Effect of different mulching and cutting regimes on the vegetation of upland meadow

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ABSTRACT

The effect of different cutting and mulching regimes on the structure of the sward and plant species diversity of semi-natural meadow (*Arrhenatherion* alliance) was investigated in manipulative experiment over five years. Mulching once a year in September (MS) and plots without management (U) developed in the same way and resulted in increase of *Veronica chamaedrys* and *Galium album* and disappearance of light sensitive *Trifolium repens*. *T. repens* increased in two cut, two cut without removal of the biomass and in three times mulched treatments. The lowest species diversity was recorded under MS and U treatments on the end of the experiment. Mulching once a year in July altered the vegetation in a different way than the MS treatment. Our results indicate high importance of term of mulching and frequency of defoliation management on the development of grassland vegetation.

Keywords: *Arrhenatherion*; botanical composition; defoliation frequency; permanent grassland; management

In 1990s the significance of semi-natural grasslands for fodder production decreased by reason of rapid reduction of cattle and sheep herds and enlarged area of grasslands in the Czech Republic. For example the number of cattle and sheep diminished from 3 360 000 and 430 000 in 1990 to 1 466 000 and 97 000 in 2002. Left to run wild abandoned species rich grasslands may change into species poor degradation phases of tall herbs or grasses able to cope effectively with the light and nutrients (Pecháčková and Krahulec 1995, Laser 2002). In many cases, unmanaged extensive meadows and pastures were invaded by shrubs as well as trees and altered into woodlands by natural way. On account of increased seeds production, an absence of defoliation management of the landscape can contribute to spread of alien or weedy species. The effect of mowing or grazing to the plant species composition was frequently documented in Czech conditions (Krahulec et al. 2001, Hejcman et al. 2002, Pavlů et al. 2003), but little is known about the consequence of mulching to the development of plant communities.

Kvítek et al. (1998) studied an effect of different defoliations regimes on the plant species composition of intensive managed meadow. In this experiment, the steep enhance of *Dactylis glomerata* was probably reaction to nutrient release from fragmented litter. In the Czech Republic, the first experiment with mulching carried out on the species rich semi-natural grasslands (*Polygono-Trisetion* and *Nardo-Agrostion* alliances) was established in the Giant Mountains (Krkonoše in Czech) (Lexa and Krahulec 2000). Results of the study indicate that mulching do not caused predomination of tall species instead of a treatment without management. In 22 years Laser's (2002) study (*Arrhenatherion* aliance) performed in central Germany was shown the significant decrease of absolute species number under mulching and treatment without management in comparison with two cuts management. Zelený et al. (2001) studied the effect of mulching on the species diversity of montane grassland (*Polygono-Trisetion* alliance) in the Šumava Mountains in Czech. Results of the study showed that mowing and mulching have positive effects on the species diversity in comparison with no management by reason of suppression of dominant graminoids by defoliation.

The question which arises with performance of mulching and has not been solved yet is an effect of its frequency and its term in a vegetation season on the structure of the sward. Practical experiences from the Krkonoše National Park (Štursa pers. com.) indicate low importance of mulching on the restriction of dominants if it performed only once a year in late summer or in autumn.

In our experiment, we investigate the effect of different management regimes on the plant species

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Table 1. Investigated treatments

Abbreviations	Applied treatments
2C	two cuts per a year with removal of a biomass performed in June and August
U	unmanaged control treatment
2CR	two cuts per a year without biomass removal performed in June and August
1MJ	mulching once per a year in July
1MS	mulching once per a year in September
3M	mulching three times per a year in May, July and in September

composition of semi-natural grassland. The aim of our study was to compare structure and plant species diversity of the sward under variety of mowed and mulched treatments which differ in frequency and term of management application.

MATERIAL AND METHODS

Study site. The experiment was carried out in the Jizerské hory Mountains (50°49'N, 15°02'E) 5 km north-west from the town Liberec, Czech Republic. The altitude of the site is 420 m with average annual temperature 7.2°C and annual precipitation 803 mm (Liberec meteorological station). The geological substratum is granite. Soil under experimental area is acid cambisol. The plant community of the study area was classified as *Arrhenatherion*. The dominant species before start of the experiment were *Festuca rubra*, *Alopecurus pratensis*, *Vicia sepium*, *Anthriscus sylvestris*, *Galium album* and *Veronica chamaedrys*. The grassland was left without management for ten years before start of the experiment. The mean forage yield of the meadow ranged from 2 to 3 t/ha of dry matter per a year. No fertilisers were applied on the locality.

