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Management effects on a mountain meadow plant community

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Abstract

The response of an oligotrophic mountain meadow plant community to mowing and mulching was studied in a manipulative experiment for four years (1997–2000) in the Bohemian Forest, Czech Republic. We established the changes of diversity and equitability of grassland vegetation as well as seasonal and year-to-year patterns of its species composition. Our results indicate that mowing and mulching have positive effect on the species diversity in comparison with no management; the main reason is increased equitability and suppression of dominant graminoids in the managed plots. Seasonal variation does not indicate considerable differences in the constituent species' response to management type. The four-year experiment seems to have been too short to enable unambiguous conclusions to be made on the advantages or disadvantages of mulching in comparison with the other management techniques tested, and with leaving the meadow fallow, with no management at all.

Key words: mulching, mowing, species richness, mountain meadow, redundancy analysis

Introduction

Mulching is applied as an alternative method of management to mountain meadows in the Bohemian Forest. At present, the demand for hay has declined and both mowing and grazing have lost their economic importance. Mulching seems to be the economically and technically least demanding type of grassland management, as compared with mowing and grazing. The effects of mowing or grazing on the meadow plant community are well known (e.g. Bakker 1989). Little is known, however, about the effect of mulching (also studied, e.g. in the Giant Mts., see Lexa & Krahulec 2000), and the effects of this treatment on plant species diversity and species composition of meadow communities remain unclear. While mowing without fertilisation may lead to gradual nutrient loss, mulching enhances mineral nutrient turnover through the decomposition of mulched plant litter (Kvítek & al. 1998). Meadows are suitable ecosystems for ecological studies – their "reaction-time" is usually relatively short and the methodological approach rather simple (Krahulec 1995). But mountain meadows react to different treatments more slowly than lowland meadows. Yet, detailed exploration of community processes in mountain meadows is needed before decisions making on their effective conservation.

This study reports on a four-year investigation of vegetation changes in a mown, mulched and unmanaged mountain meadow community in the Zhůří grassland enclave in central Bohemian Forest. The main questions to solve were:

(i) What was the effect of different management types (mowing, mulching and no treatment) on the plant species diversity and community equitability?

(ii) How did the species composition of differently managed communities change during the growing season and in the four-year perspective?

Methods

Study site

The study site was a species-rich mountain meadow, situated about 3 km north of Horská Kvilda, Šumava National Park, Czech Republic (49°05´ N, 13°33´ E, about 1150 m a.s.l.). The vegetation can be classified as the *Cardaminopsio halleri-Agrostietum* Moravec 1965 (alliance *Polygono-Trisetion*) dominated by *Deschampsia cespitosa, Festuca rubra, Avenella flexuosa, Agrostis capillaris* and *Hypericum maculatum,* with diagnostic species *Cardaminopsis halleri, Silene dioica* and *Veronica chamaedrys.* List of all species recorded in the studied part of the meadow, with their average abundances expressed in terms of cover percentages, is presented in Table 4. For detailed description and history of the experimental site, see Mašková & al. (2001).

Experimental design

A rectangular plot of 9×12 m was divided into three sub-blocks of 3×12m for each treatment – mowing, mulching and unmanaged control. Fifteen permanent plots of 1×1m each were established, five in each sub-block. The permanent plots were sampled during each growing season in 1997–2000. For examining the seasonal vegetational dynamics, sampling was done six to nine times each year (nine times in 1997–1999, and only six times in 2000). Each plot was divided into 9 sub-plots, using a wire square grid of nine cells of 0.33×0.33 m. The combined abundance and cover of each vascular plant species was estimated in each sub-plot, using the Braun-Blanquette seven-degree scale. The cover of *Festuca rubra* and *Avenella flexuosa*, both narrow-leaved tufted grasses, was estimated as that of a single species, because of difficult visual recognition of either species in the plant cover. Initial sampling was conducted in spring 1997, prior to the first experimental manipulation, in order to acquire baseline data for each plot. The treatments were applied in July in all four years, after sampling the plots.

