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Coenological and synphysiological investigations on loess grassland vegetation *(Salvio-Festucetum rupicolae)* close to Gödöllő Hills (Hungary)

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Abstract. Parallel coenological and synphysiological examinations were carried out on three typical xerophilous loess grassland stands of *Salvio-Festucetum* rupicolae community in the Gödöllő Hills, near Isaszeg village. Three stand types, a *Carex humilis*, a *Chamaecytisus austriacus* and a *Stipa dasiphylla* dominated ones were investigated at the same spatial scale (mesoscale). In our sample area apparent dominance by three species (*Festuca rupicola, Stipa dasiphylla, and Carex humilis*) suggested that these stands of this subassociation have been emerged from three types of differing species composition. According to these analyses three groups dominated by *Carex humilis, Chamaecytisus austriacus* and *Stipa dasiphylla of festucetosum rupicolae* subassociation of a stand of *Salvio-Festucetum rupicolae* association were separated. Results of the synphysiological measurements show, that water shortage and senescence in autumn are responsible for the different physiological performances of the three types. In the well-watered summer period we found significant difference only between the physiological activity of the *Carex*- and *Chamaecytisus*- dominated types, however this difference is due to the significant LAI-difference and after relating photosynthesis to 1 m^2 leaf area, the difference is non-significant.

Keywords: coefficient of variation, coenology, grassland, loess stands, multivariate analysis, *Salvio-Festucetum rupicolae* Zólyomi 1958, synphysiology.

Introduction

Temperate grasslands cover large areas of the Earth's vegetation (COUPLAND 1992), and they are locate in one of the regions where the impact of global climate change is predicted to be high (MITCHELL et al. 1990). The temperate grassland surface has large and increasing areas with arid climate. Even in the middle of Europe, Hungary has areas where the relatively low and unevenly distributed yearly precipitation results in semi-arid grasslands like loess grasslands. Loess grassland stands in the Carpathian Basin are among the richest in species considering the plant communities of the Pannonian vegetation. These stands are at the western edge of the continental-Eurasian forest steppe-steppe zone. Unfortunately, intact stands exist only as small patches today. The *Salvio-Festucetum rupicolae* association has several subassociations differing in their physiognomy.

These stands were dominated by *Festuca rupicola*, but differed in physiognomy, texture, spatial pattern, vegetation dynamical traits and physiological activity from each other. (VIRÁGH, BARTHA 1998). This may partly be caused by the constantly changing long term dynamism of spots of species (therophytes, hemitherophytes, stoloniferous species). The long term processes are frequently modified in rates or in directions of small scale disturbances. These rapid changes are expressed by degradation, decreased diversity of stands or invasion by advancing weeds or disturbance tolerant species.

Coenological and synphysiological examinations were carried out on three typical xerophilous loess grassland stands (*Carex humilis, Chamaecytisus austriacus* and *Stipa dasiphylla dominated*) of *Salvio-Festucetum rupicolae* Zólyomi 1958 community in the Gödöllõ Hills, near Gödöllõ (Isaszeg village). The synphysiological measurements were started in three apparently different and arbitrarily chosen types.

We were interested whether these types could be detected also by multivariate analysis from many coenological samples of the area. We also tried to reveal what kind of synphysiological traits are characterising the physiognomically distinct, adjacent, mosaic-like types of the *festucetosum sulcatae* subassociation.

Materials and methods

Study area, coenological survey

Sample plots were chosen between villages Isaszeg and Kerepes (230 m a. s. l.) in typical and continuous stands of the *Salvio-Festucetum rupicolae* association (ZÓLYOMI 1958). In this area the steppe grassland stands occupy marginal positions in the vicinity of Gödöllő Hills. The annual precipitation: 601 mm, the average temperature: 9,1°C, the medium daily maximum: 14,1°C, the medium daily minimum: 4,1°C. (KAKAS 1969). This flora spectrum is poor in characteristic species and contains several steppe species typical of the Central Range. Hungarian loess vegetation strictly related to eastern European steppe vegetation. This flora composition of western steppe fragments similar to e. g. Ukrainian steppe vegetation (ZÓLYOMI & FEKETE 1994), so these sample plots of this area could represent adequately the East European loess vegetation.

