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Differences in top-soil features between beech-mixture and Norway spruce forests of the Šumava Mts.

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ABSTRACT: Top-soil samples were taken from four mountain forest ecosystems in the Bohemian Forest to compare the processes in European beech-mixture (*Fs*) and Norway spruce (*Pa*) dominating ecosystems. Selected plots can be grouped into two types of forest ecosystems which are conditioned by position on the natural altitudinal gradient. Several chemical features (content of organic matter, properties of humic and fulvic acids, releasable P, Ca, Mg, Fe and Al content) were compared with the species structure of oribatid mite communities in the same samples. Strict differences between both ecosystem types were discovered. Statistically significant differences were detected in Mg content (0.42 mg/g in *Fs* ecosystems compared to 0.30 mg/g in *Pa* ecosystems) and in organic matter quality (the ratio of carbon content in humic acids to carbon content in total humus acids was 0.53 in *Fs* ecosystems and 0.66 in *Pa* ecosystems) and quantity (e.g. content of humic acid carbon was 59 and 86 mg/g in *Fs* and *Pa* ecosystems, respectively). Different dynamics of organic matter decomposition and nutrient movement lead to some opposite correlations among the soil chemical features: correlation between total ash and soluble ash (r = +0.96 and –0.86 in the *Fs* and *Pa* ecosystems, respectively) and total ash – P content correlation (r = +0.76 and –0.92 in the *Fs* and *Pa* ecosystems, respectively) can be mentioned as examples. The oribatid mite communities are markedly distinct in both ecosystem types, although parameters of species diversity and abundance are similar. Different correlations were revealed between the parameters of mite community structure (e.g. species diversity and total mite abundance) and top-soil chemical features. The correlation structure is different in both ecosystem types. It indicates differences in leading variables determining the oribatid community structure in the beech mixture ecosystem or in the Norway spruce one.

Keywords: ash content; Bohemian Forest; element content (P, Ca, Mg, Fe, Al); fulvic acids; humic acids; organic matter; Oribatida

Soil is an integral component of the forest ecosystem. Soil conditions are related to both the environmental conditions and the state of ecosystem (including partial communities, e.g. plants, animals, fungi, microorganisms). They also influence many processes in the ecosystem.

Top-soil represents the most effective part in the dynamics of chemical substances in forest ecosystems. It is an active "mesh" for aboveground litter where decomposition processes play a key role. Top-soil is the location of organic matter accumulation and formation of humus of different forms (e.g. Green et al. 1993). Relationships between humus features and vegetation properties are well known (Klinka et al. 1990). There are several examples of studies on this subject: Vránová et al. (2006) brought evidence for dependence between humus forms and tree regeneration. The impact of tree layer damage on humus layer was studied in the Bohemian Forest by Svoboda (2003a). The litter

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decomposition and humus formation are connected with dynamically changing communities of some invertebrates (e.g. Berg et al. 1998). An attempt to connect top-soil features and the structure of communities of some invertebrates should be a reasoned step of the ecosystem study in forests.

The natural altitudinal zonation of forests is important from the aspect of a change in dominant tree species and also in the ecosystem function. The main goal of this paper is to reveal differences between top-soil properties in sites in European beech-mixture and Norway spruce forest ecosystems. The forests of near-to-nature structure in the Bohemian Forest were used. The oribatid mite (*Acari*: *Oribatidae*) communities (assemblages) were used as a biological indicator (Starý 2008). Oribatid mites are the most diverse arthropod group in forest litter and soil, and they make significant contributions to decomposition as microbial grazers and saprophages (Hansen 2000). There is a lack of information about linkage between the structure of these communities and chemical properties of soil. Information on processes operating at the ecosystem level is required in order to understand differentiation of communities (assemblages) in the ecosystem. Although it is widely accepted that soil biota and trophic interactions between various groups of soil biota play a major role in the regulation of decomposition of soil organic material and recycling of nutrients, the driving mechanisms remain obscure (Berg et al. 1998).

This paper deals with this problem using an example of two types of comparable forest ecosystems differing in altitude as the driving environmental factor.

METHODS

Study plots

Four plots were selected from an altitudinal gradient on the eastern slope of Plechý Mt. in the south-eastern part of the Bohemian Forest (Šumava Mts.), South Bohemia. Plots are localized near to the state frontier. These plots are under long-term ecosystem research (Vacek et al. 2006). Basic soil properties were studied by Podrázský (2007): soil types are Cambisol (plots P13 and P14) and Ranker (P18 and P20) with podzolization process. Vegetation can be described using average plant coenological relevés from the period 1997–2007:

Plot P13: altitude 1,050 m, group of forest types 6S (*Piceeto-Fagetum mesotrophicum*; see Viewegh et al. (2003) for the applied system).

Total cover E_3 90%, E_2 80%, E_1 62%

E_3: *Acer pseudoplatanus* 2, *Fagus sylvatica* 4, *Picea abies* 1; E_2: *Fagus sylvatica* 4, *Picea abies* 1; E_1: *Abies alba* r, *Athyrium filix-femina* r, *Avenella flexuosa* r, *Calamagrostis villosa* +, *Carex brizoides* r, *C. ovalis* r, *Dryopteris dilatata* 1, *D. filix-mas* r, *Fagus sylvatica* 3, *Festuca altissima* r, *Milium effusum* r, *Oxalis acetosella* 1, *Picea abies* 1, *Prenanthes purpurea* r, *Solidago virgaurea* r, *Sorbus aucuparia* r, *Vaccinium myrtillus* 1; E_0: *Atrichum undulatum* 1, *Dicranella heteromalla* +, *Dicranum scoparium* 1, *Pleurozium schreberi* r, *Pohlia nutans* r, *Polytrichum formosum* 1.

Plot P14: altitude 1,053 m, group of forest types 6S (*Piceeto-Fagetum mesotrophicum*)

Total cover E_3 65%, E_2 80%, E_1 33%

E_3: *Fagus sylvatica* 4, *Picea abies* 1, *Sorbus aucuparia* 1; E_2: *Fagus sylvatica* 4, *Picea abies* 2, *Sorbus aucuparia* r; E_1: *Abies alba* r, *Acer pseudoplatanus* 1, *Athyrium filix-femina* +, *Calamagrostis villosa* r, *Dryopteris dilatata* 1, *D. filix-mas* r, *Fagus sylvatica* 2, *Galeobdolon luteum* r, *Gymnocarpium dryopteris* r, *Maianthemum bifolium* r, *Oxalis acetosella* +, *Picea abies* r, *Prenanthes purpurea* r, *Rubus idaeus* r, *Sorbus aucuparia* 1, *Stellaria nemorum* r, *Vaccinium myrtillus* 1; E_0: *Dicranella heteromalla* r, *Dicranum scoparium* 1, *Pleurozium schreberi* +, *Pohlia nutans* r, *Polytrichum formosum* +.

