

The species composition and dynamics in well-preserved and restored calcareous xerothermic grasslands (South Poland)

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In this paper the floristic composition and dynamics of species in unmanaged and restored xerothermic grasslands on soil of different depth were studied. On the control plots, independently of the soil thickness, there were no significant changes of the initial species composition. Mowing or cutting the calcareous grasslands on shallow soil significantly increased the species richness. However, contrary to mown plot, on the clear-cut ones, the abundance of the calcareous grassland species (*Festuco-Brometea*) was low. From the nature conservation point of view, it seems essential to preserve the existing patches of xerothermic grasslands. Restoration the calcareous grasslands from xerothermic shrubs is possible only on shallow soil.

Key words: secondary succession, active protection management, biodiversity, CA, pCCA, Poland.

Introduction

Decreasing the species richness in the calcareous grasslands after abandoning the traditional management practices is a major conservation problem throughout Western Europe (WARD, 1990; GIBSON & BROWN, 1991; FISCHER & STÖCKLIN, 1997). Experimental restoration of xerothermic grasslands by trees and shrubs clearing as well as *Brachypodium pinnatum* control by different management regimes – mowing, digging out, herbicide treatment, have been undertaken in several European countries (BOBBINK & WILLEMS, 1987; BOBBINK et al., 1987, 1988; KIEFER & POSCHLOD, 1996; DZWONKO & LOSTER, 1998; FARMER & BAXTER, 1998; HURST & JOHN, 1999; BARBARO et al., 2001). The lack of management has caused the increase of dominance of a few tall-

growing species and resulted in sharp declining of species richness (WILLEMS, 1983; BOBBINK & WILLEMS, 1987; WILLEMS et al., 1993; DZWONKO & LOSTER, 1998).

Many authors pointed out the importance of dispersal processes in restoration of species-rich xerothermic grasslands (MILBERG, 1992, 1995; DUTOIT & ALARD, 1995; PÄRTEL et al., 1998; POSCHLOD et al., 1998). However, in recent works, the role of seed rain rather than seed bank in restoration of calcareous grasslands has been stressed, mainly because most of xerothermic grassland species form a short-lived, “transient seed bank” (sensu THOMPSON et al., 1997) in the soil (WILLEMS, 1995; BAKKER et al., 1996). Seed bank may be important only for early successional stages or for population of a few certain species (PÄRTEL et al., 1998). Therefore, the most

effective way to preserve species-rich xerothermic grasslands is to maintain the traditional management regimes, especially shepherding, linking the isolated grassland sites, that enables long-distance diaspore dispersal by sheep flocks (DZWONKO & LOSTER, 1998; POSCHLOD et al., 1998). For these reasons, the protection of existing xerothermic grasslands as the source of propagules should be one of the most important aims in conservation planning.

For centuries, xerothermic grasslands have played an important role in agricultural landscape of Kraków-Częstochowa Upland, Southern Poland (DZWONKO & LOSTER, 1998; KOTAŃSKA & MITKA, 2000). At present, only remnants of formerly widespread xerothermic communities still exist. Most of them are abandoned and partially overgrown by trees and shrubs, especially in the sites lying close to woodlands. Despite the small area they cover, xerothermic grasslands provide refugia for plant and animal species, of which many are rare or endangered in Poland (MICHALIK & ZARZYCKI, 1995). Grazing is often impossible, because of difficult access to the xerothermic grassland sites and their strong fragmentation in landscape. Therefore the main management practices applied to them are cutting the shrubs and trees and mowing.

The aim of this study were to compare the changes in the species composition and rate of vegetation dynamics in species-rich xerothermic grasslands: (i) without management with those to which mowing and were applied, and (ii) on soil of different thickness.

The study area

The study was carried out in the Ojców National Park, Poland in the years 1997–2000. It lies in the southern part of the Kraków-Częstochowa Upland [19°20' E; 50°13' N]. Xerothermic grasslands form small patches on steep, rocky, calcareous slopes of Prądnik and Sąpówka stream valleys. The grasslands are of both natural and semi-natural origin and represent the *Festucetum pallentis* (KOZŁOWSKA 1928) KORNAŚ 1950, the *Origano-Brachypodietum pinnati* MEDWECKA-KORNAŚ et KORNAŚ 1963 and the *Koelerio-Festucetum rupicolae* KORNAŚ 1952.