We tried to set up plots representative to this association, rich in species, diverse in physiognomy, far from plantations (*Populus* forest, hedges, etc.).

The synphysiological study was carried out in June (summer aspect) and in September (autumn aspect) 2000. During June we made physiological measurements both under stressed and under non-stressed conditions in the vegetation's fully developed phase, while in September measurements were made under wet conditions, but in the vegetation's senescent phase. The coenological survey was carried out on 3rd July 2001. Seventy five quadrats of 2 x 2 m were chosen. The species list and cover values are detected. The species composition consists of 62 species. Dominant species with decreasing cover values are the following: *Festuca rupicola, Carex humilis, Dorycnium germanicum, Cytisus austriacus, Chrysopogon gryllus, Stipa dasiphylla.* There are several subdominant species,

e. g.: *Phleum phleoides, Seseli osseum, Teucrium chamaedrys, Galium verum,Helictotrichon pubescens, Filipendula vulgaris, Euphorbia pannonica, Asperula cynanchica.* Characteristic and accessorial species the next: *Salvia nemoralis, Isatis tinctoria* and *Agropyron repens, Agropyron caninum, Centaurea sadleriana, Hypericum perforatum, Falcaria vulgaris, Dactylis glomerata, Anthericum ramosum, Adonis vernalis.* For statistical evaluation several ecological characters of species were taken from Hungarian Database 1.2 (HORVÁTH et al. 1995). The ecological indicator values of species (BORHIDI 1995) are given in percentage pro rata. These characters are: the relative temperature requirement of species (TB), soil acidity (RB), humidity (WB), nitrate supply (NB), relative light intensity (LB), continentality (KB) and the types of social behaviour (SOC). The nature conservation ranks (NCR) (Simon 1988) are given in 10 categories separated in two groups. Proportion of the first group (U-unique, KV-strictly protected, V-protected, E-native species, K-accessorial species, TP-nature pioneers) reflects natural conditions, proportion of the second group indicates the degree of degradation (TZ-disturbance tolerant native species, A-adventives, G-cultivated species, GY-weeds) compared to the Hungarian average. The categories of simplified flora element spectrum of Hungary (FL) contain the main groups completing with relationship of Pannonic viewpoint. This kind of simplification is suitable for the analysis. The coenosystematical groups (COENOS) are established for categories of the hierarchical system. Multivariate analysis on cover values of species was carried out by using the SYN-TAX program (PODANI 1993, 1997). For the cluster analysis the Czekanowsi-index was used (PODANI 1993, 1997).

Synphysiological methods

CO_2-exchange, transpiration, air-temperature, relative humidity and vapour pressure, and stomatal conductance were measured by using a portable closed-loop IRGA gas exchange system (LI-COR 6200) sampling the air in a plexi chamber of 60 cm diameter (ground area of the chamber is 2826 cm^2) and 70 cm height with three replicate measurements in each plot (BALOGH et al. 2002). PPFD values were recorded and LAI was estimated using sunfleck ceptometers (Decagon). Canopy-surface temperature was measured with an infrared thermometer (MX4, Raytek). Soil water content was measured by a TDR reflectometer (ML2, Delta-T Devices) in three replications at 5, 10, 20 cm soil depths. Forty plots were measured in summer and 30 in autumn in each stand types.

Results and discussion

Coenological pattern

The dendrogram of the sample plots can be seen on Figure 1. Using the Czekanowski-index there are 7 well organized groups at 0.58 similarity value. The first group (1-37. sample plots) is characterized by the dominance of *Carex humilis, Chrysopogon gryllus, Chamaecytisus austriacus, Dorycnium germanicum, Teucrium chamaedrys* and the presence of *Phleum phleoides, Filipendula vulgaris (Carex* dominated type). This fragment has three levels: the tall grasses (50-70 cm), the hemikryptophyte and chamaephyte species (30-50 cm) and th therophytes (5-15 cm). The levels have compact stand.