Plot P18: altitude 1,245 m, group of forest types 7S/8N (*Fageto-Piceetum mesotrophicum*/*Piceetum lapidosum acidophilum*)

Total cover E_3 46%, E_2 0.1%, E_1 100%

E_3: *Picea abies* 3 (dead trees prevail); E_2: *Fagus sylvatica* r; E_1: *Athyrium distentifolium* 3, *Avenella flexuosa* 1, *Calamagrostis villosa* 2, *Dryopteris dilatata* 1, *Fagus sylvatica* r, *Homogyne alpina* +, *Luzula sylvatica* 2, *Oxalis acetosella* 3, *Picea abies* 1, *Prenanthes purpurea* r, *Soldanella montana* r, *Solidago virgaurea* r, *Sorbus aucuparia* r, *Trientalis europaea* r, *Vaccinium myrtillus* 3; E_0: *Abietinella abietina* r, *Atrichum undulatum* 1, *Cladonia* spp. div. r, *Dicranella heteromalla* 1, *Dicranum scoparium* 2, *Hypnum cupressiforme* r, *Pleurozium schreberi* 1, *Pohlia nutans* r, *Polytrichum formosum* 1, *Tortella tortuosa* r.

Plot P20: altitude 1,361 m, group of forest types 8N (*Piceetum lapidosum acidophilum*)

Total cover E_3 40%, E_2 24%, E_1 100%

E_3: *Picea abies* 3; E_2: *Picea abies* 2, *Sorbus aucuparia* 1; E_1: *Athyrium distentifolium* 3, *Avenella flexuosa* 4, *Calamagrostis villosa* 1, *Dryopteris dilatata* 2, *Homogyne alpina* 1, *Luzula sylvatica* 1, *Oxalis acetosella* 2, *Picea abies* 2, *Solidago virgaurea* r, *Sorbus aucuparia* +, *Trientalis europaea* +,

Table 1. Total numbers of individuals in all five samples according to the plots ("mean" samples) in September 2007. The species are ordered according to the TWINSPAN classification (d – eudominant or subdominant species)

TWINSPAN	Locality	P13	P14	P18	P20
*0000	*Carabodes labyrinthicus*			4	3
*0000	*Melanozetes meridianus*				1
*00010001	*Hermannia gibba*			19	
*00010001	*Liacarus coracinus*			2	
*00010011	*Liochthonius horridus*			1	
*0001010	*Pantelozetes paolii*			1	
*00011	*Hemileius initialis*		1	7	
*0010	*Liochthonius brevis*	2	3		1
*0011	*Atropacarus striculus*	11	12	35	6
*0011	*Berniniella sigma*	3	4	26	2
*01000	*Oribatula tibialis*		2	25	3
*0100100	*Berniniella bicarinata*			23	2
*0100101	*Brachychochthonius immaculatus*				5
*0100101	*Phthiracarus* sp. 1	1	5	6	50
*010011	*Chamobates borealis*	3	3	4	26
*010011	*Platynothrus peltifer*	16		17	77 d
*0101	*Liochthonius perfusorius*			1	5
*0101	*Tectocepheus velatus*		8	131 d	252 d
*01100	*Belba pseudocorynopus*	6	1	10	8
*01100	*Suctobelbella similis*	1	4	4	6
*01101	*Microppia minus*		1		1
*0111	*Quadroppia paolii*	1	4		1
*1000	*Adoristes ovatus*	1			1
*1000	*Achipteria coleoptrata*		5		
*1001000	*Scheloribates laevigatus*		1	1	
*100101	*Dissorhina ornata*	11	4	2	7
*10011	*Chamobates voigtsi*	16	7	11	
*10011	*Lauroppia falcata*	97 d	35	10	4
*101000	*Suctobelba regia*	3		4	
*101001	*Medioppia subpectinata*	59 d	16	14	3
*10101	*Suctobelbella subcornigera*	66 d	21	21	12
*1011	*Malaconothrus gracilis*			1	1
*1011	*Suctobelba trigona*	2	6	2	4
*11000	*Damaeobelba minutissima*	2	5	1	
*11000	*Suctobelbella falcata*	8	13	1	
*110010	*Carabodes rugosior*	2	2		
*1100110	*Suctobelbella sarekensis*	29	11	4	4
*1100111	*Brachychochthonius jacoti*	1	1		2

Table 1 to be continued

TWINSPAN	Locality	P13	P14	P18	P20
*1100111	*Oppiella nova*	126 d	50 d	6	18
*11010	*Suctobelbella subtrigona*	1			
*1101101	*Brachychochthonius zelawaiensis*	26	4		2
*1101101	*Micrermus brevipes*	1			
*110111	*Liochthonius hystricinus*		2		
*110111	*Quadroppia quadricarinata*	2	8		
*11100	*Ophidiotrichus connexus*	8	5		
*11101	*Lauroppia neerlandica*	6	20	1	
*11101	*Minunthozetes pseudofusiger*			1	
*11110	*Steganacarus herculeanus*		9		
*11111	*Nanhermannia coronata*	4	193 d	1	
*11111	*Nothrus silvestris*		22		

Vaccinium myrtillus 3; E_0: *Atrichum undulatum* 1, *Cladonia* spp. div. r, *Dicranella heteromalla* +, *Dicranum scoparium* 2, *Pleurozium schreberi* +, *Pohlia nutans* r, *Polytrichum formosum* 2.

Soil sampling and mite determination

Soil cores of 3.6 cm in diameter (area 10 cm^2) and 5 cm depth were sampled in September 2007. Five samples were taken in each plot (Starý, Matějka 2008). The first sample was taken in the proximity of laying decaying wood or stump and the other ones at distances of 1, 3, 5, and 8 m from the first sample. Samples were transported to the laboratory, where soil mites and other mesoedaphon were extracted in modified high-gradient funnels during 5 days at a temperature of 23°C, 28°C, 30°C, 33°C, and 40°C. Collected oribatid mites were cleared in slides with 80% lactic acid, determined at the species level and stored in glycerol. All determined material is deposited in the mite collection of the Institute of Soil Biology, Biological Centre Academy of Sciences of the Czech Republic at České Budějovice. The mite determination was performed mainly by using Kunst (1971), Giljarov and Krivolutsky (1975), Balogh and Mahunka (1983), and Weigmann (2006), keys and by many other papers including original descriptions of oribatid mite species.