Data analysis

Processed data are in the form of repeated-measurements – each plot was sampled six to nine times for 4 successive years. Only data from the July before-treatment samplings were taken into account to detect between-year trends in vegetation changes. Three univariate characteristics describing species diversity of the plots were used: Shannon-Wiener (SW) index (Pielou 1975), number of species per 1 m^2 plot, and equitability (Pielou 1966). These characteristics were tested by analysis of variance with repeated-measurements in the STATISTICA 5.5 package (Anonymus 1996). To achieve normal distribution, the number of species per 1 m^2 plot (*NS*) was transformed using the formula $log_{10}(NS+1)$.

Effects of treatments on the species composition were evaluated by the methods of multivariate analysis, included in CANOCO for Windows package (ter Braak & Šmilauer 1998). These methods are a useful tool for analysing the relationships between large sets of species data and environmental variables (management type in our case). Beta-diversity acquired by Detrended Correspondence Analysis (DCA) was less than 2 S.D. – in this case the use of methods with linear species response is recommended; for direct gradient analysis it is Redundancy analysis (RDA, TER BRAAK 1987). Interactions between treatments and time (Mown*Year, Mulched*Year and Unmanaged*Year) were explanatory variables of main interest, because they correspond with the effect of particular treatments in time. Positions of each plot in the experimental block (coded as many dummy variables) were used as co-variables, and so were also the years of observation (0, 1, 2, 3 for the years 1997–2000, respectively). Two analyses, non-standardised and standardised by sample norm RDA, were calculated. While non-standardised RDA takes into account both absolute values of species abundance and proportions between species, after standardisation only species proportions are evaluated. The significance of this model was tested by Monte-Carlo permutation test with 1999 permutations; the permutation scheme was modified for repeated-measurements design, as described by TER BRAAK & ŠMILAUER (1998). The resulting ordination diagram was plotted by CanoDraw (ŠMILAUER 1992) and modified by CanoPost (TER BRAAK & ŠMILAUER 1998).

Nomenclature

Scientific vascular plant names follow DOSTÁL (1989), except for *Silene dioica* (L.) Clairv, *Trifolium repens* L. and *Viola saxatilis* ssp. *polychroma* (Kerner) Kirschner et Skalický.

RESULTS

Species richness

Results of repeated-measurements ANOVA are summarised in Table 1. All three univariate variables were used, although one of them is redundant: Shannon-Wiener index of diversity links together both main components of species diversity – species richness and equitability (PIELOU 1975). For SW index, the interaction of treatment and time has a significant effect ($p<0.05$), and so has time itself ($p<0.01$). Both mowing and mulching had a positive effect on the development of diversity index in time, while this index shows a small decrease in unmanaged plots (Fig. 1). The number of species increases with time in all three treatments, but different species occur in particular ones: *Ranunculus repens, Trifolium repens* and *Sorb-*

Table 1. – Results of repeated-measurements ANOVA of Shannon-Wiener indices, number of species (per 1m² plot) and equitability. The **significant** effects are printed in **bold** types ($p<0.05$). Effect degrees of freedom (df) and mean squares (MS) = between group df and MS values, respectively; Error df and MS, respectively = within group df and MS values, respectively; F = ratio statistics; P = corresponding probability value.

	Effect		Error			
	df	MS	df	MS	*F*	*P*
SW index Treatment	2	0.1491	12	0.1657	0.8997	0.4324
Year	**3**	**0.2460**	**36**	**0.0364**	**6.7594**	**0.0010**
Treat.*Year	**6**	**0.1143**	**36**	**0.0364**	**3.1407**	**0.0140**
No of species Treatment	2	1.9500	12	19.5833	0.0996	0.9060
Year	**3**	**18.5333**	**36**	**2.0500**	**9.0407**	**0.0001**
Treat.*Year	6	0.6833	36	2.0500	0.3333	0.9148
Equitability Treatment	2	191.4964	12	92.5683	2.0687	0.1690
Year	3	66.4348	36	29.5454	2.2485	0.0993
Treat.*Year	**6**	**87.6083**	**36**	**29.5454**	**2.9652**	**0.0186**

