Silva Gabreta	vol. 7	p. 87–96	Vimperk, 2001

The effects of mountain meadows management on soil fauna communities (on example of earthworms and oribatid mites)

Václav Pižl* & Josef Starý

Institute of Soil Biology, Academy of Sciences of the Czech Republic, Na Sádkách 7, CZ-370 05 České Budějovice, Czech Republic
**pizl@upb.cas.cz*

Abstract

The impact of different management on communities of earthworms and oribatid mites was studied in a mountain meadow at Huťská hora Mt. (Bohemian Forest, Czech Republic) in 1999–2000. Significant differences in earthworm populations were found between regularly mown plots and those where management shifted to mulching or to lying fallow. Compared with the mean worm biomass of 24 g.m^{-2} in moist mown plot, mulched plot had 10 g.m^{-2} and that lain fallow 6 g.m^{-2}. Earthworm species recorded were *Aporrectodea caliginosa*, *A. rosea*, *Dendrobaena octaedra*, *Lumbricus rubellus* and *Octolasion lacteum*. Species composition did not differ between plots; however, management shifting resulted in structural changes of earthworm communities. Average density of oribatid mites was significantly lower in mulched plot (31500 ind.m^{-2}) than in lain fallow (51400 ind.m^{-2}) and moist mown ones (58900 ind.m^{-2}) in 1999. Mulching and lying fallow resulted in changes of community structure of oribatid mites; dominance and population density of eudominant species *Tectocepheus sarekensis* decreased, while the same parameters of *Berniniella hauseri* and *Brachychthonius impressus* increased.

Key words: soil fauna, earthworms, oribatid mites, mountain meadows, mulching, mowing, lying fallow

INTRODUCTION

The problem of the management practices in mountain meadows is currently receiving a special attention of farmers, scientists and nature conservationists in the Czech Republic. Most meadows are unmown or mown only occasionally due to a small number of livestock feeding on the hay. At the same time, substantial amounts of air-born nitrogen enrich the ecosystem, while the oligotrophication of regularly mown meadows proceeds due to acid rains. Mulching represents one of the possible remediation practices; however, it could have unfavourable consequences on the composition of grassland vegetation and on other ecosystem structures and processes. Soil fauna play an important role in ecosystem processes such as organic matter dynamics, nutrient cycling and soil structure dynamics (LEE 1985, ANDERSON 1988). On the other hand, a number of factors have been identified that influence faunal density in soils (BRUSSARD 1998, CURRY 1998). Among them, soil moisture and temperature, and the amount and quality of food sources are the most important (LEE 1991), all being markedly influenced by the management practice.

Mowing and haymaking may result in an increase of earthworm populations by reducing the loss of moisture by plant transpiration (BATES 1933). The decrease (37.9–43.8%) in density of oribatid mites in mown plots in comparison with plots without any management and the positive effect on development of some eurytopic oribatid species populations, i.e. *Scheloribates laevigatus*, were found by SIEPEL & VAN DE BUND (1988). NAKAMURA (1973) found strong dominance of oribatid species *Tectocepheus velatus* and *Oppiella nova* on a pasture in Central Japan affected by mowing and cattle grazing. These species are common in strongly disturbed sites or in initial and early successive stages (SKUBALA 1995, 1997). Systematic removing of plant biomass by haymaking is important factor reducing oribatid community succession in different meadow and pasture types (STARÝ 1999).

Cessation of cultivation often leads to the increase of density and diversification of soil fauna (SCHEU & SCHULTZ 1996, BRUSSARD 1998). However, the pathway of soil animal succession may vary among the particular plots, and previous land use can affect strongly the pattern of succession changes in individual groups of soil fauna. Different authors (EDWARDS 1983, EIJSACKERS 1983, SCHEU 1992, WESTERNACHER-DOTZLER 1992, PIŽL 1999) accordingly observed both the increase and decrease of earthworm populations in fallows. Main developmental trends and community changes of oribatid mites are comparatively uniform and involve an increase of average population density, species richness as well as diversity during the course of succession (FUJIKAWA 1988). BECKMANN (1988) described in detail secondary succession of oribatid mites on plots, where bulldozers destroyed the mesofauna. Distinct quantitative development of oribatid mite communities was found after five years when the average density reached the values usual in grassland successive stages. However, the species diversity and richness were still on the level of early successive stages.