Table 2. Parameters of the structure of oribatide communities in the studied plots. AVG – arithmetic mean over five samples taken from the plot; total – calculated on the "mean" sample (according to the sum of each species); *n* – average abundance (m^2); *'H* – Shannon-Wiener's index of species diversity; *S* – number of species (species richness); *e* – species equitability; *dH* – index of β-diversity in the whole plot

Locality		*n*	*'H*	*S*	*e*	*dH*
P13	AVG	103,000	3.108	16.0	0.779	
P13	total		3.486	30.0	0.711	0.378
P14	AVG	97,600	3.103	18.0	0.745	
P14	total		3.581	34.0	0.704	0.478
P18	AVG	79,400	3.150	15.0	0.813	
P18	total		3.746	33.0	0.743	0.596
P20	AVG	101,400	2.437	13.2	0.652	
P20	total		2.754	28.0	0.573	0.317

Laboratory analysis

The whole soil sample was homogenized using a laboratory grinder. Large hard particles were carefully removed.

Total ash was determined by the combustion of a sample (1–2 g) at 400°C for 6 hours. Ash was dissolved in hydrochloric acid (1 ml). The suspension was filtered. The rest of ash with filter paper was combusted again to determine insoluble ash. Soluble ash was calculated as difference between total ash and insoluble rest. Releasable content of some elements (P, Ca, Mg, Fe, Al) was determined in the HCl solution of ash. Releasable phosphorus was analyzed according to Kopácek et al. (2001). The flame atomic absorption spectrometry (Varian, model AA240FS) was employed to determine other releasable elements – Ca, Mg, Fe and Al.

Total humus acids (T) were dissolved in 0.1 mol/l NaOH (approximately 1 g of soil sample and 50 ml of hydroxide solution) and filtered.

Fulvic acids (FA) were separated by precipitation of humic acids (HA) with sulphuric acid. Humic acids were dissolved in the sodium hydroxide solution again. Absorbance at 400 nm (A_{400}) and 600 nm (A_{600}) was measured for total extract (e.g. T-A_{400}) and both fractions (e.g. HA-A_{400} and FA-A_{400}). The values were recalculated to unit mass of the sample, thickness of the cuvette and volume of the solution – standardized values are thus in units cm^2/g.

Colour quotient was calculated on the basis of absorbances: $Q_{4/6} = A_{400}/A_{600}$. Contents of carbon and nitrogen were determined by LiquiTOC II (Elementar Company, Germany) in samples of total humus solution and humic acids.

Data processing

The species composition of soil mite communities was saved in the DBreleve database (Matějka 2009) together with analogous communities according to samples from other similar localities in the Bohemian Forest (Starý, Matějka 2008), where total number of individuals per sample (INDIVIDUAL), species richness (*S*), Shannon-Wiener's index of diversity (*'H*) and equitability (*e*) were calculated. The variables *'H*, *S* and *e* are measures of α-diversity and species richness. We calculated $dH = {}'H_{\text{total}} - {}'H_{\text{AVG}}$ (${}'H_{\text{total}}$ is diversity index in the joined "average" sample and ${}'H_{\text{AVG}}$ is the arithmetic mean over diversity indices of single samples) as a measure of β-diversity among different places within the plot. The ordination technique – DCA was used to reveal similarities of individual samples. It was calculated in the CANOCO software (Ter Braak, Šmilauer 2002). Classifications of both samples and mite species were carried out using the TWINSPAN procedure (Hill 1979).

All data on both the chemical properties of soil and the structure of oribatid community for individual soil samples were processed by correlation analysis. Differences in averages among the two sets according to dominant tree species were tested by Student's *t*-test. The correlation analysis and principal component analysis (PCA) were used to describe data structure and relationships among variables in both sets separately.

Correlation analysis was carried out for subsets of data according to altitudinal zone and dominant tree species in the plant community. Differences between pairs of correlation coefficients for the same combination of variables can be tested using *Z*-transformation (Anděl 1985)

$$Z = \frac{1}{2} \ln \left(\frac{1 + r}{1 - r} \right)$$

as the standardized difference

$$U = \frac{Z_1 - Z_2}{\sqrt{\frac{1}{n_1 - 3} + \frac{1}{n_2 - 3}}}$$

where:

Z_1, Z_2 – *Z*-transformed correlation coefficients for the first and second set of samples, respectively,

n_1, n_2 – numbers of samples in both sets.

The *U* value has Gaussian distribution *N*(0,1), thus absolute values abs(U) > $u_{0.95}$ should indicate significant differences between both correlations.

RESULTS AND DISCUSSION

Oribatid mite communities

Altogether 4,287 individuals of oribatid mites belonging to 70 species were found. The average community composition can be found in Table 1. Both diversity and species richness are shown in Table 2.

Plot P13

In total 30 oribatid species were found in this plot in high average abundance and species diversity. Distinctly eurytopic oribatid species dominated in this community, especially *Oppiella nova*, *Suctobelbella subcornigera* and *Medioppia subpectinata*. The silvicolous species *Chamobates voigtsi*, which decreased its population density along the altitude gradient, was missing in the summit parts of Plechý Mt., was comparatively frequent together with another silvicolous species *Lauroppia falcata* distinctly

Table 3. Average properties (AVG) of top-soil in the examined plots and corresponding standard deviations (STD). Each plot is represented by 5 samples. D_{b-s} – statistically significant difference between samples in beech-mixture and spruce forests at levels $\alpha < 5\%$ (*), $\alpha < 1\%$ (**) or $\alpha < 5\%$ (***) using Student's *t*-test. Fractions of humus substances: T – total extract, HA – humic acids, FA – fulvic acids. DCA – score according to ordination axes. Prevailing classification groups are accompanied by the number of respective samples