Xerothermic grasslands in the area had been maintained for centuries by specific and intensive management practices, mainly by goat, cow and sheep grazing and sometimes by mowing. As a result of cessation of this traditional management, many of xerothermic grasslands patches be-

came overgrown by trees and shrubs (MICHALIK & ZARZYCKI, 1995).

Introduction of modern agricultural practices and lack of financial support for appropriate active protection management, resulted, *inter alia*, in changes in floristic composition. Until the 1980s, most of the remaining patches of xerothermic grasslands were included in strict protection schemes. Up to the present only small remnants of formerly widespread xerothermic grasslands have survived. They stand out as one of the plant communities richest in species (up to 30–40 vascular plant species in 1 m²) in Poland.

Material and methods

In June 1996, 90 permanent 1 m² study plots were established within south-west slope of the “Grodzisko” rock (ca. 2200 m²), located in south-western slope of the Prądnik Valley, Ojców National Park and covered by mosaic of xerothermic grasslands and sparse scrubland. The grasslands had been intensively managed, mainly by sheep grazing and mowing till 60-ties and then abandoned. 30 of these plots were placed within 3 randomly selected, 5 × 20 m well-preserved xerothermic grassland patches, dominated by *Festuca rupicola* (nomenclature of plants according to MIREK et al., 1995) and *Carex pediformis* (*Koelerio-Festucetum rupicolae*). In the patches, 10 plots were placed along transects lying perpendicularly to the slopes and separated from each other by 2 m wide strip of the grassland. They were left without management (K). In similar way, another 30 plots were placed in 3 xerothermic grassland patches dominated by *Festuca rupicola*, *Brachypodium pinnatum* and *Galium boreale*, and they had been mown in autumn each year since 1996 (M). Finally, 30 plots (C) were placed in 3 grassland patches occupied by xerothermic vegetation dominated by *Brachypodium pinnatum*, *Coronilla varia* and *Fragaria viridis*. In sparse shrub layer *Corylus avellana*, *Crataegus monogyna*, *Cornus sanguinea* and *Prunus spinosa* occurred. In winter 1996, all shrubs in the plots C were cleared and in consecutive years suckers were removed. In all the transects of the K, C and M treatments, the 1 m² plots were later divided into three groups, according to mean soil thickness: S1: 3–10 cm; S2: 11–25 cm; S3: > 25 cm. These groups are broadly related to soil types: protorendzinas, rendzinas and brown rendzinas (ZALEWA, 2001). The thickness of soil layer in the plots was estimated by probing them randomly ten times with a calibrated stick driven into the ground in each plots.

In summer of four consecutive years, in the same phenological season the number and percentage cover of all vascular plant species with scaled wooden frame were assessed in each plot.

The calcareous grasslands in the Ojców National Park are small patches, which occur on steep slopes of the valley with diversified relief, thus the influence of many different ecological variables should be taken into

consideration to receive the reliable results. Also the number of plots, which could be established, was limited due to of the Ojców NP protection regimes. This complicated the experimental design. Thus, some of the marginally significant results should be considered with a caution due to these methodological problems.

Data analysis

For all plots, the mean species richness, number and cover of species characteristic of the *Festuco-Brometea*, *Trifolio-Geranietea*, *Molinio-Arrhenathetea*, *Rhamno-Prunetea* and *Quercu-Fagetea* were calculated. The mean species diversity in particular plots was determined according to Shannon-Wiener formula (HILL, 1973):

$$H' = - \sum_{i=1}^S p_i \log_2 p_i$$

and the structure of dominance by means of Simpson index (HILL, 1973):

$$C' = - \sum_{i=1}^S p_i^2$$

$P_i = n_i/N$, where n_i is the % cover of the i -th species in the plots and N is the sum of % cover of all species in the plot.