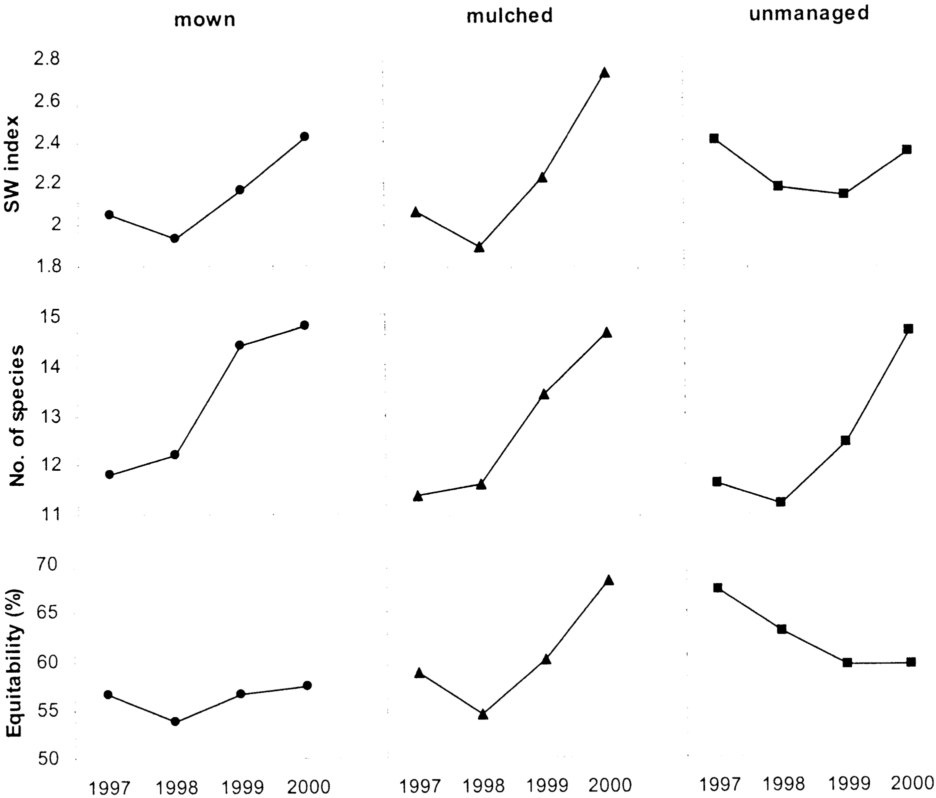

Fig. 1. – Trends of Shannon-Wiener index of diversity (top), species richness (number of species per 1m², middle) and equitability (bottom) during 1997–2000; comparison between treatments.

us aucuparia appeared in the mown plots, *Potentilla erecta, Alchemilla* sp., *Trifolium repens, Cirsium heterophyllum* and *Pilosella aurantiaca* did in mulched ones, and *Potentilla erecta, Ranunculus acris, Viola polychroma, Rhinanthus minor* and *Cerastium holosteum* occurred in unmanaged plots. Only one species disappeared from the investigated plots during the four experimental seasons, namely *Viola polychroma* from the mulched plots. Equitability increases in the mulched and decreases in the unmanaged plots. Time has significant effect on the number of species ($p<0.01$), but not on equitability, where the only significant factor is the interaction between treatment and time ($p<0.05$).

Species composition

Results of both non-standardised and standardised RDA are presented in Table 2; for the ordination diagram of non-standardised RDA see Fig. 2. Ordination diagram is a graphic representation of interactions between species and environmental variables (treatments). In the direction of the arrow, both the abundance of the given species and the value of the respective environmental variable increase; the arrow length is proportional to the size of the change. Congruent (or opposing) orientation of a species' arrow and of the arrow of a certain environmental variable indicates their positive (or negative) correlation, whereas perpendicular

Table 2. – Results of both non-standardised (Non-stand.) and standardised (Stand.) RDA analyses of species composition. The **significant** effects are printed in **bold** types (p<0.01). % ax. 1 (2) = species variability explained by the first or the second axis, respectively; r ax. 1 (2) = species-environment correlation on the first or the second axis, respectively; results of Monte-Carlo permutation test of significance of all canonical axes (1999 permutations, repeated measurements design): *F* = F-ratio statistics, *P* = corresponding probability value.

