostietum vulgaris Jovanović-Dunjić 1956

Ass. Danthonietum calycinae Cincović et Kojić 1958

Description of studied grassland communities

Ass. Ranunculo bulbosi-Arrhenatheretum elatioris Ellmauer in Mucina et al. 1993

Number of relevés: 17

Diagnostic species: *Arrhenatherum elatius, Carduus acanthoides, Centaurea scabiosa, Convolvulus arvensis, Elymus hispidus, Festuca rubra, Fragaria viridis, Lathyrus pratensis, Muscari comosum, Potentilla argentea, Potentilla recta, Vicia angustifolia, Viola tricolor*

Constant species: *Arrhenatherum elatius*

Dominant species: *Agrostis capillaris, Anthoxanthum odoratum, Arrhenatherum elatius, Elymus hispidus, Filipendula vulgaris, Lathyrus pratensis, Leontodon hispidus, Trifolium alpestre, Viola tricolor*.

Stands of this association are found at the foothills of Mt. Stol in a valley of the river Lučka Reka. The slope of the mountain has a high inclination and due to intensive leaching, nutrients accumulate at the bottom of the valley. Soils are deep and nutrient-rich, supporting the development of the edificator species *Arrhenatherum elatius*. Meadows of this association are rich in biomass, as indicated by the height of the stands of about 1.5 m. The community thrives in an altitudinal range 820-880 m, mostly on SW, W, NW and E exposition with inclination of 2-10°. The stands are very dense and total cover is 95-100%. The floristic composition, the high total number of species (108 species), and the characteristic species of the association and the alliance *Arrhenatherion elatioris* indicate a stable and homogeneous community.

Life form analysis shows that the grassland association *Arrhenatheretum elatioris* is dominated by hemicryptophytes with 86 species (81.1 %), while therophytes are represented with 6.6 %, indicating a more mesophilous character of the community.

According to the results of former large-scale research of grassland vegetation in Serbia (Kojić, 1998), communities with a prevalence of the species *Arrhenatherum elatius* developing in hilly parts of the country were assigned as *Arrhenatheretum elatioris* sensu lato, while in the northern part of Serbia, the associa-

tion *Pastinaco-Arrhenatheretum* Passarge 1964 (ass. *Arrhenatheretum medioeuropeum* Oberdorfer 1952) is known to be widely distributed on sites suitable for the development of mesophilous meadows and pastures. After comparison of nomenclature type and diagnostic and dominant species described by Ellmauer and Mucina (1993) with the results of the present study, the community of Mt. Stol should be assigned as ass. *Ranunculo bulbosi-Arrhenatheretum elatioris*, which has not been so far described for the territory of Serbia.

This community develops on some drier sites, whereas the presence of many character species of the class *Festuco-Brometea* strongly differentiates it from a similar association, the *Pastinaco-Arrhenatheretum*.

Grasslands classified within the ass. *Ranunculobulbosi-Arrhenatheretum elatioris* are mainly used for hay production, but in many cases, combined use (mowing and grazing) was observed. As reported by Stančić (2008) for Croatia, this type of grassland is disappearing because of the cessation of mowing. In Bulgaria, such grasslands are still mowed and the percentage of abandoned land is comparatively lower (Velev et al., 2011). These facts indicate a common tendency in the Balkan region concerning insufficient grassland use and abandonment of traditional management practices as reported by Dajić Stevanović et al. (2008, 2010).

This association is classified into the alliance *Arrhenatherion elatioris* comprising the meadows of Central Europe that occur on wet to moderately dry sites, and on slightly acid to neutral, mostly braun soils. Most of these meadows are mown 2-6 times per year (Ellmauer and Mucina, 1993). The center of the distribution area of the alliance is in central Europe, but its habitats can be found throughout Europe (Kučera, 2007). Plant communities of the *Arrhenatherion* as lowland mesic meadows and pastures, are also frequently found in western parts of the Balkan Peninsula, occupying not only the lowlands, but mountain habitats as well. Although many associations have been already described in Europe on the basis of the regional floristic differences (Dierschke, 2001), we still lack a clear overview of the alliance. So far, in the literature there are different concepts about the range and syntaxonomic diversity of the alliance *Arrhenatherion elatioris*. According to several authors (Ellmauer and Mucina, 1993; Borhidi, 2003, Hájková et al. 2007; Uhliarová et al. 2007, Velev et al., 2010, 2011) the syntaxonomic diversity within this alliance is high. This is valid for the center of the distribution, while Päzolt and Jansen (2004) indicate only one association, *Arrhenatheretum elatioris* Br.-Bl. 1915, at the edge of the area of the alliance.