The *Chrysopogon gryllus* is almost absent from the second group (2-50. samples), and there is less *Chamaecytisus austriacus, Phleum phleoides, Filipendula vulgaris, Dorycnium germanicum, Teucrium chamaedrys* too, however the dominance of *Festuca rupicola* is more pronounced, and the

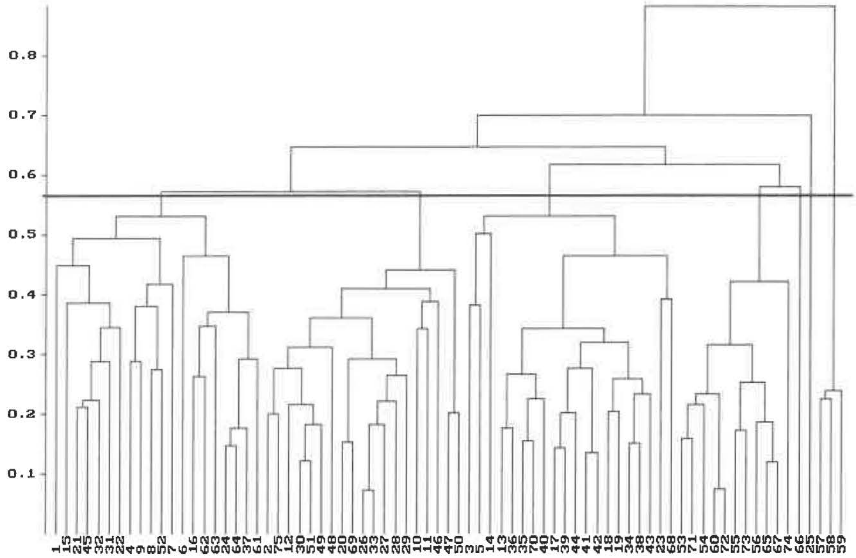

Figure 1. Dendrogram of sample plots of *Festucetum rupicolae* stand.

denominative species of this association, *Salvia nemorosa* is also present (*Cytisus* dominated type). This fragment is compact too, but smaller (50 cm) than the *Carex* type.

The third group (3-68.) (*Stipa* dominated type) is characterized by lower cover values of *Stipa dasiphylla, Chrysopogon gryllus, Chamaecytisus austriacus, Dactylis glomerata, Festuca rupicola, Filipendula vulgaris, Phleum phleoides, Teucrium chamaedrys, Helictotrichon pubescens.* The four other groups are different from each other in species composition and cover values, but are coupled by the presence of *Stipa dasiphylla.* This fragment is not so compact, it comprised loose and tall grass tufts and spots (50-70 cm) and smaller other hemikryptophyte and chamaephyte species. There are sevaral gaps between the grass tufts (30-40 cm).

Result of principal coordinates analysis (PCoa) shows 3 loose groups of sample plots (data are not shown), identical with the three types found by cluster analysis. The rest of sample plots contains rare species making them diverse and mosaic-like, not typical to festucetosum rupicolae subassosiation.

Analysing several standard coenological attributes the investigated area and the three grassland types can be characterized as follows. The distribution of temperature indicator values (TB) shows two peaks, similarly to the continentality diagram's two maximum values. The proportion of mesophyl and xerophyte species is more than 55 %. The high frequency of these species is characteristic for both open or closed grassland communities.

The distribution of relative humidity indicator values (WB) shows a normal bell-shaped form (Table 1.). Its maximum value is due to the high frequency of xerotolerant plants. The diagram is asymmetric in the case of xeromorph habitats.

The distribution of soil acidity values (RB) sign the high frequency of basiphylous species in the area's three types. 10 % of them are lime indicator species and do not occur on acidic soil (*Carex humilis, Chamaecytisus austriacus, Thalictrum pseudominus*).