In arable land, mulching is known to attenuate the increase of soil temperature and to retain higher soil moisture content (LAL & al. 1980) in addition to providing food for soil animals. Numerous studies have demonstrated the positive influence of adding plant residues as mulch on earthworm populations of arable fields, vineyards and orchards (BARNES & ELLIS 1979, JENSEN 1985, LEE 1985, TIAN & al. 1993, etc.). Crop residues, grass and other types of mulch favour soil mite populations (BARING 1956). HÖLLER-LAND (1958) has observed almost two times lower annual population density of soil mites on mown than on mulched plots, and ATLAVINYTÉ (1971) reported a ten times increase of soil mite population in plots mulched by straw in comparison with control where no straw was added.

No information is available, however, on the effects of different types of management on the soil fauna in mountain grasslands. The objective of this study was to assess the impact of management shifting from regular mowing to mulching or lying fallow on the communities of earthworms and oribatid mites in a mountain grassland ecosystem.

MATERIAL AND METHODS

The site and experimental plots

The experimental site was an acidophilous mountain meadow located in the Huťská hora Mt. near the Horská Kvilda village, the Bohemian Forest, at the altitude of 1050 to 1080 m a.s.l. The meadow (association *Cardaminopsio halleri – Agrostietum,* phytosociological alliance *Polygono – Trisetion*) was situated on a SW-facing slope, inclination 10°. The experiment was organised in 1997 and involved three types of treatment: i) M – mulching with native vegetation (once a year, usually June–July), ii) F – lying fallow (cessation of mowing at the start of experiment) and iii) C – control, mowing (once a year, at the same dates as mulching was applied). Experimental plots of 100×50 m were established for each treatment. In addition, the second control plot (CW) was established at the bottom of the slope possessing higher soil moisture content than C. For more detailed description of the site and experimental setup see MAŠKOVÁ & al. (2001a,b).

Sampling

Soil samples were taken at each plot in May, July and September 1999 and in May, August and October 2000. On each sampling occasion, five soil cores measuring 625 cm^2 in area × 10 cm in depth were collected for the study of earthworms, and five soil cores measuring 10 cm^2 in area × 10 cm in depth for the study of oribatid mites.

Animal extraction and analyses

Earthworms were extracted from soil samples by heat using the modified Kempson apparatus. The lumbricids obtained were fixed in 4% formalin and stored in 7% solution of the same fixative. All results concerning earthworm biomass are given in g of formalin preserved material. Oribatid mites were extracted from soil samples by modified Berlese–Tullgren funnels, fixed in 80% ethanol, cleared in 60% lactic acid and after species identification preserved in glycerol. The earthworm communities of individual plots were characterised by density, biomass, composition of species and their relative density. The average density, species richness and dominance of important species were used for characterisation of oribatid mite communities. The nomenclature of earthworms and oribatid mites follows Easton (1983) and Mashall & al. (1987), respectively.

Statistical analysis of earthworm and oribatid mite density and earthworm biomass was carried out by means of an analysis of variance (ANOVA). Student-Newman-Keuls test was performed for comparison of means. The Correspondence analysis (CA) based on the species density and Principal coordinates analysis (PCA) with Sörensen index (SYN–TAX 5.02, Podani (1994)) were respectively used for analyses of similarity and heterogeneity of earthworm and oribatid communities.

Results

Species and community structure

Five earthworm species were recorded during the study, namely *Aporrectodea caliginosa* (Savigny, 1826), *A. rosea* (Savigny, 1826), *Dendrobaena octaedra* (Savigny, 1826), *Lumbricus rubellus* Hoffmeister, 1843 and *Octolasion lacteum* (Örley, 1881). These species occurred in all study plots. The dominance structures of the earthworm communities in individual plots are given in Fig. 1. High proportions of endogeic species (*A. caliginosa*, *A. rosea* and *O. lacteum*) were found in both regularly mown control plots, and declined markedly after the shift of management. Epigeic earthworms *D. octaedra* and *L. rubellus* highly predominated in both lain fallow and mulched plot. The results of CA ordination, displayed in Fig. 3, are roughly in accordance with the management divergence, the position of species in the ordination space corresponding to their preferences for individual plots. One species only, *Dendrobaena octaedra*, preferred mulched plot and fallow, while *Aporrectodea rosea* and *A. caliginosa* showed preferences for the regularly mown meadow.