For consistent syntaxonomic classification of lowland mesophilous grassland communities of Serbia, studies on a larger scale are needed. This would clarify the syntaxonomic diversity of the alliance and link these communities with similar ones in the region (Croatia, Bulgaria, Romania, Hungary).

Ass. *Asperulo-Agrostietum vulgaris*
Jovanović-Dunjić 1956

Number of relevés: 20

Diagnostic species: *Crataegus monogyna, Festuca rupicola, Fragaria vesca, Stellaria graminea*

Constant species: *Agrostis capillaris*

Dominant species: *Achillea millefolium, Agrostis capillaris, Briza media, Festuca pratensis, Filipendula vulgaris, Hieracium pilosella, Hypericum perforatum, Thymus pulegioides, Trifolium montanum*

In the Stol area, communities of *Asperulo-Agrostietum vulgaris* thrive on larger surfaces where the potential vegetation is beech forest. The altitudinal range is between 830-880 m, mostly on SW, W, E and NE exposition and inclination between 3-10°. Total cover is 90%-100%. The floristic composition is made up of 126 species. The community is dominated by perennial hemicryptophytes (76.9%). The second most abundant life form is therophytes, while chamaephytes and geophytes are less represented.

The ass. *Asperulo-Agrostietum vulgaris* was described by Dunjić-Jovanović (1956) on Mt. Rtanj and as character species besides the dominant *Agrostis capillaris,* she pointed out mainly endemic species, *Asperula ciliata* and *Dianthus pelviformis*. For Serbia, the name *Agrostidetum vulgaris* Z. Pavlović 1955 is widely used for stands dominated by *Agrostis capillaris*. However, this association thrives at higher altitudes (1400-1600 m a.s.l.) and is rich with species of the *Pancicion* and *Polygono-Trisetion* alliances. Therefore, classification into the *Asperulo-Agrostietum vulgaris* described in the vicinity in similar ecological conditions is more appropriate.

Grasslands of *Agrostietum vulgaris* s. lat. (according to Kojić et al., 2004) are widely distributed in hilly and mountain regions of Serbia in the zone of oak and beech forests and also in regions of the central part of the Balkans (Serbia, Romania, and Bulgaria). It was pointed out that communities with a domination of *Agrostis capillaris* develop under similar ecological conditions but differ in (phyto)geographical characteristics (Horvat et al., 1974). Similarly, in Serbia within the different altitudes there are several distinct grassland communities with a prevalence of *Agrostis capillaris* (Kojić et al., 2004), which were classified into different higher syntaxa (alliances, even classes).

Horvat and al. (1974), Petković (1985), Jovanović-Dunjić and Jovanović (1989), Stančić (2000), Šegulja (2005), and Trinajstić (2008) refer such associations with dominant *Agrostis vulgaris* for Balkan Peninsula to the *Arrhenatherion* alliance. The same opinion is shared by Studer-Ehrensberger (2000), Uhliarova et al. (2007), Janišova et al. (2010) and Rozbrojova et al. (2010).

On the other hand, *Agrostis*-dominated communities were classified into the alliance *Cynosurion* (Jurko, 1974; Coldea, 1990; Zuidhoff et al., 1995; Sanda et al., 1999; Mihăilescu, 2001; Apostolova and Meshinev, 2006; Bărbos; 2006; Chytrý 2009; Velev et al., 2010). According to Wendelberger (1965) and Hegedüšova et al. (2012), *Agrostis* communities should be classified into the alliance *Polygono-Trisetion*, while according to Redžić (2007) into the alliance *Festuco-Agrostion capillaris.*