Table 1. Percentage (%) distribution of relative humidity indicator values (WB) of the species in the investigated temperate loess grassland.

categories	1	2	3	4	5	6	7
WB values of Carex-type	0,15	3,75	20,6	5,86	1,2	1,65	0,15
WB values of Cytisus-type	0,18	4,42	19,3	6,63	1,29	1,47	
WB values of Stipa-type	0,18	4,59	19,6	6,53	0,53	1,94	

Distribution of relative nitrogen indicator values (NB) can be seen in Table 2. Half of the species are characteristic of habitats very poor in nitrogen, 10 % of them live in places extremely poor in nitrogen or in dry places (*Seseli osseum, Minuartia verna, Phleum phleoides*).

Table 2. Percentage (%) distribution of relative nitrogen indicator values (NB) of the species in the investigated temperate loess grassland.

categories	1	2	3	4	5	6	7
NB values of Carex-type	8,11	15,6	4,35	1,8	0,6	1,65	1,35
NB values of Cytisus-type	8,29	15,3	3,13	1,47	1,47	1,66	2,03
NB values of Stipa-type	8,11	18,2	3,17	1,06	0,18	1,94	0,71

In terms of temperature (TB), water (WB) and soil (RB) requirements the distribution and the maximum of values are similar in the three types. The tendency of the distribution of nitrogen requirement (NB) is similar to the others, but the rate of Stipa type is higher at the maximum value (9%), that at the Chamaecytisus type.

Distribution of relative light indicator values (LB) shows high ratio of light plants (45%), full light plants of open habitats (20%) and shadow tolerant ones (32%). There are only few typical shadow plants (Table 3.).

Table 3. Percentage (%) distribuiton of relative light indicator values (LB) of the species in the investigated temperate loess grassland.

categories	5	6	7	8	9
LB values of Carex-type	0,3	0,45	11,6	15	5,86
LB values of Cytisus-type	0,74	0,18	12,3	14	6,08
LB values of Stipa-type	0,35	0,71	10,9	12,5	8,82

The distribution of plants according to degree of continentality shows two peaks (Table 4.). The first maximum corresponds to the suboceanic species, mainly central European but expanding to East (*Bromus sterilis, Teucrium chamaedrys, Galium verum, Agrimonia eupatoria*), the second max-

Table 4. Percentage (%) distribuiton of species according to degree of continentality of the species in the investigated temperate loess grassland.

categories	3	4	5	6	7	8
KB values of Carex-type	1,35	9,46	5,56	4,05	9,61	3,15
KB values of Cytisus-type	1,1	10,3	4,79	3,31	12	1,84
KB values of Stipa-type	1,23	8,99	5,64	5,82	8,11	3,53

imum shows the continental-subcontinental species spread in East Europe (*Festuca rupicola, Isatis tinctoria, Silene otites*). The difference between the maximum values of light requirement (LB) and nitrogen requirement (NB) of the *Stipa* and *Chamaecytisus* type is nearly the same (8%). The values of continentality (KB) are markedly different being 10 % higher in the *Chamaecytisus* type, than in the *Stipa* type. This *Stipa* dominated group of plots is the most uniformly distributed out of the three types.

The distribution of categories of nature conservation values (SIMON 1988) shows native species are the most frequent (60%), native accessorial species are less abundant (20%). The proportion of disturbance tolerant native species is low (10 %), as the proportion of weeds, cultivated plants and adventitious species too (less, than 4%). There is however considerable quantity of strictly protected and protected species of Hungary (8 %), like *Stipa dasiphylla, Centaurea sadleriana, Adonis vernalis, Thalictrum pseudominus.*

According to distribution of floral elements (FL) the share by the Eurasian elements is the highest (27%), the submediterranean and the Pontic-Pannonian elements (e. g. *Chamaecytisus austriacus, Isatis tinctoria*) are present in considerable quantity (together 28 %) and there is a smaller quantity (10%) of the Pannonian (*Dianthus pontederae*) and the Pannonian-Balkan elements (*Euphorbia pannonica*). The proportion of cosmopolitan species is less than 5% (*Koeleria cristata*), and the rate of adventive species is low (1,5%, e. g. *Erigeron canadensis, Onobrychis viciifolia*). This shows that this area is more or less intact. The distribution of the floral elements shows that the *Stipa* type has the highest quantity of Eurasian, continental and submediterranean elements, in contrast to the *Carex* type that almost have the lowest levels of these. The *Chamaecytisus* group has the highest quantity of European and Pontic-Pannonian elements.