Dominant tree species				*Fagus sylvatica*				*Picea abies*			
Plot				P13		P14		P18		P20	
Property	Unit	Abbreviation	D_{b-s}	AVG	STD	AVG	STD	AVG	STD	AVG	STD
Total ash	%	ash1		27.3	21.7	16.2	13.6	24.2	26.9	21.8	21.8
Soluble ash	%	ash2		1.69	0.51	1.38	0.26	1.29	0.39	1.13	0.24
Soil humus substances											
T: A_{400}	cm^2/g	T_A400	*	545	159	609	52	839	261	725	148
T: A_{600}	cm^2/g	T_A600	*	77.8	22.8	83.4	14.6	107.5	31.3	101.5	19.5
T: $Q_{4/6}$		T_Q4/6		7.10	1.24	7.48	1.07	7.71	0.60	7.14	0.54
FA: A_{400}	cm^2/g	FA_A400		101.4	18.0	111.5	1.2	109.8	26.8	96.9	8.6
FA: A_{600}	cm^2/g	FA_A600	*	4.18	0.76	4.54	0.56	3.87	0.77	3.31	0.65
FA: $Q_{4/6}$		FA_Q4/6		25.13	6.73	24.95	3.40	28.56	6.66	30.06	4.10
HA: A_{400}	cm^2/g	HA_A400	*	756	276	783	103	1279	414	987	162
HA: A_{600}	cm^2/g	HA_A600	*	117	35	110	24	175	55	158	45
HA: $Q_{4/6}$		HA_Q4/6		6.51	1.32	7.30	1.16	7.25	0.44	6.47	1.03
T: C	mg/g	T_C_mg_g		109	26	111	8	131	38	128	27
T: N	mg/g	T_N_mg_g		4.69	1.15	4.52	0.54	4.84	1.45	4.97	1.23
HA: C	mg/g	HA_C_mg_g	**	59.3	17.9	58.8	7.4	91.8	28.7	79.5	15.5
HA: N	mg/g	HA_N_mg_g	*	2.77	0.36	2.99	0.51	3.59	0.64	3.59	0.56
T: C/N		T_C_N	*	23.3	1.9	24.8	2.2	27.3	2.2	26.2	3.6
HA: C/N		HA_C_N		21.1	4.9	20.0	2.7	25.2	6.6	22.3	4.2
C_{HA}/C_T		C-HA_T	***	0.536	0.040	0.527	0.048	0.693	0.046	0.627	0.032
Releasable element content											
Ca	mg/g	Ca_mg_g		3.10	1.50	2.91	0.35	2.38	1.18	2.24	0.83
Mg	mg/g	Mg_mg_g	*	0.437	0.102	0.411	0.072	0.308	0.118	0.289	0.086
P	mg/g	P_mg_g		1.017	0.194	0.878	0.044	0.826	0.276	0.777	0.237
Fe	mg/g	Fe_mg_g		2.63	1.87	1.55	0.94	1.39	0.32	1.26	0.30
Al	mg/g	Al_mg_g		1.34	0.61	1.25	0.46	1.64	0.64	1.17	0.17
Structure of oribatid mite community											
Individuals		individual		103.0	20.9	97.6	24.6	79.4	55.8	101.4	13.8
'H		h		3.11	0.32	3.10	0.69	3.15	0.42	2.44	0.49
e		e		0.779	0.040	0.745	0.153	0.813	0.115	0.652	0.112
DCA_1		dca1	***	0.744	0.154	1.236	0.367	–0.466	0.157	–0.670	0.123
DCA_2		dca2		0.068	0.080	–0.062	0.151	0.616	0.878	0.134	0.160
DCA_3		dca3	*	0.152	0.057	–0.202	0.084	–0.144	0.279	–0.464	0.278
DCA_4		dca4		0.054	0.136	–0.030	0.166	0.378	0.838	–0.216	0.186
Prevailing Ward's classification group				*00 (5)		*01 (4)		*101 (3)		*1101 (5)	
Prevailing TWINSPAN group				*1101 (4)		*101 (3)		*01 (3)		*0001 (5)	

preferring the beech forest at a lower altitude. Rare and faunistically important can be the following oribatid species: *Ceratozetella sellnicki*, *Chamobates spinosus* and *Suctobelbella atomaria*.

Plot P14

The species richest oribatid community with high average abundance and species diversity living in this plot in comparison with the other ones in the studied altitude gradient. Dominance of the hygrophilous and silvicolous species *Nanhermannia coronata* was distinct because this species prefers moist forest litter and mosses of peat bogs. High dominance and species density of this hygrophilous species reflects the high soil moisture of some parts in this plot. Other distinct dominant species were eurytopic and silvicolous *Oppiella nova* and *Lauroppia falcata*. An important and rare species was *Steganacarus herculaneus*, which prefers submontane beech forests of Central Europe, their juvenile stages, like also other representatives of the family Phthiracaridae mining conifer needles and leaf petioles (Hagvar 1984).

Plot P18

A rich oribatid community was found in this plot regarding the species richness with the highest average and total species diversity, but with distinctly lowest average abundance. The euryvalent cosmopolitan species *Tectocepheus velatus* distinctly dominated, which was found in lower population density and dominance in beech forests in comparison with spruce forest at a higher elevation. The hygrophilous and silvicolous species *Atropacarus striculus*, which participates significantly also in the secondary decomposition of coniferous needles in forests of Central Norway (Hagvar 1998), found its ecological optimum in this plot. The species characteristic of submontane forests of Central Europe like: *Hermannia gibba*, *Belba pseudocorynopus*, and *Platynothrus peltifer* were found at a subdominant level in this plot. The species *Chamobates voigtsi* was substituted in the context of increasing altitude by the allied species *Chamobates borealis*. Important and rare species were *Liochthonius perfusorius* and *Damaeobelba minutissima*.

Plot P20

The poorest oribatid community was found on this plot at the highest altitude with the lowest average and total species diversity and equitability. Dominance was concentrated to a few species, first of all to eurytopic *Tectocepheus velatus* reaching there the highest population density and dominance in the studied altitude transect together with hygrophilous *Chamobates borealis*. Rare species were *Brachychochthonius jacoti*, *Melanozetes meridianus* and *Quadroppia monstruosa*.

Soil features

Comparing sets of samples from beech and spruce ecosystems, it is possible to list the basic findings (Table 3):

- Content of total ash is comparable in both sets of samples.
- There is no difference in the content of soluble ash.
- The soluble humus matter (FA + HA) content is moderately higher in the top-soil under Norway spruce. This difference is not statistically significant.
- Content of humic acids is higher in the top-soil under Norway spruce.
- Qualitative features (as $Q_{4/6}$) of humic acids are similar in both sets.
- The quotient $Q_{4/6}$ for fulvic acids is moderately higher in the top-soil under Norway spruce.
- The share of humic acids in total soluble humus matter is higher in the top-soil under Norway spruce with high statistical importance.
- The C/N ratio is higher in the top-soil soluble humus matter under Norway spruce.
- Higher releasable Mg content in the top-soil under beech is the sole statistically significant difference in the set of studied elements, nevertheless average Ca content was also higher in this sample set.

More rapid dynamics of organic matter in the soil of beech-mixture forests is possible as indicated by higher nitrogen content in soluble humus matter and higher content of base cations.