Our results have shown that the syntaxonomic position of this association for Serbia is within the *Chrysopogono-Danthonion* alliance. The association *Asperulo-Agrostietum vulgaris* studied in the present work is well differentiated from the other two associations of the researched area. This is in accordance with Kojić (1998). The plant associations, *Asperulo-Agrostietum vulgaris* and *Danthonietum calycinae*, are classified into the *Chrysopogono-Danthonion calycinae* alliance that comprises grasslands on acidophilous-neutrophilous habitats developing on moderate humid to moderate xerothermic sites, mostly on lime-poor sandy soils (Kojić, 1998; Rodwell, 2002). The alliance *Chrysopogono-Danthonion* was first described by Kojić (1958) and it is characterized as a specific vegetation type for the Balkans, being transitional between mesophytic and xerophytic types of grasslands. Its communities occupy mainly silicate terrains, while the species composition includes a high number of Balkan floristic elements and, at the same time, hosts many steppe species.

Ass. *Danthonietum calycinae* Cincović et Kojić 1958

Number of relevés: 23

Diagnostic species: *Calamagrostis epigejos, Carduus candicans, Carlina acanthifolia* ssp. *acanthifolia, Centaurea jacea, Crataegus pentagyna, Crepis biennis,* **Danthonia alpina**, *Gymnadenia conopsea, Hieracium pilosella, Leucanthemum vulgare, Polygala vulgaris, Prunella laciniata, Rhinanthus rumelicus, Rosa canina, Thymus pannonicus, Veronica jacquinii,* **Vicia cracca**.

Constant species: **Danthonia alpina**

Dominant species: *Betonica officinalis, Briza media, Danthonia alpina, Elymus hispidus, Filipendula vulgaris, Hieracium pilosella, Holcus lanatus, Inula hirta, Vicia cracca***.**

Tab. 1. Soil properties in selected relevés of the investigated area

Soil type	Sand Total (2-0.02 mm)	Sand Coarse sand (2-0.2 mm)	Sand Fine sand (0.2-0.02 mm)	Physical clay (<0.02 mm)	Silt (0.02-0.002 mm)	Colloid clay (<0.002 mm)	Humus %	pH (H_2O)	pH (KCl)	H (m. Ekv.)	S (m. Ekv.)	T (m. Ekv.)	V
Cambic Leptosol Eutric	47.44	15.72	31.72	52.56	29.82	22.74	7.71	6.30	4.86	7.31	30.38	37.69	80.60
Ferralic Cambisol Dystric	58.44	28.40	30.04	41.56	28.04	13.52	6.59	5.28	4.25	22.75	4.77	27.52	17.33
Cambic Leptosol Eutric	27.64	1.50	26.14	72.36	31.24	41.12	8.46	6.51	5.80	8.94	23.22	32.16	72.20
Ferralic Cambisol Dystric	57.68	13.00	44.68	42.32	27.72	14.60	5.21	5.66	4.73	17.87	2.08	19.95	10.43
Haplic Luvisol Epydistric	64.70	26.17	38.53	35.30	24.55	10.75	7.47	5.33	4.35	23.72	0.00	23.72	0.00
Umbric Gleysol Dystric	60.00	30.70	29.30	40.00	28.68	11.32	5.20	5.52	4.44	17.22	1.87	19.09	9.79
Umbric Stagnosol Distric	59.80	31.80	28.00	40.20	26.24	13.96	3.79	5.03	4.21	21.29	3.42	24.71	13.84
Stagnic Luvisol Epidystric	64.32	15.00	49.32	35.58	25.24	10.44	5.41	5.72	4.30	20.80	6.02	26.82	22.44
Ferralic Cambisol Dystric	51.09	12.56	38.53	43.25	25.68	13.54	4.86	5.45	4.68	16.54	1.95	19.26	9.54

In the area of Mt. Stol, the communities of the ass. *Danthonietum calycinae* are developed within the zone of beech forests. The altitudinal range is 850-890 m, mostly on W, SW E and NE exposition and inclination between 1-10°. Total cover is 95%-100%. It consists of 133 species. The association *Danthonietum calycinae* has distinct hemicryptophytic character (73.7%). Higher proportion of geophytes and chamaephytes (low shrubs) compared with the two other studied communities, indicates that these grasslands prefer dryer and warmer habitats. In the studied area, the *Danthonietum* grasslands are mown (but rather late) and afterwards grazed, so they are under constant use.