Thirty-nine oribatid species were found in the material of 4999 individuals. Total number of oribatid mites was similar in all plots: C – 24, CW – 21, F – 23 and M – 24. Comparison of oribatid mite dominance structure on studied plots is given in Fig. 2. It shows that eurytopic *Tectocepheus sarekensis* Trägardh, 1910 predominated in all plots. However, its population density was almost two times higher in mown plots than in mulched plot and fallow. The inverse trend, but not such distinct, was found in the dominance of *Berniniella hauseri* (Mahunka, 1974). The dominance of *Achipteria coleoptrata* (Linnaeus, 1758) and *Diopterobates humeralis* (Hermann, 1804) was influenced by soil moisture as documented by diffe-

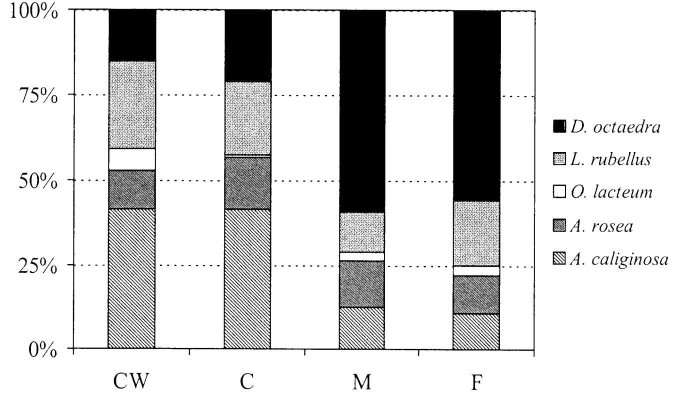

Fig. 1. – Comparison of earthworm species dominance structures in differently managed mountain meadows. C – mown meadow, CW – mown moist meadow, F – fallow, M – mulched meadow.

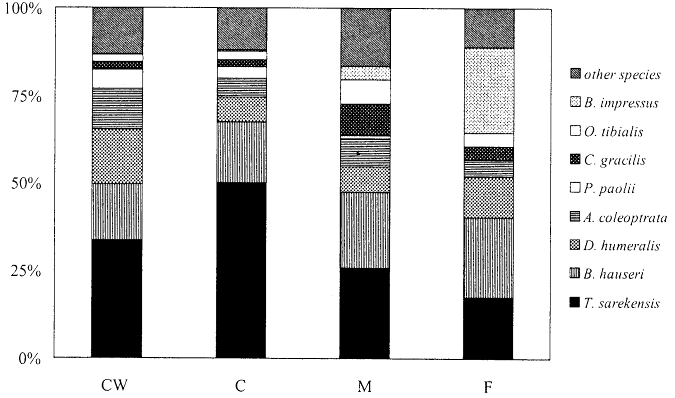

Fig. 2. – Comparison of oribatid mite species dominance structures in differently managed mountain meadows. C – mown meadow, CW – mown moist meadow, F – fallow, M – mulched meadow.

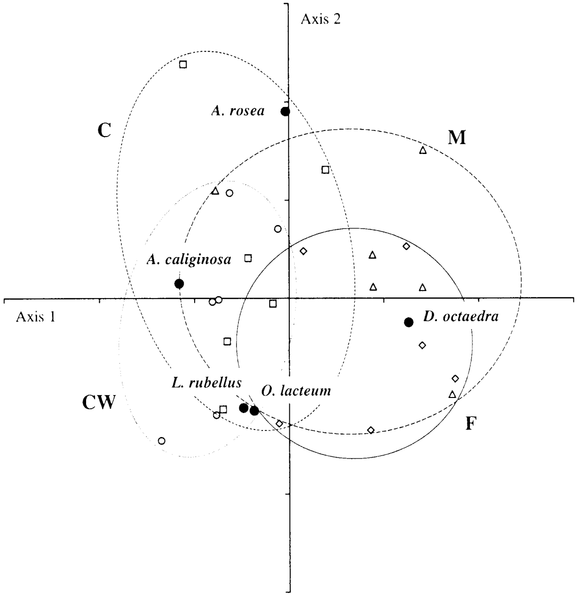

Fig. 3. – CA ordination of samples and earthworm species in differently managed mountain meadows. C – mown meadow, CW – mown moist meadow, F – fallow, M – mulched meadow.