Analysis	% ax. 1	r ax. 1	% ax. 2	r ax. 2	*F*	*P*
Non-stand.	0.020	0.613	0.013	0.450	2.520	**0.005**
Stand.	0.012	0.462	0.010	0.457	1.762	0.144

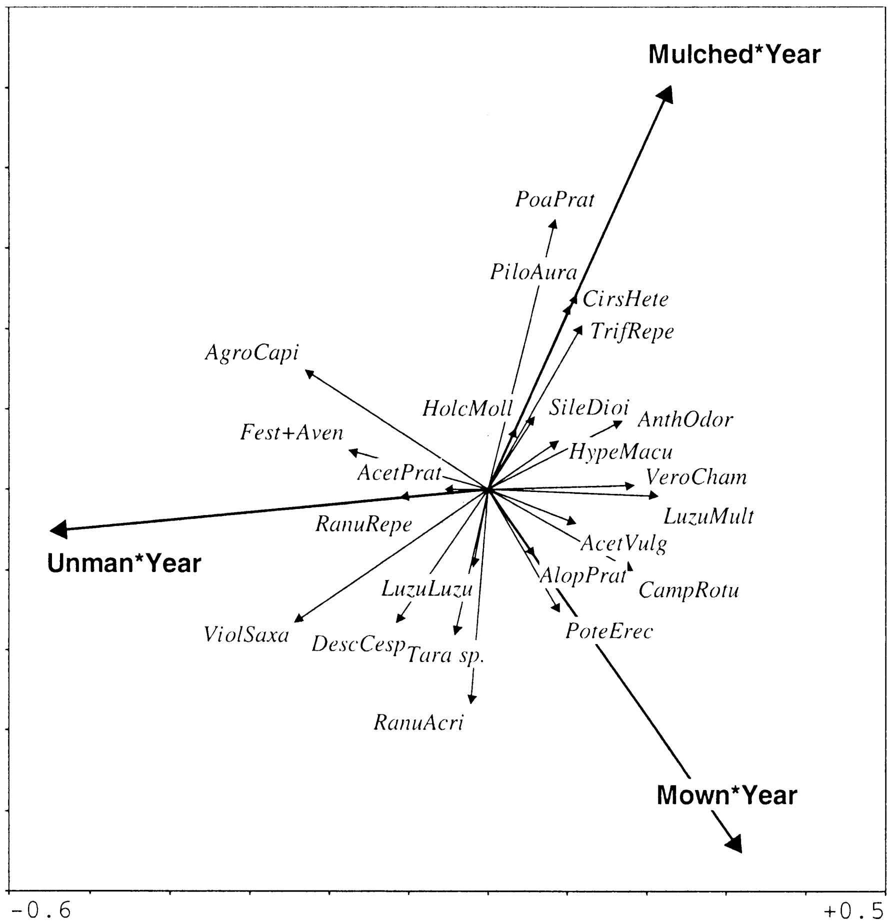

Fig. 2. – RDA ordination diagram (non-standardized data); Monte-Carlo permutation test of significance of all canonical axes: F=2.520, p=0.0045. Species abbreviations: ***AcetVulg*** *Acetosella vulgaris*, ***AcetPrat*** *Acetosa pratensis*, ***AgroCapi*** *Agrostis capillaris*, ***AlopPrat*** *Alopecurus pratensis*, ***AnthOdor*** *Anthoxanthum odoratum*, ***CampRotu*** *Campanula rotundifolia*, ***CirsHete*** *Cirsium heterophyllum*, ***DescCesp*** *Deschampsia cespitosa*, ***Fest+Aven*** *Festuca rubra + Avenella flexuosa*, ***HolcMoll*** *Holcus mollis*, ***HypeMacu*** *Hypericum maculatum*, ***LuzuLuzu*** *Luzula luzuloides*, ***LuzuMult*** *Luzula multiflora*, ***PiloAura*** *Pilosella aurantiaca*, ***PoaPrat*** *Poa pratensis*, ***RanuAcri*** *Ranunculus acris*, ***RanuRepe*** *Ranunculus repens*, ***SileDioi*** *Silene dioica*, ***Tara sp.*** *Taraxacum sp.*, ***TrifRepe*** *Trifolium repens*, ***VeroCham*** *Veronica chamaedrys*, ***ViolSaxa*** *Viola saxatilis* ssp. *polychroma*.