The association *Danthonietum calycinae* was first described by Cincović and Kojić (1958) in western Serbia. This association settles on deep soils (mountain black soils and parapodzols) that have an acid reaction. It is widely distributed and has an important role in livestock production in the mountain regions of Serbia. The sites have different exposition and an altitudinal range between 600-1100 m (Kojić et al., 2004).

Cincović and Kojić (1958) pointed out character species of the association: *Danthonia alpina, Danaa cornubiensis* and *Danthonia decumbens*. It is important to mention that *Danthonia calycina* is not exclusively characteristic for this association. Moreover, it is found within the different hilly meadows developed under similar environmental conditions in Serbia. The species has a very wide diagnostic significance, binding all communities dominated by *Danthonia* into the alliance *Chrysopogono-Danthonion calycinae*. *Danthonia alpina* could be used as a transgressive character species for the association and the alliance. Later Kojić et al. (2004) expanded the characteristic species combination into *Danthonia alpina, Danaa cornubiensis, Danthonia decumbens,*

Filipendula hexapetala, Stachys officinalis, Euphrasia stricta, Rhinanthus rumelicus, Hypochoeris maculata, Festuca rubra, Leucanthemum vulgare, Polygala comosa, Trifolium montanum, Galium verum, Agrostis capillaris, Trifolium campestre, Briza media, Thymus pulegioides and *Genista sagittalis*. The species *Danthonia alpina* is very frequent in grassland communities of eastern Serbia; it is thermophilous species mostly occurring on skeletal and sandy soils (Mišić, 1978).

Ordination and soil analysis

The position of three grassland communities identified on Mt. Stol in relation to studied soil features is shown in Fig. 3 and Table 1.

Relevés of *Ranunculo bulbosi-Arrhenatheretum elatioris* in the ordination graph are distributed mainly on the right side and occur on Cambic Leptosol Eutric (Rendzina) and Ferralic Cambisol, deep and moderate or high-fertility soils that develop on limestone. Relevés of *Danthonietum calycinae* are concentrated on the left side of the ordination diagram and this association occurs on Haplic Luvisols, illuvial soils with high base saturation (50%), an increase in the clay amount in the subsoil and low fertility. In the upper side of diagram there are concentrated relevés of the association *Agrostietum vulgaris* that develops on low fertile, dark brown soils with gleyic (i.e. with high influence of groundwater) and stagnic properties where A horizon is rich in organic matter (acid Cambisol and umbric Stagnosol).

The strong effect of soil features on the vegetation composition is well documented (e.g. Critchley et al, 2002, Cousins and Eriksson, 2002, Auestad et al. 2008, Janišova et al. 2010), whereas the soil chemistry and land management were generally considered to be the most important factors affecting species composition and diversity in grassland ecosystems (e.g. Myklestad, 2004, Klimek, 2007, Michalková, 2007, Škodová, 2007, Rozbrojová et al. 2010). Grassland communities of the studied area alternate over short distances due to changes in soil physical and chemical properties (prevalent limeatheretum elatioris inhabiting sites rich in nutrients whose relevés group on the right part of the ordination graph. The meadow community *Asperulo-*