Table 5 shows the distribution of social behaviour types (SOC). Generalists (G) and the competitors (C) give half of the species. The cover by natural pioneers (NP)(*Myosotis stricta*) and specialists (S)(*Adonis vernalis, Thalictrum pseudominus*) is remarkable, too (together 26 %). There are few (15 %) disturbance tolerant (DT) species (*Achillea collina, Agrimonia eupatoria, Galium verum*). The quantity of weeds (W), alien competitors (AC) and ruderal competitors (RC) is insignificant (*Viola arvensis, Descurainia sophia*), less than 4,5 %.

Table 5. Percentage (%) distribution of social behaviour types (SOC) of the species in the investigated temperate loess grassland.

categories	**c**	**s**	**g**	**np**	**dt**	**w**	**rc**	**ac**
soc. behav. typ. Carex-type	6,16	1,95	17,9	0,15	5,41	0,6	0,9	0,15
soc. behav. typ. Cytisus-type	5,16	1,66	18,2	0,37	5,16	1,29	1,47	
soc. behav. typ. Stipa-type	7,41	1,06	18,7		5,29	0,18	0,53	0,18

The distribution according to the coenosystematic categories shows the group of indifferent species is comprised of several xerophilous species (*Hypericum perforatum, Melandrium album*) and species occurring due to anthropogenic disturbance (*Erigeron canadensis*), with a share of 14 %. Presence of forest elements shows the bushy character of this area. The rest are the elements of grassland associations (80 % of all). The distributions of the social behaviour type (SOC) and of the nature conservation rank categories (NCR) are similar in the three types.

The rate of monocotyledons/dicotyledons/Fabaceae shows (Table 6.) that the quantity of Fabaceae species is double in the *Stipa* type as compared to the two other groups (*Carex*, *Chamaecytisus*). Effects of a warmer and drier climate may favor the spread of species from the *Chamaecytisus* and the *Stipa* types.

Table 6. The percentage (%) rate of monocotyledons/dicotyledons/Fabaceae of the species in the investigated temperate loess grassland.

categories	monocotyl	dicotyl	fabaceae
Carex-type	8,69	24,63	2,17
Cytisus-type	10,52	22,8	1,75
Stipa-type	10,71	22,61	4,76

Synphysiological characteristics

Synphysiological measurements were started in three apparently, physiognomically different types of the community. The above mentioned coenological considerations prove that there's many differences in the three types' composition, constraints by abiotic conditions, etc., but the physiological performance is not necessarily different.

Considering the whole dataset of summer (120 plots) and autumn (91 plots) aspect physiological measurements (temporal variability) it is obvious, that the average values and coefficient of variation of photosynthesis are higher in summer (Table 7.). Decreasing values of these variables till autumn is partly caused by senescence. The last two columns show that comparing summer water-stressed (56 plots) and non-stressed (64 plots) periods separately, CV values are much smaller in the latter case.

Table 7. Some data of the photosynthetical performance of a temperate loess grassland in summer and autumn 2000.

	Summer aspect	Autumn aspect	Non-stressed summer period	Water-stressed summer period	Carex-type, non-stressed summer period	Carex-type, water-stressed summer period
Mean of LAI ($m^2. m^{-2}$)	3,09	3,84	2,91	3,30	1,64	3,66
SD of LAI	1,25	0,97	1,44	0,96	0,49	0,84
CV of LAI (%)	40,35%	25,20%	49,34%	29,13%	30,05%	23%

The estimated average value of LAI (Table 8.) was higher in autumn than in summer, but the method used for LAI-estimation does not distinguish photosynthetically active and fully senescent leaves. Nor did we pursue the interannual change of LAI, the measurements in summer may have not been at the highest LAIas it can be inferred from increasing average LAI with decreasing CV in June (non-stressed period: 2000. 06.08., 13., 15., 16.; water-stressed period: 2000. 06. 21., 22.).