Table 3. – Means and standard deviations (S.D.) of cover for species visualized in Fig. 3. Standard deviation for each species is calculated for all three treatments together, means are for each treatment separately.

species	mean			S.D.
	mown	**mulch.**	**unman.**	
Deschampsia cespitosa	30.70	28.56	25.12	15.29
Festuca + Avenella	35.07	36.26	34.00	13.58
Agrostis capillaris	6.49	12.46	19.23	12.35
Luzula luzuloides	3.51	1.13	7.79	8.99
Hypericum maculatum	18.38	24.54	17.06	15.83
Silene dioica	1.13	5.70	2.16	3.91

orientation means no effect of the given environmental variable on that species. It is evident from the diagram, e.g., that *Poa pratensis, Pilosella aurantiaca, Cirsium heterophyllum* and *Trifolium repens* were most promoted by mulching, whereas *Luzula luzuloides, Deschampsia cespitosa* and *Ranunculus acris* were most suppressed. The diagram shows relative trends between treatments; for example, *Cirsium heterophyllum* is not promoted exclusively, but mostly, in the mulched plot. The result of Monte-Carlo permutation test was significant only for non-standardised RDA; this seems to indicate that either an increase or a decrease in absolute species abundance, rather than changes in species proportions, cause between-year changes. The variability explained by the model is rather small – 3.3% for non-standardised and 2.3% for standardised analysis; spatial-temporal heterogeneity of the vegetation and variability of climatic and other environmental factors seem to play a dominant role while the effect of management type is rather marginal.

The course of abundance of selected dominant species is shown in Fig. 3. Of interest are not absolute differences in between-year abundance, but differences in relative trends. Standardised values of abundance were therefore used (for means and standard deviations see Table 3). The course of species abundance is influenced by between-year fluctuations; in some cases, however, general trends are obvious, e.g, the abundance of *Deschampsia cespitosa* increased in the mown plots and decreased in mulched ones, that of *Luzula luzuloides* increased in the mown and unmanaged plots, while mulching had only negligible effect.

Seasonal dynamics

Seasonal development of six selected dominant species is shown in Fig. 4, where only data from the first and the last year of observation were taken into account. Great difference was found between the seasonal development of *Silene dioica* in 1997 and 2000: its cover and abundance rapidly increased after the application of a treatment (mainly in the mulched plots) in 1997, while treatment had negative effect on its seasonal development in 2000 (note the significant decrease in overall abundance of *S. dioica* subjected to all three treatments in 2000). Nevertheless, between-year comparisons of seasonal trends did not bring any significant results.

Discussion

The most interesting question of this study was the effect of mulching and mowing on the species richness and diversity in the mountain meadow vegetation. Our results confirm the hypothesis, that the treatments applied (mowing and mulching) increase the species diversity of the mountain meadow vegetation, in comparison with unmanaged plots. As it is evident