To compare the rate of changes in species richness on managed, unmanaged plots, and plots on different soil thickness, mean cumulative species richness (overall and that of *Festuco-Brometea* species) were calculated by summing up the species occurring on the plot since the start of the experiment (VAN DER MAAREL & SYKES, 1993, 1997).

To examine the main direction of variance in the data in relation to the soil thickness, the Correspondence Analysis (CA, TER BRAAK, 1988) was performed separately for S1–S3 groups of the plots. To relate the ordination scores of the first CA axis with plots characteristics were calculated, a Kendal (τ) rank correlation index was used.

In order to examine how the changes in the cover of species in the plots depend on the management type and soil depth the partial Canonical Correspondence Analyses (pCCA; JONGMAN et al., 1995; TER BRAAK, 1987; TER BRAAK & WIERTZ, 1994; DZWONKO & LOSTER, 1998; PALMER, 1998) were applied. Several explanatory variables were used: year, plots, treatments, soil depth, treatment \times year and soil depth \times year interactions. The “Year” variable is considered both as the time from the start of the experiment (quantitative variable with 0, 1, 2, 3 values) and as a set of four dummy variables (categorical variable with 1997, 1998, 1999, 2000 values). In the later case I searched the general differences in dynamics (LEPŠ & ŠMILAUER, 1999). Plot identifiers (coded as dummy variables) were treated as covariables. In this way I subtracted the average over years of each plot and only

the changes in particular plot were analysed (LEPŠ & ŠMILAUER, 1999). To test statistical significance of the models a restricted (taking into account the experimental design) Monte Carlo tests with 499 permutations were used. I tested both the significance of the first axis and the overall model.

Results

Species richness and structure of communities

In total, 148 vascular plant species were found in the plots. There were great differences in the mean species number and composition between managed and unmanaged plots. In xerothermic grasslands without management, the mean species numbers in the plots were high, compared to managed plots and increased on average from 17.2 to 20.3 for the period of 1997–2000. The value of H' coefficient was also high and fluctuated only slightly throughout the study period (Fig. 1). Mean value of Simpson’s dominance index was lower as compared to mown and clear-cut plots and slightly decreased throughout the study period. In the mown plots, the mean values of species richness and species diversity H' increased and

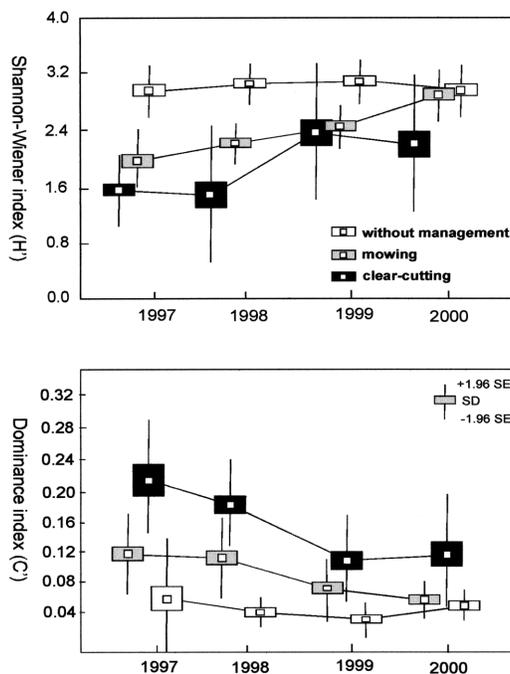


Fig. 1. Mean diversity (H') and dominance (C') index value in managed and unmanaged plots in “Grodzisko” rock.

were only slightly lower than those in xerothermic grasslands without management, and the mean C' value decreased (Fig. 1). The mean number of species in plots increased from 11.4 to 21.6 in the 1997–2000 period.

On the cleared plots, the mean species richness was similar to mown and unmanaged grasslands in the last year of the experiment. However, the mean H' value was much lower when comparing unmanaged and mown grasslands and it varied greatly between particular plots (Fig. 1, 2).

Changes in space and time

As shown in Figure 2, there was a great disparity in species accumulation rate between plots on soils of different thickness. Generally, accumulation of overall species richness and species of *Festuco-*

Brometea-class lowered from shallow (S1) to deep (S3) soil. These differences were visible especially on mown and clear-cut plots (Fig. 2).