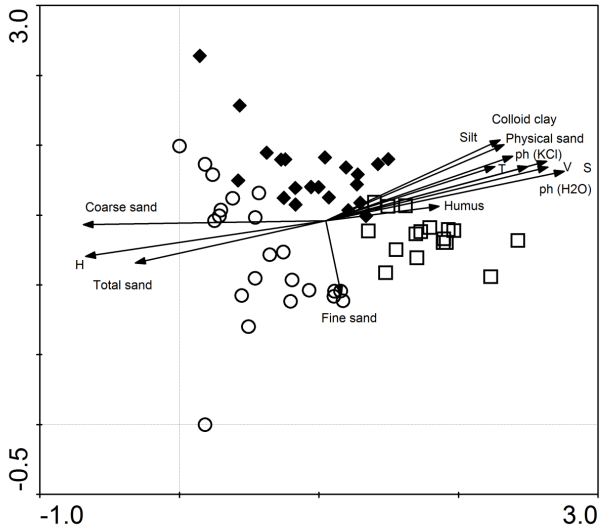

Fig. 3. Detrended correspondence analysis (DCA) ordination diagram of the relevés from grassland associations, with passively projected explanatory variables. Associations: ○ - *Danthonietum calycinae;* ◇ - *Asperulo-Agrostietum vulgaris*; □ - *Ranunculo bulbosi- Arrhenatheretum elatioris.*

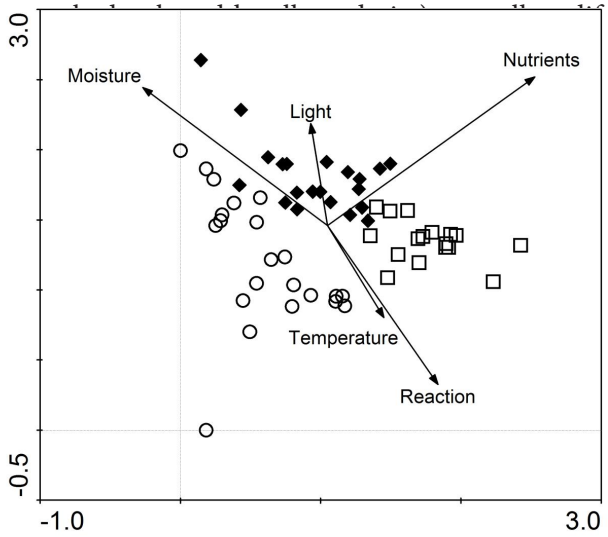

Fig. 4. Detrended correspondence analysis (DCA) ordination diagram of the relevés from grassland associations, with passively projected explanatory variables. Associations: ○ -ass. *Danthonietum calycinae;* ◇ - ass. *Asperulo-Agrostietum vulgaris*; □ - ass. *Ranunculo bulbosi-Arrhenatheretum elatioris.*

Table 2. Synoptic table produced by cluster analysis of grassland vegetation on Stol Mt. Species values are percentage frequencies and fidelity (φ multiplied by 100). Species with a fidelity higher than 10 are considered to be diagnostic and ranked by decreasing fidelity value. Only species present in two clusters are shown.