Table 8. Some data of the estimated leaf area index.

	Summer aspect	Autumn aspect	Non-stressed summer period	Water-stressed summer period	Carex-type, non-stressed summer period	Carex-type, water-stressed summer period
Mean of LAI ($m^2. m^{-2}$)	3,09	3,84	2,91	3,30	1,64	3,66
SD of LAI	1,25	0,97	1,44	0,96	0,49	0,84
CV of LAI (%)	40,35%	25,20%	49,34%	29,13%	30,05%	23%

Consideration of the three different types shows, that water shortage and senescence in autumn are responsible for the different physiological performances. In the well-watered summer period (soil water content: 12,38% in the *Carex*-type, 10 plots; 13,54% in the *Chamaecytisus*-type, 12 plots and 11,86% in the *Stipa*-type, 40 plots) we found significant difference only between the physiological activity of the *Carex*- and *Chamaecytisus*- dominated types, however this difference is due to the significant LAI-difference and after relating photosynthesis to 1 m2 leaf area, the difference is non-significant.

In the case of water-stressed summer period (soil water content: 6,55% in the *Carex*-type, 28 plots; 7,54% in the *Chamaecytisus*-type, 28 plots) photosynthesis were significantly different between the types and the same was found for the autumn period (soil water content: 7,02 and 11,33% in the Carex-type on the two days of investigation, 10,89% in the *Chamaecytisus*-type) (Table 9.).

Table 9. Some data of the photosynthetical performance of different types of the investigated grassland in different conditions. (, ** means significant difference when referred to 1 m^2 leaf area)

	Non-stressed summer period			Stressed /water deficient/ summer period		Autumn aspect		
	Carex-type	Cytisus-type	Stipa-type	Carex-type	Cytisus-type	Carex-type	Cytisus-type	Stipa-type
Mean of A ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	17,89	29,15	22,55	2,53(**)	3,29(**)	3,24(**)	4,55(*,**)	2,87(*)
SD of A	8,00	13,72	10,35	1,53	1,32	1,83	1,60	1,38
CV of A (%)	44,71%	47,07%	45,9%	60,45%	39,97%	56,39%	35,23%	47,9%

These results contain both abiotic and biotic variability rates. At higher light intensities (PPFD>1000 $\mu mol.m^{-2}.s^{-1}$) the average CO_2 exchange rates were higher and CVs were lower (Table 10.) except for the case of the stressed period measurements.

There is a clear trend of increase of the value of photosynthesis and decrease of its CV (number of plots are: summer: 74, autumn: 44, water-stressed period: 24, non-stressed period: 50).

Table 10. Data of photosynthetical performance at saturating light conditions.

	Summer aspect	Autumn aspect	Non-stressed summer period	Stressed /water deficient/ summer period
Mean of A ($\mu mol \cdot m^{-2} \cdot s^{-1}$)	16,63	3,62	23,36	2,59
SD of A	12,69	1,66	9,80	1,60
CV of A (%)	76,34%	45,72%	41,94%	61,79%

Conclusions

In a typical stand we tried to set up plots, which represents this *Salvio-Festucetum rupicolae* association. Statistical evaluation of several ecological characters of species was carried out together with a hierarchical cluster analysis. According to these analyses three groups dominated by *Carex humilis, Chamaecytisus austriacus* and *Stipa dasiphylla* of *festucetosum rupicolae* subassociation of a stand of *Salvio-Festucetum rupicolae* association were separated. Results of the synphysiological measurements show that water shortage and senescence in autumn are responsible for the different physiological performances of the three types. In the well-watered summer period we found significant difference only between the physiological activity of the *Carex*- and *Chamaecytisus*- dominated types, however this difference is due to the significant LAI-difference and after relating photosynthesis to 1 m^2 leaf area, the difference is non-significant.

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