The first CA axes ($\lambda_1 = 0.63 - 0.68$), which represent the main gradient variation in the data, show the strong positive correlation with number of species of the *Rhamno-Prunetea* ($\tau = 0.30 - 0.60$; $p < 0.001$) and *Quercu-Fagetea* ($\tau = 0.29 - 0.38$; $p < 0.001$) and negative with mean number of species ($\tau = -0.46$ to -0.56 ; $p < 0.001$) and number of species of the *Festuco-Brometea* ($\tau = -0.54$ to -0.61 ; $p < 0.001$), *Trifolio-Geranietea* classes ($\tau = -0.41$ to -0.57 ; $p < 0.001$).

The spatial and temporal changes in the cover of particular species within managed and unmanaged plots were explored by partial Canonical Correspondence Analyses (Tab. 1.). The first two

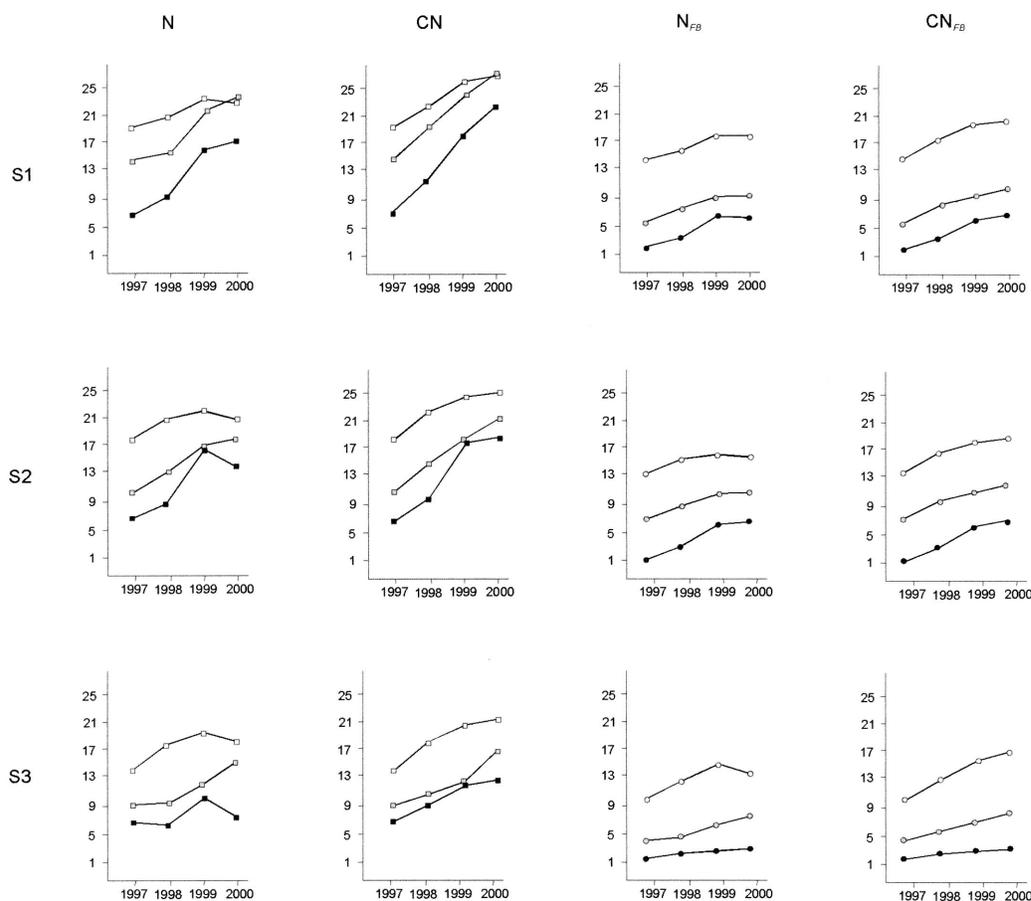


Fig. 2. Mean total number of species (N), mean cumulative total number of species (CN)/1 m² and *Festuco-Brometea* class (N_{FB} and CN_{FB} respectively) in unmanaged (open symbols), mown (grey symbols) and clear-cut (dark symbols) sites in plots with different soil thickness (S1: 3–10 cm; S2: 11–25 cm; S3: > 25 cm).