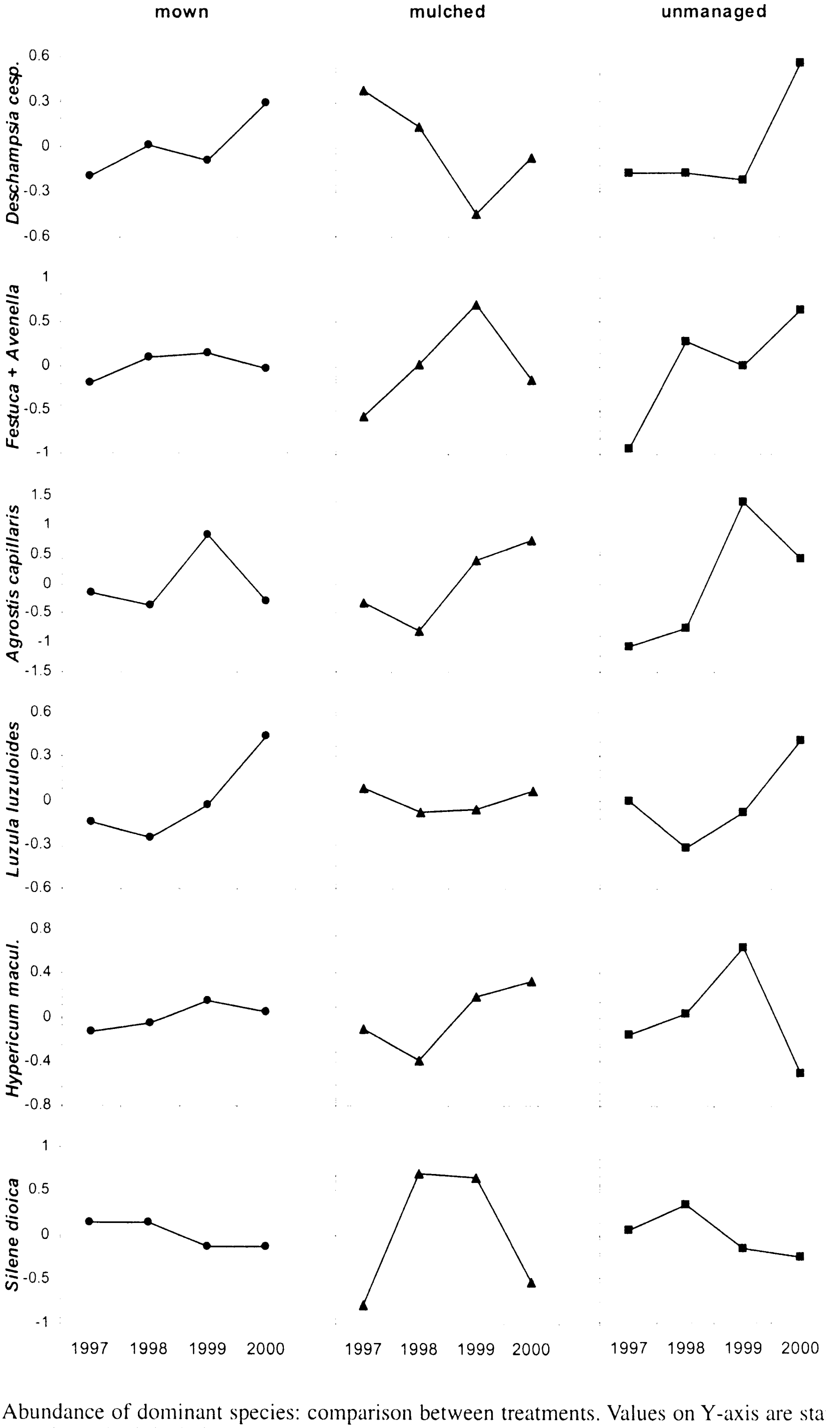

Fig. 3. – Abundance of dominant species: comparison between treatments. Values on Y-axis are standardised (for means and standard deviations see Table 3), the unit is standard deviation.