Design of the experiment. The experiment was established in two complete randomised blocks in the spring 1997. An each plot was rectangle 10.0 × 3.7 m. Investigated treatments are described in the Table 1. We used unmanaged control, two cuts per a year with biomass removal, two cuts per a year without biomass removal, mulching once per a year in July and in September and mulching three times per a year.

Plant species composition. The cover of all present plant species rooting in the monitoring plot was visually estimated directly in percentages of occupied space of the plot. To remove an edge effect we estimated central 8.0 × 2.5 m rectangle of the each permanent plot. Collecting of relevés was performed annually in May before first application of the management regimes. To obtain the baseline data, the initial plant cover estimation was performed before experimental manipulation in 1997.

Functional groups. Based on description of vascular plants in the regional flora (Kubát et al. 2002), all plant species within the study area were a priori classified according to their main traits. We recognized categories of tall grasses, short grasses, prostrate herbs, annuals and other forbs. The presence of revealed species in the recognized categories is in the Table 2.

Species diversity. To evaluate the effect of investigated managements to species diversity of vascular plants, the number of species per a monitoring plot was counted and statistically analysed.

Data analyses. Redundancy analysis (RDA) in CANOCO program (ter Braak and Šmilauer 1998) was used to evaluate the multivariate vegetation data. Redundancy analysis is a direct gradient analysis method based on the assumption of a linear response and was used because the data set was relatively homogeneous. In all analyses we used centering by species and log transformation [$y' = \log 10\ (y + 1)$] of species data. Blocks were defined

Table 2. Functional groups of the study sward

Tall grasses	Short grasses	Prostrate herbs
Alopecurus pratensis	*Agrostis capillaris*	*Plantago lanceolata*
Dactylis glomerata	*Festuca rubra*	*Taraxacum* sp.
Elytrigia repens	*Poa pratensis*	*Trifolium repens*
Festuca pratensis		

by covariables. In direct gradient analysis, various combinations of environmental variables, covariables and their interactions can be used with an appropriate Monte Carlo permutation test to test a wide range of hypothesis (ter Braak and Šmilauer 1998). Our data is in the form of repeated measures; using the permutation scheme adjusted to the repeated measures design provided an opportunity to test particular effects in a way directly comparable to repeated measures ANOVA. We used split plot design and permutations were performed within the each block of plots. Whole plots were records of one permanent plot repeated in time and were permuted completely at random. Split plots were not permuted. The significant effect of time and treatment interaction indicates divergent temporal development of plots under different managements. The biplot ordination diagram, constructed by the CANODRAW program (ter Braak and Šmilauer 1998), was used to visualize the results of the analyses. Repeated measurements ANOVA was used to analyse univariate data (coverage of functional groups, species diversity). After obtaining of significant results of ANOVA analyse ones to want knows which treatments differs each other. Tukey *HSD* post hoc test (or multiple comparison test) was used to determine the significant differences between tested treatments.

For nomenclature see Kubát et al. (2002).

RESULTS

Plant species composition

We recorded the successional development of the vegetation. The effect of a year was significant and explained 13.6% of species data variability (see Table 3 for results of RDA analyses). The effect of all treatments together was significant and explained 35.4% of the data set variability. Results of these analyses were visualized in the form of ordination diagram (Figure 1). Direction of treatments arrows indicates their influence on the vegetation development. From the ordination diagram is visible similar effect of 1MS and U treatments

Table 3. Results of the repeated measures RDA analyses of cover estimates in 8 × 2.5 m plots