Table 1. Results of the pCCA analyses of cover of the species in the 1 m². Data are centered by species. % var 1-st axis: percent of species cover variability explained by the first canonical axis, r 1-st axis: species-environment correlation on the first axis. F: the F-ratio statistics for trace. P – corresponding probability value obtained by the means of Monte Carlo permutation tests with 499 random permutations; Y – serial number of the year; K – without management; M – mowing; C – clear cutting; PLOT – identifier of each plot; S1-S3 plots of different soil thickness. Only the significant (< 0.05) interaction) are shown (M*Y is the exception).

Analysis	Explanatory variables	Covariables	%Var 1-st axis	r 1-st axis	F	P
1	Y; K*Y; M*Y; C*Y; S1*Y; S2*Y; S3*Y	PLOT	6.6	0.872	11.284	0.005
2	K*Y; M*Y; C*Y; S1*Y; S2*Y; S3*Y	PLOT; Y	4.4	0.865	11.348	0.050
3	K*Y; M*Y; C*Y;	PLOT; Y; S1*Y; S2*Y; S3*Y	4.2	0.860	11.538	0.005
4	S1*Y; S2*Y; S3*Y	PLOT; Y; K*Y; M*Y; C*Y;	2.3	0.699	3.485	0.005
5	M*Y	PLOT; Y; M*Y; C*Y; S1*Y; S2*Y; S3*Y	0.40	0.541	1.173	0.060
6	C*Y	PLOT; Y; K*Y; M*Y; S1*Y; S2*Y; S3*Y	1.0	0.684	2.527	0.005
7	S1*Y	PLOT; Y; K*Y; M*Y; C*Y; S2*Y; S3*Y	0.50	0.423	0.777	0.050
8	M*S1*Y	PLOT; Y; K*Y; M*Y; 0.11 C*Y; M*(S1,S3)*Y; K*(S1-S3)*Y; C*(S1- S3)*Y	0.806	1.735	0.050	
9	C*S1*Y	PLOT; Y; K*Y; M*Y; C*Y; *(S1,S3)*Y; K*(S1- S3)*Y; M*(S1-S3)*Y	0.35	0.825	4.452	0.040

axes in the model, with treatments, years and soil thickness as environmental variables, accounted for 7.5% variation in the species data and 73.7% fitted variation in the cover of species ($\lambda_1 = 0.494$; $\lambda_2 = 0.204$; Tab. 1.). The temporal changes in species composition depended on of the management type and to the smaller extent – on the soil thickness (analyses 2–4, Tab. 1).

Among the treatments applied only cutting the trees with subsequent suckers removal had significant effects on temporal changes in the species

composition (analyses 5–6, Tab. 1.). On the mown plots as a whole, these changes were nearly significant ($P = 0.06$). However, when soil depth was taken into account, the significant changes in floristic cover were confined to the mown and clear-cut plots on shallow (S1) soil (Tab. 1, analyses 7–9). In xerothermic grassland with no management (as a whole), the changes in cover of species in the plots were negligible.

When comparing the position of centroids, representing particular plots and species in mul-