It is not possible to find any correlation among determined soil variables in the set of all samples. Different situation occurs after dividing the samples into two groups according to forest altitudinal zones and dominant tree species. There arises a unique data structure in each set. The relationship among variables in both data sets was calculated (Tables 4 and 5). The basic significant difference was revealed in the correlation between total ash and soluble ash. Both values are positively correlated in the beech-mixture forest, but they have a negative correlation in the Norway spruce forest. This fact together with other correlations points to another finding:

(1) The litter falling onto the soil surface in the beech-mixture forest brings mineral elements. Litter is rapidly decomposed and mineral elements concentrate in the top-soil organic-mineral complex.

Table 4. Correlation coefficients among the studied soil properties (see Table 3 for abbreviations) in the set of samples from beech-mixture forests. Only statistically significant values are typed. The most important values are in bold

	ash1	ash2	T_A400	T_A600	T_Q4/6	FA_A400	FA_A600	FA_Q4/6	HA_A400	HA_A600	HA_Q4/6	T_C mg_g	T_N mg_g	HA_C mg_g
ash1	o	**0.955**	–0.711		–0.768	–0.778					**–0.938**	–0.804		
ash2	**0.955**	o	–0.858			–0.669			–0.713		–0.854	–0.888	–0.699	–0.756
T_A400	–0.711	–0.858	o	0.795					0.958			**0.946**	**0.916**	**0.953**
T_A600			0.795	o					0.873	**0.917**		0.649	0.795	0.785
T_Q4/6	–0.768				o	0.744		0.767			0.847			
FA_A400	–0.778	–0.669			0.744	o		0.669			0.765			
FA_A600							o	–0.737						
FA_Q4/6					0.767	0.669	–0.737	o						
HA_A400		–0.713	**0.958**	0.873					o	0.749		0.896	**0.970**	**0.980**
HA_A600				0.917					0.749	o			0.696	0.646
HA_Q4/6	–0.938	–0.854			0.847	0.765					o	0.635		
T_C mg_g	–0.804	–0.888	**0.946**	0.649					0.896		0.635	o	0.899	**0.937**
T_N mg_g		–0.699	**0.916**	0.795					**0.970**	0.696		0.899	o	**0.976**
HA_C mg_g		–0.756	**0.953**	0.785					**0.980**	0.646		**0.937**	**0.976**	o
HA_N mg_g				0.662										
T_C_N					0.661									
HA_C_N		–0.656	0.698						0.722			0.790	0.728	0.761
C-HA_T				0.746					0.742	0.753			0.726	0.710
Ca mg_g					0.667	0.726		0.639						
Mg mg_g									–0.705	–0.692			–0.682	
P mg_g	0.759	0.737			–0.660	–0.890					–0.699			
Fe mg_g	**0.982**	**0.929**	–0.658		–0.821	–0.855		–0.658			**–0.936**	–0.741		
Al mg_g	**0.914**	0.792			**–0.926**	–0.771		–0.740			–0.913			
Individual							0.648							
h														
e														
dca1														
dca3														

Table 4 to be continued

	HA_N mg_g	T_C_N	HA_C_N	C–HA_T	Ca mg_g	Mg mg_g	P mg_g	Fe mg_g	Al mg_g	Individual	h	e	dca1	dca3
ash1							0.759	**0.982**	**0.914**					
ash2			–0.656				0.737	**0.929**	0.792					
T_A400			0.698					–0.658						
T_A600	0.662			0.746										
T_Q4/6		0.661			0.667		–0.660	–0.821	**–0.926**					
FA_A400					0.726		–0.890	–0.855	–0.771					
FA_A600										0.648				
FA_Q4/6					0.639			–0.658	–0.740					
HA_A400			0.722	0.742		–0.705								
HA_A600				0.753		–0.692								
HA_Q4/6							–0.699	**–0.936**	**–0.913**					
T_C mg_g			0.790					–0.741						
T_N mg_g			0.728	0.726		–0.682								
HA_C mg_g			0.761	0.710										
HA_N mg_g	o													
T_C_N		o		–0.743										
HA_C_N			o											
C–HA_T		–0.743		o		–0.711					–0.792	–0.783		
Ca mg_g					o									
Mg mg_g				–0.711		o					0.647	0.662		
P mg_g							o	0.855	0.665					
Fe mg_g							0.855	o	**0.919**					
Al mg_g							0.665	**0.919**	o					
Individual										o				
h				–0.792		0.647					o	**0.936**		
e				–0.783		0.662					**0.936**	o		
dca1													o	–0.647
dca3													–0.647	o