Cluster	1	2	3
No. of relevés	17	20	23
Ranunculo bulbosi-Arrhenatheretum elatioris			
Arrhenatherum elatius	94 $^{56.9}$	55 $^{---}$	52 $^{---}$
Elymus hispidus	41 $^{31.7}$	15 $^{---}$	
Viola tricolor	94 $^{18.9}$	60 $^{---}$	35 $^{---}$
Vicia angustifolia	82 $^{16.1}$	60 $^{---}$	. $^{---}$
Carduus acanthoides	59 $^{14.7}$	25 $^{---}$	4 $^{---}$
Potentilla recta	47 $^{12.6}$	20 $^{---}$	4 $^{---}$
Centaurea scabiosa	29 $^{12.6}$	. $^{---}$	9 $^{---}$
Muscari comosum	24 $^{12.5}$	. $^{---}$	4 $^{---}$
Convolvulus arvensis	41 $^{11.8}$	5 $^{---}$	17 $^{---}$
Fragaria viridis	59 $^{11.7}$	. $^{---}$	57 $^{8.1}$
Lathyrus pratensis	82 $^{11.6}$	50 $^{---}$	48 $^{---}$
Festuca rubra	82 $^{10.7}$	55 $^{---}$	57 $^{---}$
Potentilla argentea	71 $^{10.1}$	40 $^{---}$	26 $^{---}$
Asperulo-Agrostietum vulgaris			
Fragaria vesca	. $^{---}$	60 $^{26.8}$	. $^{---}$
Crataegus monogyna	12 $^{---}$	40 $^{13.3}$	4 $^{---}$
Stellaria graminea	29 $^{---}$	80 $^{12.0}$	48 $^{---}$
Festuca rupicola	. $^{---}$	40 $^{11.4}$	22 $^{---}$
Danthonietum calycinae			
Danthonia alpina	35 $^{---}$	75 $^{---}$	100 $^{52.8}$
Vicia cracca	. $^{---}$	. $^{---}$	39 $^{24.8}$
Thymus pannonicus	. $^{---}$	. $^{---}$	26 $^{18.8}$
Crataegus pentagyna	. $^{---}$	. $^{---}$	35 $^{18.3}$
Rosa canina	. $^{---}$	. $^{---}$	35 $^{18.3}$
Gymnadenia conopsea	. $^{---}$	. $^{---}$	22 $^{15.0}$
Polygala vulgaris	6 $^{---}$	25 $^{---}$	57 $^{14.8}$
Centaurea jacea	29 $^{---}$	20 $^{---}$	70 $^{14.5}$
Crepis biennis	. $^{---}$	. $^{---}$	17 $^{13.2}$
Veronica jacquinii	6 $^{---}$	. $^{---}$	26 $^{12.7}$
Rhinanthus rumelicus	35 $^{---}$	85 $^{---}$	87 $^{12.5}$
Prunella laciniata	24 $^{---}$	45 $^{---}$	65 $^{11.8}$
Calamagrostis epigejos	6 $^{---}$	10 $^{---}$	35 $^{11.6}$
Carduus candicans	6 $^{---}$	. $^{---}$	22 $^{11.1}$
Carlina acanthifolia ssp. *acanthifolia*	. $^{---}$	10 $^{---}$	26 $^{10.9}$
Hieracium pilosella	35 $^{---}$	55 $^{---}$	83 $^{10.3}$
Leucanthemum vulgare	41 $^{---}$	75 $^{---}$	91 $^{9.8}$

Table 2. *Continued*

Achillea crithmifolia	6 ---	5 ---	26 9.1
Thymus pulegioides	29 ---	60 ---	74 9.1
Chrysopogono-Danthonion calycinae			
Filipendula vulgaris	88 ---	90 ---	91 ---
Hypochaeris maculata	53 ---	85 ---	91 ---
Betonica officinalis	53 ---	75 ---	74 ---
Euphrasia stricta	24 ---	50 ---	61 ---
Moenchia mantica	. ---	35 ---	26 ---
Hypochaeris radicata	. ---	5 ---	4 ---
Festuco-Brometea			
Trifolium alpestre	100 ---	90 ---	83 ---
Agrostis capillaris	94 ---	100 ---	100 ---
Scabiosa columbaria	94 ---	90 ---	78 ---
Briza media	82 ---	100 ---	91 ---
Trifolium montanum	82 ---	90 ---	91 ---
Dianthus pontederae	76 ---	80 ---	83 ---
Sanguisorba minor	59 ---	90 9.4	65 ---
Galium verum	53 ---	50 ---	70 ---
Hypericum perforatum	53 ---	50 ---	52 ---
Brachypodium pinnatum	47 ---	45 ---	61 ---
Trifolium campestre	41 ---	45 ---	13 ---
Hieracium bauhinii	35 ---	45 ---	52 ---
Euphorbia cyparissias	35 ---	15 ---	35 ---
Holcus lanatus	29 ---	55 ---	39 ---
Helianthemum nummularium	18 ---	55 ---	52 ---
Viola canina	18 ---	45 ---	26 ---
Plantago media	18 ---	15 ---	35 ---
Centaurea phrygia	18 ---	25 ---	. ---
Ranunculus bulbosus	6 ---	10 ---	26 ---
Alyssum montanum	18 ---	. ---	4 ---
Orchis morio	. ---	25 ---	13 ---
Chamaecytisus polytrichus	. ---	15 ---	26 ---
Inula hirta	. ---	5 ---	13 ---
Eryngium campestre	. ---	10 ---	. ---
Anthyllis vulneraria	. ---	10 ---	. ---
Allium carinatum	. ---	5 ---	. ---
Avenula pratensis	. ---	. ---	9 ---
Arrhenatherion			
Poa pratensis	53 ---	40 ---	39 ---
Plantago lanceolata	41 ---	55 ---	65 ---