rences between mown plots C and CW. Only *Oribatula tibialis* (Nicolet, 1855) and *Ceratozetes gracilis* (Michael, 1884) clearly preferred mulched plots. There was conspicuous increase of the dominance of *Brachychthonius impressus* Moritz, 1976 in mulched and lain fallow plots, while this species was missing in both mown plots. Opposite trend was established for *Pantelozetes paolii* (Oudemans, 1913). The results of PCA analysis (Fig. 4) correspond with changes in species composition of oribatid communities occurring in studied plots. The position of samples in the ordination space shows clear separation of fallow from both mown plots. Samples from mulched plot are in an intermediate position. Heterogeneity of samples collected in the fallow is much lower than that of samples collected in mown and mulched plots.

Density and biomass

The density and biomass of earthworms in individual plots did not vary much over the individual years of study (Table 1). There were no significant differences in both parameters between controls, nevertheless earthworm populations tended to be more abundant in CW than

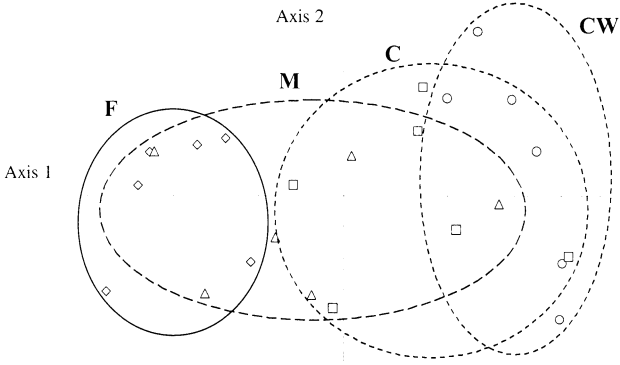

Fig. 4. – PCA ordination of samples with oribatid mites in differently managed mountain meadows. C – mown meadow, CW – mown moist meadow, F – fallow, M – mulched meadow.

in C. In comparison with the moist control plot, earthworm density was lower in the fallow and lower biomass was found in both mulched and lain fallow plots. Earthworm populations in F and M differed by non-significant amounts.

The values of density and species richness of oribatid mites are given in Table 2. The lower average density was found in mulched plot (M) than in moist mown plot (CW) and fallow (F) in 1999. Other differences between plots were not significant; nevertheless, there was a tendency of oribatid mite populations to be denser in fallow than in mown plots.

Table 1. – Average density (D, ind.m^{-2} ± S.D.) and biomass (B, ind.m^{-2} ± S.D.) of earthworms in differently managed mountain meadows. C – mown meadow, CW – mown moist meadow, F – fallow, M – mulched meadow.

Year		**C**	**CW**	**F**	**M**
1999	D	80.0±42.3	123.8±37.7	55.4±6.6	116.8±35.6
	B	16.23±12.13	20.60±11.44	6.13±1.63	13.01±3.34
2000	D	72.5±30.7	126.9±79.3	64.0±42.3	98.13±46.6
	B	13.99±11.65	27.25±13.79	6.27±5.96	7.90±3.71
1999–2000	**D**	**76.3±33.3^{ab}**	**125.4±55.6^{b}**	**59.7±27.5^{a}**	**107.5±38.5^{ab}**
	B	**15.12±10.71^{ab}**	**23.93±11.90^{b}**	**6.19±3.91^{a}**	**10.46±4.22^{a}**

^{a,b} – In a row, significant different values are followed by different letter (P = 0.05)

Table 2. – Average density (D, ind.10^3 .m^{-2} ± S.D.) and species richness (R, number of species per sample ± S.D.) of oribatid mites in differently managed mountain meadows. C – mown meadow, CW – mown moist meadow, F – fallow, M – mulched meadow.