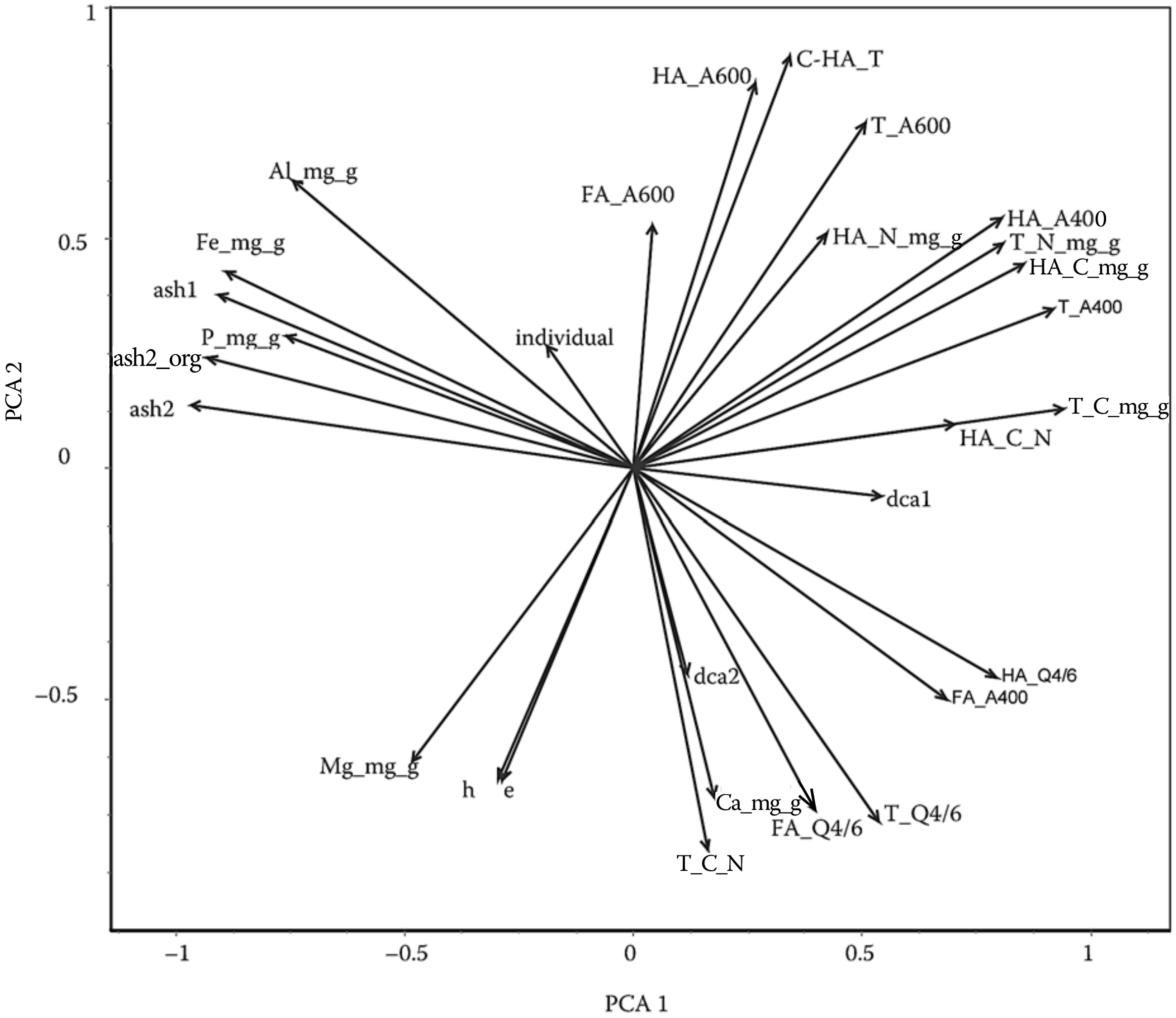

Fig. 1. PCA ordination of soil variables in samples from beech-mixture forests (plots P13 and P14)

(2) The litter is decomposed slowly in the Norway spruce ecosystem. Free mineral elements are leached (probably with organic acids, fulvic acids prevail) from the top-soil to a lower horizon.

A difference in the movement of matter between both forest categories is consistent with conclusions of other authors (e.g. Remeš, Kulhavý 2009). The contrast is reflected in the distribution of soil features in the respective ordination space (Figs. 1 and 2).

Descriptions of differences in the soil features in different types of forest ecosystems are frequent. They unfortunately use the basic soil parameters (e.g. pH, nutrient content, and base saturation of sorption complex) only. Some papers were aimed at the investigation of air-pollution impact on soil chemistry (e.g. Kreutzer, Weiss 1998). Planted forests are in focus (e.g. Fabiánek et al. 2009). Natural forests are objects of study less frequently (e.g. Koreň 1984; Průša 1985). A comparison of spruce and beech forests is available from the Krkonoše Mts. (Podrázský 1996). Nevertheless, these data are not comparable with the results presented here because:

- other papers do not study samples in spatial variation in the sample plot,
- other papers are not focused on qualitative parameters of organic matter,
- it is not possible to analyze the relationship among soil properties in a comparable type of ecosystem.

Humus matter in the mountain forest soils of the Bohemian Forest was analyzed in several papers (Kalousková 1995; Novák et al. 1999). All values of the C/N ratio for humic acids from top-soil (averages according to plot vary between 26 and 35) are markedly higher compared to these values for fulvic acids isolated from the B-horizon of soil in a similar ecosystem (15.9 reported by Novák et al. 1999). Bitumens (soil lipids) should be another important fraction of the soil organic matter, which were studied in the locality near to the presented site P20 (Novák 1995; Novák et al. 1998). Bitumen