Table 2. *Continued*

Leontodon hispidus	35 ---	50 ---	57 ---
Galium mollugo	18 ---	10 ---	13 ---
Trisetum flavescens	12 ---	20 ---	13 ---
Medicago lupulina	18 ---	5 ---	. ---
Molinio-Arrhenatheretea			
Achillea millefolium	100 ---	95 ---	96 ---
Dactylis glomerata	88 9.0	60 ---	43 ---
Anthoxanthum odoratum	76 ---	70 ---	78 ---
Tragopogon orientalis	71 8.8	45 ---	26 ---
Lychnis viscaria	71 ---	80 ---	65 ---
Clinopodium vulgare	59 ---	60 ---	26 ---
Campanula sparsa ssp. *sphaerotrix*	47 ---	40 ---	17 ---
Cynosurus cristatus	41 ---	60 8.1	22 ---
Rumex acetosella	35 ---	35 ---	26 ---
Lotus corniculatus	29 ---	55 ---	61 ---
Tanacetum corymbosum	29 ---	10 ---	22 ---
Festuca pratensis	24 ---	45 ---	57 ---
Luzula campestris	18 ---	80 9.4	65 ---
Rumex acetosa	18 ---	65 9.0	48 ---
Salvia pratensis	12 ---	5 ---	26 ---
Ajuga genevensis	12 ---	15 ---	9 ---
Ferulago sylvatica	12 ---	15 ---	4 ---
Bromus hordeaceus ssp. *hordeaceus*	12 ---	5 ---	9 ---
Salvia verticillata	12 ---	5 ---	4 ---
Potentilla reptans	6 ---	10 ---	13 ---
Lathyrus latifolius	12 ---	10 ---	. ---
Myosotis arvensis	12 ---	5 ---	. ---
Geranium dissectum	12 ---	. ---	. ---
Alopecurus pratensis	6 ---	. ---	. ---
Anthriscus sylvestris	6 ---	. ---	. ---
Other			
Teucrium chamaedrys	88 6.1	60 ---	61 ---
Rosa sp.	18 ---	35 9.9	4 ---
Nepeta nuda	18 ---	5 ---	13 ---
Primula veris	6 ---	20 ---	13 ---
Seseli annuum	6 ---	20 ---	4 ---
Astragalus glycyphyllos	6 ---	20 ---	4 ---
Campanula glomerata	6 ---	10 ---	9 ---
Elymus repens	6 ---	5 ---	4 ---
Origanum vulgare	6 ---	5 ---	9 ---
Anchusa officinalis	6 ---	5 ---	4 ---

Table 2. *Continued*

Coronilla coronata	12 ---	10 ---	. ---
Tripleurospermum inodorum	12 ---	15 ---	. ---
Trifolium incarnatum	12 ---	5 ---	. ---
Euphorbia virgata	6 ---	10 ---	. ---
Cruciata laevipes	6 ---	5 ---	. ---
Thesium linophyllon	6 ---	. ---	9 ---
Seseli varium	6 ---	. ---	9 ---
Phleum pratense	. ---	30 ---	17 ---
Cerastium caespitosum	. ---	25 ---	13 ---
Trifolium pratense	. ---	20 ---	17 ---
Prunella vulgaris	. ---	15 ---	17 ---
Dactylorhiza sambucina	. ---	15 ---	13 ---
Campanula cervicaria	. ---	15 ---	4 ---
Veronica chamaedrys	. ---	15 ---	4 ---
Taraxacum officinale	. ---	15 ---	4 ---
Festuca sp.	. ---	10 ---	4 ---
Veronica officinalis	. ---	10 ---	22 ---
Carex hirta	. ---	10 ---	22 ---
Ranunculus polyanthemos	. ---	10 ---	13 ---
Equisetum arvense	. ---	10 ---	9 ---
Colchicum autumnale	. ---	10 ---	9 ---
Silene italica	. ---	5 ---	13 ---
Oenanthe banatica	. ---	5 ---	9 ---
Carex sp.	12 ---	. ---	. ---
Smyrnium perfoliatum	6 ---	. ---	. ---
Verbascum sp.	6 ---	. ---	. ---
Rubus sp.	6 ---	. ---	. ---
Vicia grandiflora	6 ---	. ---	. ---
Digitalis lanata	. ---	10 ---	. ---
Arctium lappa	. ---	10 ---	. ---
Trifolium repens	. ---	10 ---	. ---
Ajuga reptans	. ---	10 ---	. ---
Trifolium ochroleucon	. ---	10 ---	. ---
Arenaria serpyllifolia	. ---	10 ---	. ---
Carex lepidocarpa	. ---	10 ---	. ---
Potentilla inclinata	. ---	5 ---	. ---
Ranunculus repens	. ---	5 ---	. ---
Silene vulgaris	. ---	5 ---	. ---
Trifolium arvense	. ---	5 ---	. ---
Danthonia decumbens	. ---	. ---	13 ---
Stachys germanica	. ---	. ---	13 ---