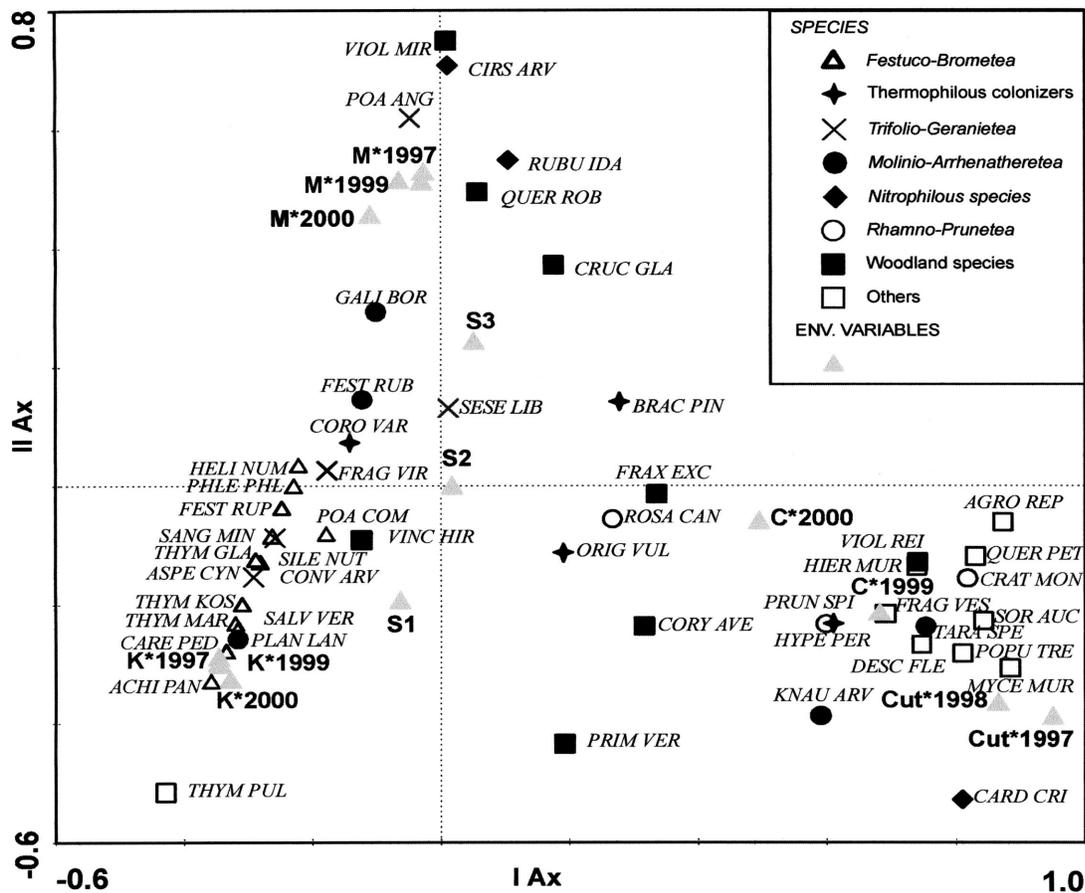


Fig. 3. Results of partial Canonical Correspondence Analysis. Biplot of centroids of soil depth, and type of management by year combination and species. Years are treated as categorical variable. Diagram shows the first two CCA axes ($\lambda_1 = 0.494$, $\lambda_2 = 0.204$). This model accounted for 7.5% variation of species cover and 73.7% of species cover fitted to explanatory variables. Species with at least 4% fit to the explained variance are shown. Species abbreviations (Latin names of species according to MIREK et al. 1995): Achi pan – *Achillea pannonica* SCHEELE, Agro rep – *Agropyron repens* (L.) P. BEAUV, Aspe cyn – *Asperula cynanchica* L., Brac pin – *Brachypodium pinnatum* (L.) P. BEAUV., Card cri – *Carduus crispus* L., Care ped – *Carex pediformis* C. A. MEY., Cirs arv – *Cirsium arvense* (L.) SCOP., Conv arv – *Convolvulus arvensis* L., Cory ave – *Corylus avellana* L., Coro var – *Coronilla varia* L., Crat mon – *Crataegus monogyna* JACQ., Cruc gla – *Cruciata glabra* (L.) EHREND., Desc fle – *Deschampsia flexuosa* (L.) TRIN., Fert rub – *Festuca rubra* L. s. s., Fert rup – *Festuca rupicola* HEUFF., Frag vir – *Fragaria viridis* DUCHESNE, Frag ves – *Fragaria vesca* L., Frax exc – *Fraxinus excelsior* L., Gali bor – *Galium boreale* L., Heli num – *Helianthemum nummularium* (L.) MILL. subsp. *obscurum* (ELAK.) HOLUB, Hier mur – *Hieracium murorum* L., Hype per – *Hypericum perforatum* L., Knau arv – *Knautia arvensis* (L.) J. M. COULT, Sese lib – *Libanotis pyrenaica* (L.) BOURG., Myce mur – *Mycelis muralis* (L.) DUMORT., Orig vul – *Origanum vulgare* L., Phle phl – *Phleum phleoides* (L.) H. KARST., Plan lan – *Plantago lanceolata* L., Poa ang – *Poa angustifolia* L., Poa com – *Poa compressa* L., Popu tre – *Populus tremula* L., Prim ver – *Primula veris* L., Prun spi – *Prunus spinosa* L., Quer rob – *Quercus robur* L., Quer pet – *Quercus petraea* (MATT.) LIEBL., Rosa can – *Rosa canina* L., Rubu ida – *Rubus idaeus* L., Salv ver – *Salvia verticillata* L., Sang min – *Sanguisorba minor* SCOP., Sile nut – *Silene nutans* L., Sorb auc – *Sorbus aucuparia* L. em. HEDL., Tara spe – *Taraxacum* sect. *Ruderalia*, Thym gla – *Thymus glabrescens* WILLD., Thym kos – *Thymus kostelekyanus* OPIZ (= *Th. pannonicus* ALL.), Thym mar – *Thymus marschallianus* WILLD., Thym pul – *Thymus pulegioides* L., Vinc hir – *Vincetoxicum hirundinaria* MEDIK. Viol rei – *Viola reichenbachiana* JORD. ex BOREAU