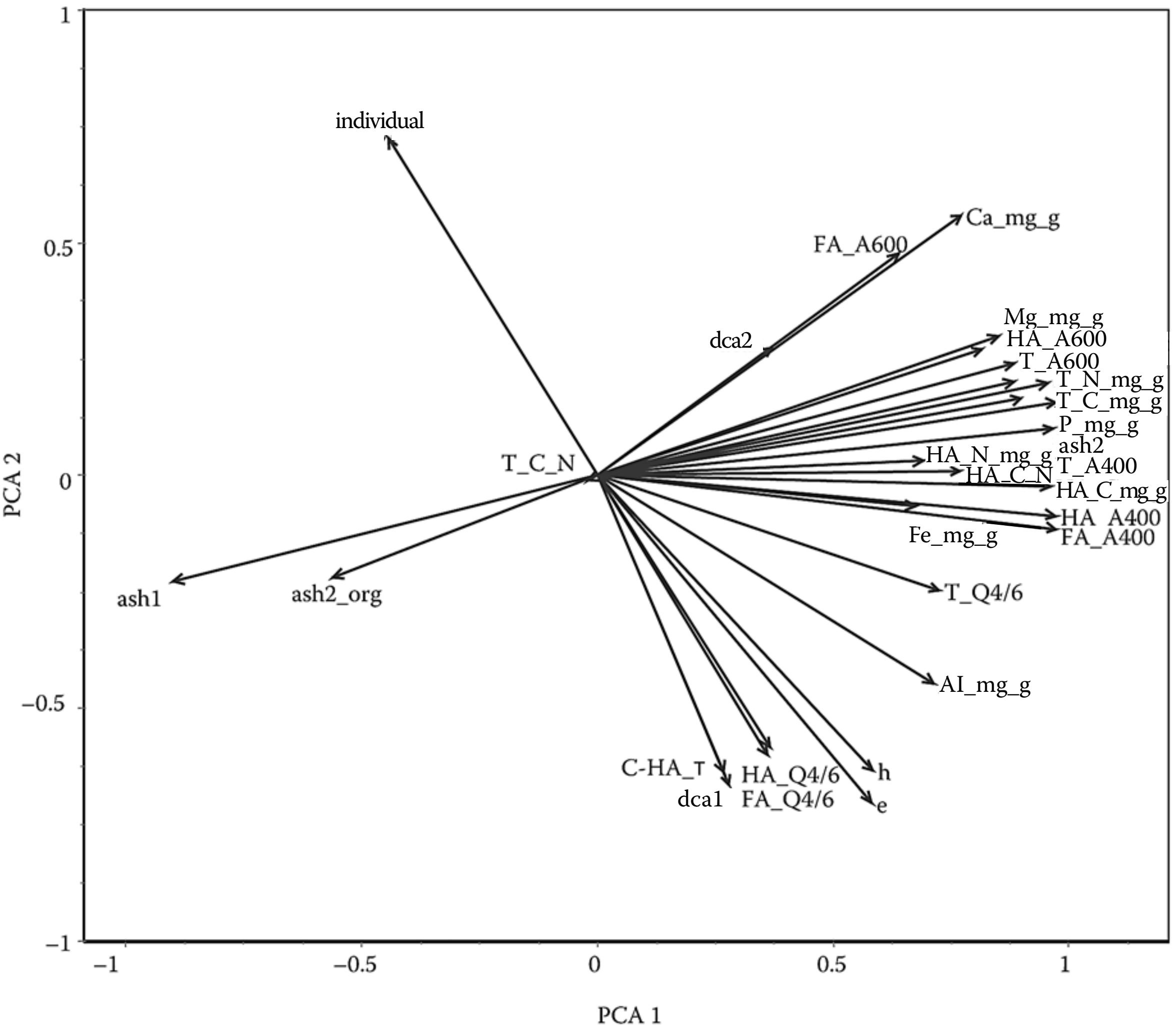

Fig. 2. PCA ordination of soil variables in samples from Norway spruce forests (plots P18 and P20)

content in the top-soil of Norway spruce forests varies around 6%. Soils of the same region were studied by Svoboda (2003b).

Oribatid mite communities and environmental conditions

A difference between oribatid communities in both forest types is manifested at the first (highest) classification level of samples using both TWINSPAN divisive method and Ward's agglomerative classification (Table 3). Our data point to a different relationship among top-soil features in the mite community (assemblage) structure in beech-mixture and Norway spruce dominated forest ecosystems. Statistically significant correlations were found by diversity measures (total diversity *'H* and equitability *e*). While these variables were correlated with the humic acid carbon share in total humus carbon in the beech-mixture ecosystems, the most important correlation with optical properties of humic acids ($Q_{4/6}$) was found under the spruce stands. Moreover, the number of mite individuals in the beech-mixture ecosystems was related to optical density (A_{600}) of fulvic acids (Tables 4 and 5).

The comparison of average abundance shows that the community of both plots with beech forest (P13, P14) was quantitatively richer than the community of montane spruce forest at a higher altitude (P18, P20). The average species richness decreases with the altitude gradient whereas the lowest species number and average species richness were found on Plot P20 at the highest elevation. The average species diversity was distinctly lowest on Plot P20, other plots showed a similar level of this character. Distinct concentration of dominance to one eurytopic, cosmopolitan, parthenogenetic and microphytophagous species *Tectocepheus velatus* and an increase in its population density can be observed along the altitude gradient. This species as one of the few oribatid mites is capable to tolerate strong anthropogenic stress colonizing frequently at high dominance localities

Table 5. Correlation coefficients among the studied soil properties (see Table 3 for abbreviations) in the set of samples from Norway spruce forests. Only statistically significant values are typed. The most important values are in bold

	ash1	ash2	T_A400	T_A600	T_Q4/6	FA_A400	FA_A600	FA_Q4/6	HA_A400	HA_A600	HA_Q4/6	T_C_ mg_g	T_N_ mg_g	HA_C_ mg_g
ash1	o	-0.859	-0.857	-0.808	-0.637	-0.865			-0.792	-0.740		**-0.959**	-0.892	-0.865
ash2	–0.859	o	**0.968**	**0.926**		**0.902**	0.672		0.943	0.844		**0.947**	0.875	**0.927**
T_A400	–0.857	**0.968**	o	**0.959**		**0.930**	0.636		0.964	**0.926**		**0.948**	0.799	**0.972**
T_A600	–0.808	**0.926**	**0.959**	o		0.839			0.894	**0.952**		**0.923**	0.713	**0.912**
T_Q4/6	–0.637				o	0.720			0.662				0.695	0.661
FA_A400	–0.865	**0.902**	**0.930**	0.839	0.720	o			**0.962**	0.784		0.897	0.793	**0.939**
FA_A600		0.672	0.636				o							
FA_Q4/6								o						
HA_A400	–0.792	**0.943**	**0.964**	0.894	0.662	**0.962**			o	0.855		0.889	0.763	**0.942**
HA_A600	–0.740	0.844	**0.926**	**0.952**		0.784			0.855	o		0.854	0.635	0.862
HA_Q4/6											o			
T_C mg_g	**–0.959**	**0.947**	**0.948**	**0.923**		0.897			0.889	0.854		o	0.884	**0.947**
T_N mg_g	-0.892	0.875	0.799	0.713	0.695	0.793			0.763	0.635		0.884	o	0.776
HA_C mg_g	–0.865	**0.927**	**0.972**	**0.912**	0.661	**0.939**			0.942	0.862		**0.947**	0.776	o
HA_N mg_g	–0.641	0.669			0.766								0.870	
HA_C_N	–0.708	0.751	0.828	0.862		0.790			0.794	0.784		0.803		0.870
C-HA_T														
Ca mg_g	–0.784	0.852	0.791	0.796		0.674	0.798		0.724	0.770		0.808	0.802	0.664
Mg mg_g	–0.825	0.895	0.789	0.749		0.765	0.688		0.772			0.828	0.895	0.701
P mg_g	**–0.919**	0.860	0.784	0.689	0.716	0.853	0.711		0.786			0.882	**0.932**	0.791
Fe mg_g		0.748	0.645						0.673				0.660	
Al mg_g		0.645	0.730			0.736			0.765					0.812
Individual								–0.681						
h											0.825			
e						0.643					0.823			
dca1														
dca2							0.633							

Table 5 to be continued

	HA_N mg_g	HA_C_N	C-HA_T	Ca mg_g	Mg mg_g	P mg_g	Fe mg_g	Al mg_g	Individual	h	e	dca1	dca2
ash1	-0.641	-0.708		-0.784	-0.825	**-0.919**							
ash2	0.669	0.751		0.852	0.895	0.860	0.748	0.645					
T_A400		0.828		0.791	0.789	0.784	0.645	0.730					
T_A600		0.862		0.796	0.749	0.689							
T_Q4/6	0.766					0.716							
FA_A400		0.790		0.674	0.765	0.853		0.736			0.643		
FA_A600				0.798	0.688	0.711							0.633
FA_Q4/6									-0.681				
HA_A400		0.794		0.724	0.772	0.786	0.673	0.765					
HA_A600		0.784		0.770									
HA_Q4/6										0.825	0.823		
T_C mg_g		0.803		0.808	0.828	0.882							
T_N mg_g	0.870			0.802	0.895	**0.932**	0.660						
HA_C mg_g		0.870		0.664	0.701	0.791		0.812					
HA_N mg_g	o				0.686	0.688							
HA_C_N		o						0.663					
C-HA_T			o					0.812					
Ca mg_g				o	**0.916**	0.780							
Mg mg_g	0.686			**0.916**	o	0.885	0.634						
P mg_g	0.688			0.780	0.885	o							
Fe mg_g					0.634		o	0.638					
Al mg_g		0.663	0.812				0.638	o					
Individual									o		-0.719	-0.633	
h										o	**0.965**		
e									-0.719	**0.965**	o	0.718	
dca1									-0.633		0.718	o	
dca2													o