Year		C	CW	F	M
1999	D	39.9±11.4 [ab]	58.9±10.8 [b]	51.4±3.6 [b]	31.5±3.1 [a]
	R	11.3±2.5	12.7±1.5	13.7±1.5	14.3±1.2
2000	D	25.9±0.3	32.2±11.9	50.4±19.3	42.8±34.3
	R	13.3±1.5	12.7±2.5	13.3±2.5	15.7±2.1
1999–2000	**D**	**32.8±10.5**	**45.6±17.8**	**50.9±12.4**	**37.2±22.7**
	R	**12.3±2.1**	**12.7±1.9**	**13.5±1.9**	**15.0±1.7**

[a, b] – In a row, significant different values are followed by different letter (P = 0.05)

Discussion

All earthworm species recorded during the study belong to frequent inhabitants of mountain meadows (Zajonc 1970, Glasstetter 1991, Kübelböck & Meyer 1981) as well as of a variety of natural and man-made habitats. *Dendrobaena octaedra* and *Lumbricus rubellus* represent epigeic earthworms, which need the accumulation of litter to settle and have short life spans and high fertility rates. *Aporrectodea caliginosa, A. rosea* and *Octolasion lacteum* are mineral soil dwellers with perennial development. The density and biomass of earthworms in the meadow under study were sometimes higher and sometimes lower than those found by Zajonc (1970) in the Carpathian grasslands.

Shifting of meadow management had no effect on species composition of earthworms. However, their community structure changed and density and biomass decreased in both lain fallow and mulched plots. This corresponds with observation by Pižl (1999) who found that earthworm density decreased in the submontane meadow after the cessation of haymaking, most likely due to the changed soil water regime. Similarly, Zou & Gonzales (1997) observed the decrease of earthworm density during the secondary succession in pastures. They suggested that changes in soil moisture content and in the chemistry of organic inputs were responsible, rather than those in litter amount and in other soil properties. In addition, structure of earthworm community at the start of succession could be of importance. There was a high proportion of endogeic earthworms in the meadow under study, while Eijsackers (1983) and Pižl (1999) recorded that the increase of earthworm density during secondary succession occurred only in sites where epigeic species were dominant. Nevertheless, the reasons of the decrease of endogeic earthworms in mulched plot remain unclear.

The community of oribatid mites in the studied meadow was similar to that described by Persson & Lohm (1977) from cultural pasture in Sweden. Density and species richness of oribatid mites corresponded well with those inhabiting two submontane meadows (Starý 1999). However, there were strong differences between sites in species composition and community structure, particularly in the occurrence of *Tectocepheus sarekensis*. This species is clearly related to *Tectocepheus velatus* (Michael, 1880), some authors consider them conspecific (Nübel-Reidelbach 1994). Schenker (1984) classified *T. velatus* as an ubiquistic, cosmopolitan species. It was frequently recorded from arable soils, early stages of succession, mown and grazed pastures, etc. (Nakamura 1973, Skubala 1997, Starý 1999) where commonly belongs to dominant species. Such wide range of distribution could be explained by its tolerance to drought, parthenogenesis and microphytophagy, especially feeding on soil algae and fungi (Siepel 1995, Luxton 1972, 1981).

In general, the density, species richness and diversity of oribatid mites depend above all on the state of soil litter layer. Mowing reduces markedly the development of litter, and subsequently restricts food sources for many oribatid species and leads to unfavourable microclimatic changes. This possibly influenced the density of oribatid mites that was relatively low in mown control plot, where the species less tolerant to disturbances were absent or found only scarcely. A slight increase of oribatid density was recorded in mulched and lain fallow plots. This is in agreement with STARÝ (1999) who observed that after the cessation of cultivation, oribatid mite community developed much more slowly in previously mown than in undisturbed grasslands. Shifting of management resulted in the development of dense populations of small gracile oribatid species, such as *Brachychthonius impressus*, that are very sensitive to soil desiccation. They probably compete with *T. sarekensis* and decrease its population density.

Acknowledgement. We wish to thank to V. Bosák (Sacramento, California, USA) for his kind linguistic and stylistic review of this paper. The study was supported by the Grant Agency of the Czech Republic, Project No. 206/99/1410, and by the Research Plan of the Institute of Soil Biology ASCR (Z6 066 911).

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