Table 2. *Continued*

Digitalis grandiflora	. ---	. ---	13 ---
Dorycnium herbaceum	. ---	. ---	13 ---
Silene nutans	. ---	. ---	13 ---
Thlaspi perfoliatum	. ---	. ---	13 ---
Crupina vulgaris	. ---	. ---	9 ---
Juncus effusus	. ---	. ---	9 ---
Geranium sanguineum	. ---	. ---	9 ---
Stachys recta	. ---	. ---	9 ---
Lysimachia nummularia	. ---	. ---	9 ---
Thymus longicaulis	. ---	. ---	9 ---
Erigeron acris	. ---	. ---	9 ---
Spiranthes spiralis	. ---	. ---	4 ---
Mentha longifolia	. ---	. ---	4 ---
Thalictrum minus	. ---	. ---	4 ---
Seseli peucedanoides	. ---	. ---	4 ---
Scirpus sylvaticus	. ---	. ---	4 ---
Carlina vulgaris	. ---	. ---	4 ---
Rorippa pyrenaica	. ---	. ---	4 ---
Eriophorum latifolium	. ---	. ---	4 ---
Serratula tinctoria	. ---	. ---	4 ---
Sambucus ebulus	. ---	. ---	4 ---
Viola alba	. ---	. ---	4 ---

Agrostietum vulgaris (developing on moderate wet habitats) is separated from the *Danthonietum calycinae* (occurring on moderate dry and moderate warm habitats) along the second ordination axis, viewed as a moisture gradient.

The studied communities are of a similar origin to the other semi-natural grasslands in the area, as a consequence of former forest cutting and long-term use by mowing and grazing. Strong human influence enables their development, while abandonment leads to spontaneous succession towards forest community (Dajić Stevanović et al., 2008, 2010).

Such types of grasslands are an important source for livestock production. In the past, meadows like these were cut twice a year in combination with grazing in early spring and autumn. In the last few decades, most of the meadows in Serbia and the Balkans were not mowed and are seriously endangered by abandonment, succession and afforestation. The grasslands of Mt. Stol are famous for their high species richness as a result of the long-term grassland management (regular mowing and grazing) and variable environmental conditions in micro-relief.

The studied communities are listed within Priority for Protection Habitat types represented on the territory of the Republic of Serbia ("Official gazette of RS" no. 35/2010) as Dry siliceous meadows with [*Danthonia calycina*] species, Dry siliceous meadows with redtop [*Agrostis vulgaris*] and red fescue [*Festuca rubra*], as well as Colline moderately moist hay meadows of tall oat-grass [*Arrhenatherum elatius*], the priority habitats according to NATURA 2000 (6240 and 6510). Aside from being rare and vulnerable species, the orchids occurring in the studied grasslands are of special importance (e.g. *Orchis morio*, *Dactylorhiza*

sambucina, *Spiranthes spiralis*, *Campanula sphaerothrix* – the Balkan endemics). Nowadays, the grasslands in Serbia are seriously threatened. The abandonment of grasslands causes changes in the species composition and the rapid progression of shrubs and tree species. Semi-natural grasslands represent refuge habitats for many rare thermophilous plant species, as well as grassland nesting birds, many insects and mammals, and significantly contribute to the species and habitat diversity in Serbia.

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