extremely impacted by human activity like arable soil, early stages of secondary succession, young fallows (Starý 1996, 1999), early stages of primary succession, colliery dumps after brown coal mining (Frouz et al. 2001; Starý 2002) and also plots with extreme soil microclimate and soil chemistry. The extremely high dominance of a single species can indicate the negative impact of a stressor like sparsely stocked forest stand and following soil desiccation as a consequence of the bark beetle gradation in plots P20 and especially in P18. Other plots show the dominance distribution of more eurytopic species, which is a characteristic feature of developed and stabilized oribatid communities.

So far there have been only a few studies on the effect of altitude on the distribution of oribatid mites (Walter 1985; Lamoncha, Crossley 1998; Schatz 1998), but unfortunately none in Central Europe, so our data on this subject in our conditions are very scarce. This phenomenon was studied in other zoogeographical realms and areas. Hasegawa et al. (2006) studied changes in oribatid communities with the altitude gradient in conditions of tropical forest on Mount Kinabalu, Malaysia. The density and species richness of oribatid mites decreased with elevation, but the effects of altitude on density on non-ultrabasic bedrock were less significant than on the ultrabasic substrate. Oribatid density correlates positively with the concentration of soil organic phosphorus and negatively with that of exchangeable Ca in soil. The species richness of oribatid mites positively correlated with phosphorus concentration in litter, aboveground biomass, tree diversity and litter amount and negatively correlated with elevation and Ca in soil. The species composition of oribatid mite communities was quite different from our results because of different zoogeographical realm. Canonical correspondence analysis showed the importance of altitude for the community structure of oribatid mite. A different trend was found in the study of the influence of altitude gradient on soil animals in oak forests in the Moroccan Atlas Mts. (Sadaka, Ponge 2003). There was found a decrease in the population abundance of soil mites according to the altitude gradient. The main effect of altitude was probably an increase in the thickness of soil horizons where most soil mites were living. Reasons for an increased abundance of organic matter at a higher altitude can be found in a decreased rate of microbial decomposition due to a lower soil temperature. Kallimanis et al. (2002) stressed that the altitude does not induce any clear oribatid distribution pattern, acting mostly indirectly through the effect on the formation of local soil and vegetation.

The structure of oribatid mite communities depending on the soil horizon and decomposition stage of litter was studied on an example of Scots pine forest (Berg et al. 1998). Our approach of the total analysis of top-soil cores of defined depth considers all mite individuals as a community (assemblage). The structure of such community depends on the thickness of horizons to present in the sample. It can also be viewed as a local soil feature. This fact is emphasized by comparison with chemical properties of the samples.

CONCLUSIONS

Both the oribatid mite community and top-soil features are distinct in European beech-mixture (in the 6th forest altitudinal zone) and Norway spruce (in the 8th forest altitudinal zone) dominated forest ecosystems.

Relationships among soil chemical properties should be studied in the strictly limited group of sites only, because different correlations occur among several soil features. It is not possible to mix up plots belonging to different forest altitudinal zones. Such a serious difference was found between the 6th and 8th forest altitudinal zone.

Communities of oribatid mites are related to some properties of the top-soil. The most important top-soil features are ash content and releasable Fe concentration in the beech-mixture forests, which would probably be related to different microsites according to the accumulation of litter and/or different plant microcoenosis (sensu Matějka 1992). The community structure can be related to some qualitative features of organic matter in Norway spruce forests. Qualitative parameters of organic material are probably related to the stage of litter decomposition in the microsite.

To neglect spatial variability within a forest ecosystem can lead to omission of important features of soil which indicate major ecosystem processes bound to litter decomposition and chemical element movement.

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Rozdíly vlastností povrchové vrstvy půdy ve smíšených bukových a smrkových lesích Šumavy

ABSTRAKT: Vzorky povrchové vrstvy půdy byly odebrány ze čtyř horských lesních ekosystémů na Šumavě ke srovnání procesů v bukových smíšených lesích (*Fs*) a v lesích s dominancí smrku (*Pa*). Tyto dva typy lesních ekosystémů jsou podmíněné pozicí na výškovém gradientu a výsledky lze tedy interpretovat jako popis rozdílů na výškovém gradientu. Několik chemických vlastností (celkový obsah organické hmoty, vlastnosti huminových kyselin a fulvokyselin, uvolnitelný P, Ca, Mg, Fe a Al) byly srovnávány s druhovou strukturou společenstev pancířníků ve stejných vzorcích. Byly zjištěny výrazné rozdíly mezi oběma typy ekosystémů: obsah Mg (0,42 mg/g v *Fs* ekosystémech ve srovnání s 0,30 mg/g v *Pa* ekosystémech), kvalita organické hmoty (poměr obsahu C huminových kyselin k obsahu C v celkových extrahovatelných humusových látkách byl 0,53 v *Fs* ekosystémech a 0,66 v *Pa* ekosystémech) i množství organické hmoty (například obsah C huminových kyselin byl 59 a 86 mg/g v *Fs* a *Pa* ekosystémech). Rozdílná dynamika dekompozice organické hmoty a transport minerálních prvků vedou k některým opačným korelačním závislostem mezi chemickými vlastnostmi půdy: korelace mezi celkovými a rozpustnými popelovinami (r = +0,96 a –0,86 v *Fs* a *Pa* ekosystémech) a korelace celkové popeloviny – obsah P (r = +0,76 a –0,92 v *Fs* a *Pa* ekosystémech) představují nejvýraznější příklady. Společenstva pancířníků jsou zřetelně odlišná v obou typech ekosystémů. Odhaleny byly rozdílné korelace mezi parametry druhové struktury společenstev pancířníků (například druhová diverzita a elková abundance pancířníků) a chemickými vlastnostmi povrchové vrstvy půdy. To indikuje rozdíly v tom, jaké proměnné jsou determinující pro strukturu společenstev pancířníků ve smíšeném bukovém nebo ve smrkovém lesním ekosystému.

Klíčová slova: obsah popelovin; Šumava; obsah chemických prvků (P, Ca, Mg, Fe, Al); fulvokyseliny; huminové kyseliny; organická hmota; Oribatida

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