tidimensional space we can see that after four years (in this analysis, years were treated as categorical variables, Fig. 3.), there are still great differences in species composition between managed and unmanaged and also between the mown and clear-cut plots. Moreover there are discrepancies in species composition between plots on soils of different thickness. (Fig. 3). The occurrence of *Festuca rupicola*, *Carex pediformis*, *Salvia verticillata*, *Thymus kosteleckyanus*, *Th. marschallianus* and *Th. glabrescens* was confined to well-preserved xerothermic grasslands on shallow soil (Fig. 3). Other species of the *Festuco-Brometea*, such as *Libanotis pyrenaica*, *Origanum vulgare* and *Coronilla varia* occurred in both unmanaged and mown plots. The expansive grass species *Brachypodium pinnatum* dominated on thick soil, especially during the first three years in mown plots and in the last two years on clear-cut plots. Additionally, on mown plots, the cover of nitrophilous species: *Rubus idaeus*, *R. plicatus* and *Cirsium arvense* has decreased. After clearing of shrubs, the number and cover of species increased rapidly, mainly as a result of the expansion by species of *Rhamno-Prunetea*: *Prunus spinosa*, *Crataegus monogyna* and *Quercus-Fagetea* classes, despite the removal of suckers (Fig. 3). Among the thermophilous species apart from *Brachypodium pinnatum*, only *Hypericum perforatum* and *Origanum vulgare* the higher abundance and the other *Festuco-Brometea* species occurred sporadically.

Discussion

In this study, a strong difference in both species composition and dynamics of species between species-rich, unmanaged and restored xerothermic grasslands has been found. Similar results were obtained by DZWONKO & LOSTER (1998) and KIEFER & POSCHLOD (1996). In xerothermic grassland without management, during the whole study period there were no statistically significant changes in floristic composition (Tab. 1). Small changes of mean number of species in calcareous grasslands were frequently observed (SYKES et al., 1994; ROSEN, 1995; RUSCH & VAN DER MAAREL, 1992). As a possible cause, strong influence of climatic conditions such as temperature or precipitation during early spring period was reported (HUBER, 1994; KAMMER, 2002).

In the calcareous grassland without management, the value of DN_c dynamics coefficient, calculated as difference between the mean number of species in 1997 and the mean cumulative number of species at the end of this study ($DN_c = 7.6$,

Fig. 2) was similar to those obtained for 0.25 m² and 2.5 m² plots in the unmanaged calcareous grasslands of the Öland K (Sweden) and was similar or lower as compared to annually mown plots in Limburg (The Netherlands) (SYKES et al. 1994).