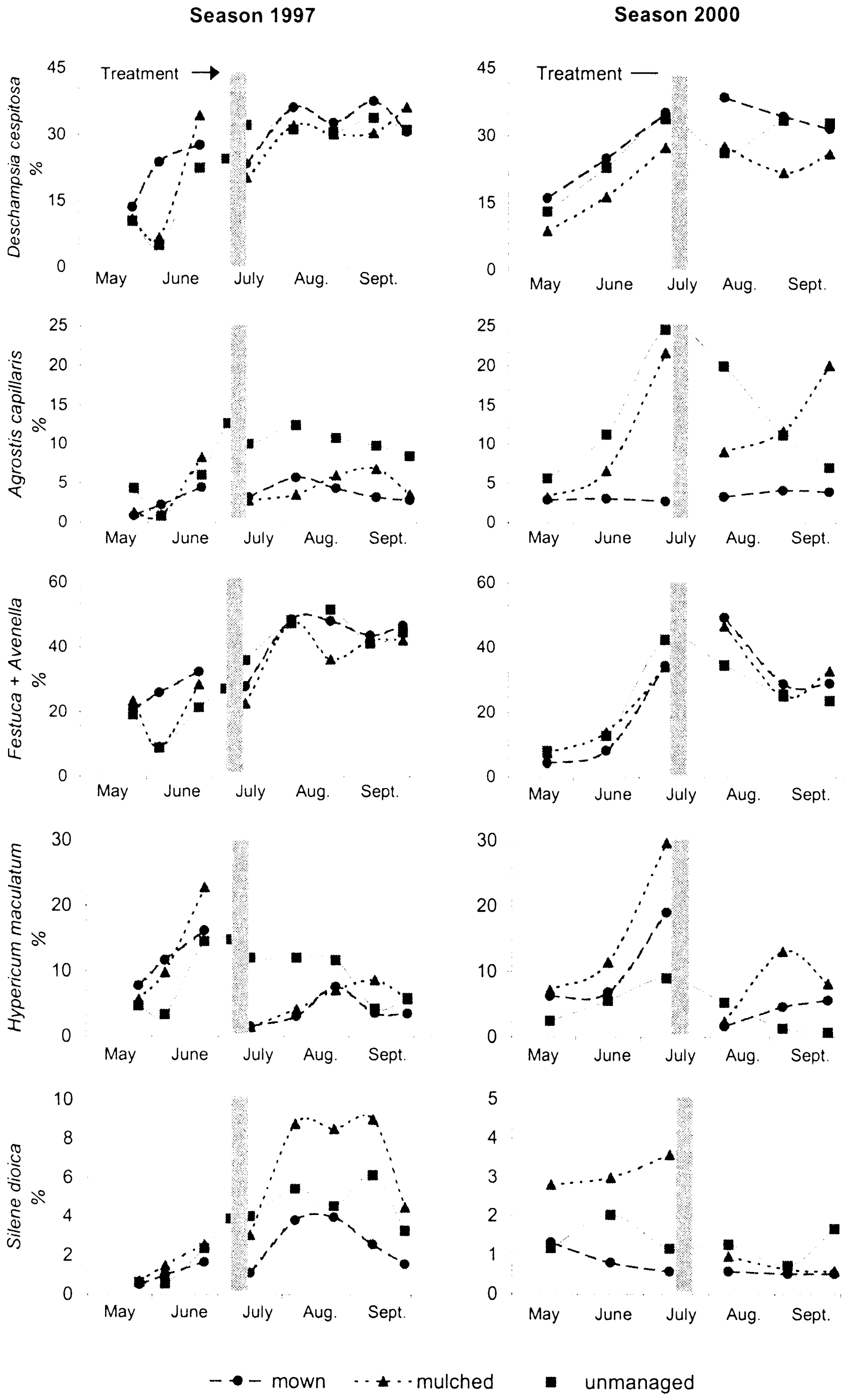

Fig. 4. – Changes in species cover during the growing season, comparison between treatments; the first (1997) and the last (2000) season are visualised. Grey blocks separate before-treatments and after-treatments data. Values on Y-axis are percentage cover; note different Y-axis range in graphs for *Silene dioica*.

Table 4. – List of species recorded in the experimental mountain meadow site at Zhůří – Huťská hora and their approximated abundance in the sample plots; r = cover less than 0.01%.