	Tested hypotheses	Explanatory variables	Covariables	% ax 1 (all)	*F*-ratio	*P*-value
A1	Is there a common successional trend in species composition?	Y	2C*Y, U*Y, 2CR*Y, 1MJ*Y, 1MS*Y, 3M*Y, PlotID	13.6	8.211	0.004
A2	Is there any effect of treatments on species composition?	2C*Y, U*Y, 2CR*Y, 1MJ*Y, 1MS*Y, 3M*Y	Y, PlotID	21.1 (35.4)	13.089 (4.668)	0.080 (0.024)
A3	Is there any effect of 2C treatment?	2C*Y	Y, U*Y, 2CR*Y, 1MJ*Y, 1MS*Y, 3M*Y, PlotID	4.2	2.133	0.054
A4	Is there any effect of U treatment?	U*Y	Y, 2CR*Y, 1MJ*Y, 1MS*Y, 3M*Y, PlotID	3.8	1.943	0.098
A5	Is there any effect of 2CR treatment?	2CR*Y	Y, U*Y, 1MJ*Y, 1MS*Y, 3M*Y, PlotID	3.6	1.815	0.066
A6	Is there any effect of 1MJ treatment?	1MJ*Y	Y, U*Y, 2CR*Y, 1MS*Y, 3M*Y, PlotID	6.0	3.152	0.041
A7	Is there any effect of 1MS treatment?	1MS*Y	Y, U*Y, 2CR*Y, 1MJ*Y, 3M*Y, PlotID	3.4	1.726	0.110
A8	Is there any effect of 3M treatment?	3M*Y	Y, U*Y, 2CR*Y, 1MJ*Y, 1MS*Y, PlotID	6.5	3.422	0.040

% ax 1 (all) = % species variability explained by axis 1 (all) – measure of the explanatory power of the explanatory variables; *F*-ratio = statistics for the test on the trace (all axes); *P*-value = corresponding probability value obtained by the Monte Carlo permutation test (499 permutations, i.e. Type I error probability in testing the hypothesis that the effect of one [all] explanatory variables is zero); *Y* = time (serial year number); PlotID = identifier of each plot; * = interaction
For abbreviations of treatments see Table 1

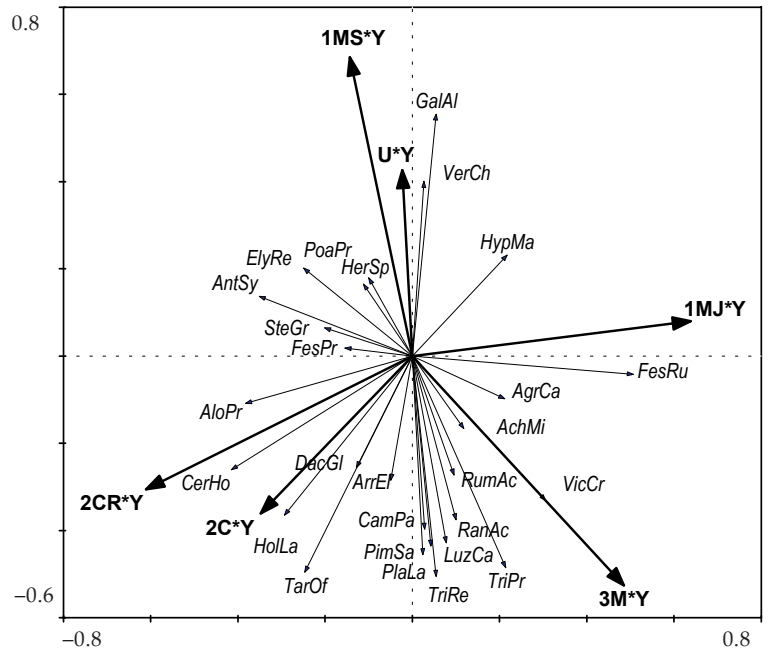

Figure 1. Ordination diagram showing the results of RDA analysis A2 in the Table 3