The lower rate of species dynamics of the unmanaged grassland as compared to the managed ones may also be associated with characteristics of the species forming these communities. These are principally perennial species often termed "core species" (HANSKI, 1982; RUSCH & VAN DER MAAREL, 1992), of tussock form, slow rate of growth, and vegetative manner of reproduction. The studies in Ukrainian steppe communities (VORONTZOVA & ZAUGOLNOVA, 1985), the individual specimens of *Festuca rupicola*, a species which, like in the Ojców National Park, is the main floristic component of these species-rich grasslands, reached the age of 30–80 years and showed a very slow growth pattern. Another long-term experiments in grasslands dominated by *Festuca vallesiaca*, *F. rupicola* and *Carex humilis* in Bohemian Karst (HROUDOVA & PRACH, 1994) and in calcareous grasslands dominated by *Festuca rupicola* in "Skolczanka" nature reserve in Southern Poland (DZWONKO & LOSTER, 1998), confirmed the high stability of the floristic composition of this community, arising from the attributes of the dominant species. Moreover, the unmanaged grasslands under study were characterized by low proportion of highly expansive species, *inter alia*, of *Brachypodium pinnatum*.

The proportion of saplings, however, increased somewhat in the last two years of the study indicating that in the absence of any additional management practices these patches will turn into xerothermic shrubland.

The extent of alterations in the species richness and the floristic composition on the plots under various management practices applied depended strongly on the soil thickness. The yearly mowing of xerothermic grasslands, on shallow soil (S1), increased significantly the species richness and those on the deeper (S2, S3) allowed their initial rich composition to survive. This is principally because the percentage cover of *Brachypodium pinnatum* was controlled. The fast expansion of this species, linked with excessive fertilisation of grasslands with nitrogen compounds from air is regarded as one of the principal causes of the reduction of the richness of the calcareous grasslands (WILLEMS, 1983; WILLEMS et al. 1993). In my experiment, on the mown plots a slight decline of species richness with increasing the soil thickness was observed. However, the species

accumulation was similar in all mown plots.

In more advanced succession stages of grasslands on deep soil, restoring the species composition typical for well-preserved grasslands was impossible. The same conclusions were shared by DZWONKO & LOSTER (1998) and KIEFER & POSCHLOD (1996). Although the significant increase in the total richness was obtained, especially in the second and third years of the experiment, the species composition on the plot after removing shrubs was remarkably different from of the typical composition of xerothermic grasslands. In the last year of study, the rate of species accumulation lowered and it decreased dramatically in the clear-cut plots on thick soil. Similar results were noted in the "Skolczanka" reserve in southern Poland (DZWONKO & LOSTER, 1998) and in other studies (BAŁA, 2003; ROSÉN, 1982; KIEFER & POSCHLOD, 1996; STAMPFLI & ZEITER, 1999).

Although on the clear-cut plots the increase in number of species from the *Festuco-Brometea* and *Trifolio-Geranietea* classes was noted, this increase was somewhat lower as compared to other plots. Only several species of this group, namely *Hypericum perforatum* and *Euphorbia cyparissias* colonised the exposed patches of soil. They are often recorded in years immediately following the removal of trees and shrubs (KIEFER & POSCHLOD, 1996; DAVIES & WAITE, 1998; DZWONKO & LOSTER, 1998). This is because these species, as only a few of xerothermic grassland-associated plants, form persistent soil seed bank (Type IV – THOMPSON & GRIME, 1979) or appear as a principal component of a "seed rain" (HILLER, 1990, and references given there).

The high density of tree and shrub species, mainly off-shot type, which appeared on clear-cut plots, caused major overshadowing effect on the herb layer which practically prevented other heliophilous xerothermic species, typical for well-preserved grasslands, from penetrating and remaining there.

It seems that the restoration of species-rich xerothermic grassland is a long-term and high-cost process, depending on many factors such as: initial floristic composition of plot (PÄRTEL et al., 1998), local species-pool richness (ZOBEL et al., 1998), propagule availability, historical process (ROSÉN, 1982; BAKKER, 1989) and type of management practices. In order to protect the rich xerothermic flora, it seems essential to preserve the existing patches of grasslands and their early secondary succession stages by active protection practices: mowing with biomass removal and cutting the shrubs.

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