Species	Cover %	*Species*	Cover %
Acer pseudoplatanus (juv.)	r	*Luzula luzuloides*	4.15
Acetosa pratensis	0.26	*Luzula multiflora*	0.21
Acetosella vulgaris	0.88	*Phleum pratense*	r
Agrostis capillaris	12.73	*Pilosella aurantiaca*	0.06
Achillea millefolium s.l.	0.09	*Poa pratensis*	0.85
Alchemilla sp.	r	*Potentilla erecta*	0.16
Alopecurus pratensis	r	*Ranunculus acris*	0.03
Anthoxanthum odoratum	1.04	*Ranunculus repens*	r
Campanula rotundifolia	0.38	*Rhinanthus minor*	r
Cardaminopsis halleri	1.26	*Silene dioica*	3.00
Carex pilulifera	r	*Sorbus aucuparia* (juv.)	r
Cerastium holosteoides	r	*Stellaria graminea*	0.06
Cirsium heterophyllum	0.03	*Taraxacum* sp.	0.08
Deschampsia cespitosa	28.13	*Trifolium medium*	r
Festuca rubra + *Avenella flexuosa*	35.11	*Trifolium repens*	0.7
		Veronica chamaedrys	0.77
Galium sp.	r	*Veronica serpyllifolia*	r
Holcus mollis	r	*Viola saxatilis* ssp. *polychroma*	0.01
Hypericum maculatum	20.00		
Lilium bulbiferum	r		

from Fig. 1, differences in diversity trends between managed and unmanaged plots are not caused by an increase in species number (all three treatments resulted in an increase in the number of species with time), but by the differences in equitability. In the unmanaged plots, the equitability shows a strong decrease, while it increases in the managed plots (slightly in the mown plots, more in the mulched ones). So, the main effect of the treatments on plant species diversity seems to be the suppression of dominant species. This trend is evident also from the ordination diagram in Fig. 2 – negative effect of mowing on *Agrostis capillaris* and merged *Festuca rubra* + *Avenella flexuosa* (no effect on *Deschampsia cespitosa*), as well as of mulching on *Deschampsia cespitosa* (no effect on *Agrostis* and *Festuca+Avenella*). In general, two groups of species could be distinguished in the diagram: (i) species in the right part of the diagram, promoted by mowing or mulching and suppressed in unmanaged plots, (ii) species in the left part, suppressed by mowing or mulching and enhanced in unmanaged plots. All grass dominants (*Deschampsia, Agrostis, Festuca* and *Avenella*) are in the second group, while most of the dicotyledonous plants are in the first one (*Hypericum maculatum, Silene dioica, Campanula rotundifolia,* etc.). The disturbance caused by the treatments is indicated by, e.g., *Trifolium repens*, which was absent in the first year of observation, and appeared in the mown and mulched plots (mainly in mulched ones) during the experiment; or *Pilosella aurantiaca,* which occurred in the third and fourth year, namely in mulched plots. On the other hand, *Deschampsia cespitosa* seems to be suppressed by mulching, while being promoted in unmanaged and mown plots – the possible explanation could be rotting away of new tillers below wet mulch, due to their increased sensitivity to oxygen deficiency during their growth (D. Blažková, pers. comm.).

The main difference between mowing after which the vegetation is removed, and mulching, is the dispersion of the cut and chopped plant material on the soil surface as a result of mulching. This fresh litter is bound to have several both direct and indirect effects on the soil and vegetation properties. These effects comprise the reduction of the temperature amplitude in the soil, reduction of soil evaporation, retention of rainfall, and formation of a physical barrier to seedling recruitment. Important is also the impact of an irregular and patchy accumulation of the mulched plant material ("mulch") and litter on the community pattern (Faceli & Picket 1991). Mulch and litter also play an important role in mineral nutrient turnover.

The sampled data allow us to observe not only between-year changes, but also the seasonal development of the plant cover, depending on the type of treatment (Fig. 4). Keeping in mind that percentage cover (projective dominance), not biomass, of the constituent species was estimated, it is clear that the species differ in their reactions to the experimental treatments simulating different types of meadow management. But one cannot make any general conclusions because the observed trends were evidently strongly influenced by during-season and year-to-year fluctuations of the weather and other factors, and the interpretation of these effects is unclear. For further investigation of the seasonal vegetation dynamics, another manipulative experiment will be necessary; our study represents only the first approach, allowing only an approximate assessment of the real pattern.

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