* indicates interaction of environmental variables

Y – year, 1MS, U, 2CR, 1MJ, 2C, 3M treatments see Table 1

AchMi – Achillea milefollium, AgrCa – Agrostis capillaris, AloPr – Alopecurus pratensis, AntSy – Anthriscus sylvestris, ArrEl – Arrhenatherum elatius, CamPa – Campanula patula, CerHo – Cerastium holosteoides, DacGl – Dactylis glomerata, ElyRe – Elytrigia repens, FesPr – Festuca pratensis, FesRu – Festuca rubra, GalAl – Galium album, HerSp – Heracleum sphondylium, HolLa – Holcus lanatus, HypMa – Hypericum maculatum, LuzCa – Luzula campestris, PimSa – Pimpinella saxifraga, PlaLa – Plantago lanceolata, PoaPr – Poa pratensis, RanAc – Ranunculus acris, RumAc – Rumex acetosa, SteGr – Stellaria graminea, TarOf – Taraxacum sp., *TriPr – Trifolium pratense, TriRe – T. repens, VerCh – Veronica chamaedrys, VicCr – Vicia cracca*

to successional changes of the vegetation. Species supported by these treatments were *Galium album*, *Veronica chamaedrys*, *Ranunculus repens*, *Hypericum maculatum*, *Heracleum sphondylium*, *Elytrigia repens* and *Anthriscus sylvestris*. The most diverse to two previous management regimes was 3M treatment. Different development of the vegetation is indicated by almost opposite direction of arrow for this management in the ordination diagram. *Agrostis capillaris*, *Achillea millefolium*, *Vicia cracca*, *Rumex acetosa*, *Ranunculus acris*, *Trifolium pratense*, *Luzula campestris*, *Trifolium repens*, *Plantago lanceolata*, *Pimpinella saxifraga* and *Campanula patula* were species the most promoted by three times mulching. Effects of 2C and 2CR treatments to the development of the meadow plant community were similar (Figure 1), although under 2C treatment the biomass was removed after cutting. *Trifolium repens*, *Plantago lanceolata*, *Pimpinella saxifraga*, *Campanula patula*, *Taraxacum* sp., *Holcus lanatus*, *Dactylis glomerata*, *Veronica serpyllifolia*, *Cerastium holosteoides* and *Alopecurus pratensis* were species thriving with two cuts managements. Species associated with 1MJ treatment was *Festuca rubra*. The once a year mulched plots differed according to the term of mulching performance. While mulching in July altered the vegetation in a different way in comparison with unmanaged plots, mulching in September had similar effect on the vegetation as the control without any management.

Number of species

We recorded significant effects of treatments to temporal development of species diversity data (Table 4). Significant differences were recorded between unmanaged control (U) and 2C, 2CR and 3M treatments (Table 5). The lower species diversity under U and 1MS treatments was remarkable at the end of the experiment where mean number of species per plot was 31.5, 24, 31, 30.5, 27 and 34 under 2C, U, 2CR, 1MJ, 1MS and 3M treatments, respectively. There was found the significant effect of a year, which indicates high year to year variability and temporal trend in species diversity data under all plots particularly independent of tested managements. We recorded in average 20.7 species

Table 4. Results of repeated measurements ANOVA analyses

Variable	Effect	*Df*	*F*-ratio	*P*-value
	treatment	5	4.40	0.065
Number of species	year	4	10.56	**0.021**
	year × treatment	20	2.61	**0.0188**
	treatment	5	6.41	**0.030**
Prostrate herbs	year	4	13.79	**0.013**
	year × treatment	20	7.93	**< 0.001**
	treatment	5	1.30	0.392
Tall grasses	year	4	1.89	0.276
	year × treatment	20	2.32	**0.033**
	treatment	5	0.58	0.715
Short grasses	year	4	7.14	**0.042**
	year × treatment	20	1.26	0.307

per plot before application of different management regimes in 1997. The mean number of species per plot without categorization according to treatments was 29.7 at the end of the experiment in 2001. This increase of species diversity is well visible from the Figure 2.

Functional groups

Prostrate herbs. The reaction of prostrate herbs to investigated treatments was the most conspicuous of all tested functional groups (Figure 3). We recorded significant effect of a year, treatment and also interaction year and treatment (Table 4). Multiple comparison of all treatments is shown in the Table 5. The cover of prostrate herbs in the baseline data was in the range from 0.5 to 2.25%, whereas at the end of the experiment, we recorded higher variability caused by application of the different treatments. Mean coverage of prostrate herbs was 25, 0.25, 5, 1.5, 0.75 and 25.25 under 2C, U, 2CR, 1MJ, 1MS and 3M treatments, respectively. The most remarkable reaction was an increase of *Trifolium repens* in frequently managed plots.

Tall grasses. We do not reveal significant effect of treatment and year to the coverage of tall grasses, but the interaction year and treatment was significant. This result indicates nonparallel and different temporal development of the tall grasses coverage under tested treatments. We recorded gradual decrease of the cover under all treatments with high year to year variability, with exception of 2CR treatment. The tall grasses coverage was in the range from 22.5 to 36.75% before start of the experiment. In 2001, the cover of tall grasses varied from 13.5 under 3M to 41% under 2CR treatment, respectively (see Figure 4).

Short grasses. The effect of a treatment and interaction year and treatment was not significant

Table 5. Results of Tukey *HSD* test

	2C 1	U 2	2CR 4	1MJ 7	1MS 8	3M 10
2C 1		N, P		P, T	P	
U 2			N, T			N, P
2CR 4				T	T	T
1MJ 7						P
1MS 8						P
3M 10						

Letters indicate significant differences between treatments for number of species (N), prostrate herbs (P) and tall grasses (T)

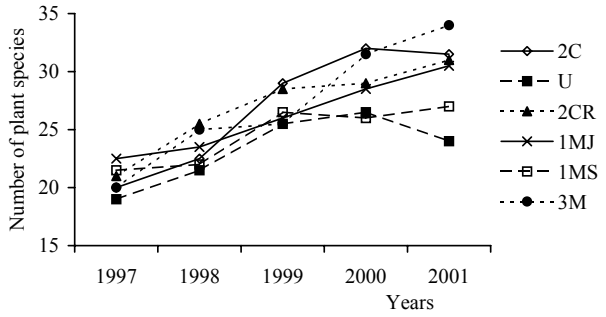

Figure 2. Number of plant species (1MS, U, 2CR, 1MJ, 2C, 3M treatments see Table1)

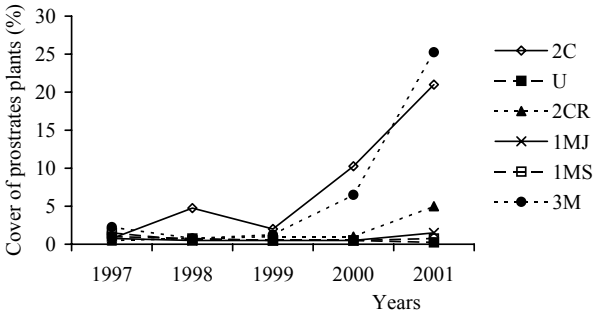

Figure 3. Cover of prostrate plants (1MS, U, 2CR, 1MJ, 2C, 3M treatments see Table 1)

on the cover of short grasses. Only year was the significant factor in the analyze indicating high year to year variability in the data. Mean coverage of short grasses was 3.6% in 1997. In 2001 at the end of the experiment it was 6.1% indicating moderate increase in the course of time (Figure 5).

DISCUSSION

Plant species composition and functional group

This study was carried out to investigate alternative grassland management aim at cultural landscape maintenance in Czech conditions of low fodder demand and decreased agricultural activities. Mulching seems to be probably the only possible way of grassland management without agricultural justification in the future. The effect of term and frequencies of grassland mulching on plant species diversity and spread of weed species are often discussed topics by the reason lack of long term experiences with this management in Czech Republic.

Obvious is dissimilar development of plots mulched once a year in July and in September. Mulching in September, similarly as plots without management, supported *Galium album* and *Veronica chamaedrys* which are tolerant to changed environmental conditions under abandoned sward. These plots were characterized by big amount of the undecomposed mulch remained on soil surface until the next vegetation season. *V. chamaedrys* is relatively shade tolerant and able to persist under dense canopy with litter accumulation (Pavlů et al. 2003).

The most of mulched or cut biomass in the other treatments was decomposed more quickly probably due to higher content of easily degradated compounds, as was visible during the run of the experiment. We recorded an increase of some light sensitive species (*Trifolium repens*, *Taraxacum* sp.) there. It is generally known that higher defoliation frequency increase competition ability of prostrate herbs in sward (Bakker 1989). Only the prostrate herbs were functional group with the obvious reaction to the different frequencies of defoliation. Similarly to Pavlů et al. (2003), it can be concluded that the frequency of defoliation management, instead of effect of left biomass, was decisive factor for the increase of prostrate herbs.

Both two cut regimes had similar effect to the course of succession of the plots with exception of tall grass *Alopecurus pratensis* which increased

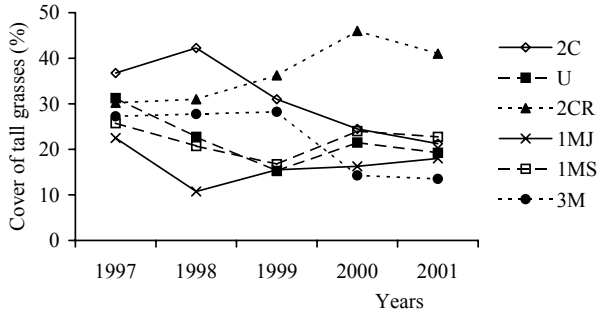

Figure 4. Cover of tall grasses (1MS, U, 2CR, 1MJ, 2C, 3M treatments see Table 1)

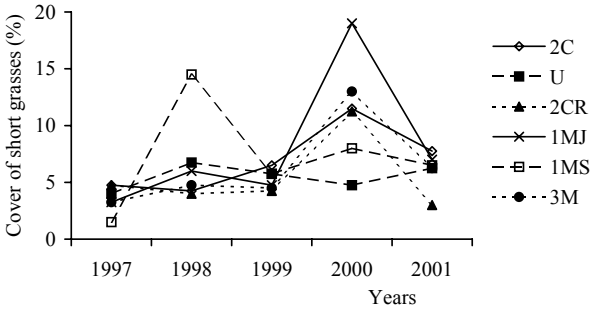

Figure 5. Cover of short grasses (1MS, U, 2CR, 1MJ, 2C, 3M treatments see Table 1)

in plots with biomass left in rows. Kvítek et al. (1998), for example, recorded increase of nitrophylous *Dactylis glomerata* in mulched treatments in his study. These species of rich soils were probably promoted as a reaction to increased nutrients released from the death biomass.

The term of mulching was revealed as a decisive factor for the effectiveness of grassland management to prevent plant community degradation. The mulching of grasslands in September was frequently performed in Czech Republic in 1990s. The main reason for low effective late mulching was setting of agricultural subsidization system and its control.

Number of species

We recorded significant effects of treatments to changes in the species diversity, the marked increase of species diversity was found in the multiply cut or mulching treatments. This finding corresponds to Ziliotto et al. (2002) study, that the frequent management increases the species number in the sward. On the other hand, the lowest number of species was found in unmanaged control and mulching once a year in September after four years of the experiment.

Similar results were published by Laser (2002) on *Arrhenatherion* or by Ryser et al. (1995) on *Bromion* aliance. The cessation of grassland defoliation management leads frequently to decrease of plant species diversity (see Bakker 1989 and references therein, Smith and Rushton 1994, Pecháčková and Krahulec 1995, Laser 2002).

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ABSTRAKT

Vliv různých režimů mulčování a kosení na vegetaci podhorské louky

Na polopřirozeném travním porostu svazu *Arrhenatherion* byl sledován vliv různých způsobů obhospodařování (kosení a mulčování) na strukturu porostu a jeho druhovou pestrost v průběhu pěti let. Porost se na variantě mulčované jednou ročně v září a na variantě bez obhospodařování vyvíjel podobně, přičemž se rozšiřovaly druhy *Veronica chamaedrys* a *Galium album*. Na variantách třikrát ročně mulčované, dvakrát kosené s hmotou odklízenou

i na variantě dvakrát ročně kosené s hmotou ponechávanou v řádcích bylo zaznamenáno zvyšování pokryvnosti *Trifolium repens*. Během pokusu byl nejmenší počet rostlinných druhů zjištěn na porostu bez obhospodařování a na porostu jednou ročně mulčovaném v září. Mulčování jednou ročně v červenci má na vývoj porostu odlišný vliv než mulčování na konci vegetace. Výsledky ukazují velký význam termínu a frekvence mulčování pro vývoj vegetace na travním porostu.

Klíčová slova: *Arrhenatherion*; botanické složení; frekvence defoliace; trvalý travní porost; management

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