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Quality of organic and upper mineral horizons of mature mountain beech stands with respect to herb layer species

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ABSTRACT: The study analyses the chemical properties of the soil in open-canopy beech stands in relation to the predominant species of ground vegetation. A hypothesis is examined whether the predominant ground vegetation species can represent in chemical terms different site conditions. Four localities were used for testing reed grass, myrtle blueberry, wavy hair grass and vegetation-free patches. Samples were taken from three organic horizons (litter (OL), fragmented (OF) and humus (OH)) and from the humic first mineral horizon. Significant differences between the variants were found only in the OL horizon, in which the vegetation species explained 65% of the variability in data. The OL horizon in the vegetation-free variant showed the significantly lowest pH/KCl and the lowest potassium content. The most distinct particular differences were observed between the blueberry variant and the grass variants. Although the studied variants of vegetation growing under the beech stand represented significant differences in the litter horizon chemistry, the effects on the other humus horizons and on the upper mineral horizon were marginal.

Keywords: forest floor; top soil layers; soil chemical characteristics; *Calamagrostis villosa*; *Vaccinium myrtillus*; *Avenella flexuosa*

Soil properties (parent rock material, soil type, soil depth, chemistry, soil moisture content, soil organisms, humus etc.) determine the occurrence, character and development of forest ecosystems (Otto 1994). Soil chemistry is one of the most crucial factors affecting the nutrition and prosperity of plants. Organic horizons are strongly affected by external factors as they constitute the soil compartment which receives the atmospheric inputs first. The quality and role of the organic horizon in forest ecosystems are controlled by several factors such as climate, parent material of soil, topography, biota and time (e.g. Brimhall et al. 1992; Kopp, Schwanecke 1994; Prescott et al. 2000; Montagne et al. 2009).

Ground vegetation accounts for a minor part of the biomass of forest ecosystems but may play an important role in the soil formation and nutrient turnover (Singer, Munns 1996). A considerably important role in the soil cycle is played by higher plants. The influence of plants on the soil environment depends on the rate of biomass growth and accumulation, on rooting depth, amount and composition of root exudates, types of mycorrhiza and soil bacteria, on the abundance and quality of dead material returned into the soil in the form of litter as well as on the conditions for humification (Perry et al. 1995). The effect of tree species on forest soils is well documented (Barbier et al. 2008), fewer studies were written on the effect of ground vegetation species (Perry et al. 1995; Andreasson et al. 2012). Individual plant species require different amount and proportions of nutrients for their growth (Aerts, Chapin 1999; Bruelheide, Udelhoven 2005) but in specific conditions the differences between species can be small (Ingestad 1979; Andreasson et al. 2012). Dominance of particular site-specific undergrowth species (site indicators) is a basis for many forest site classifications including the Czech typological system (e.g. Kopp, Schwanecke 1994; Průša 2001; Viewegh et al. 2003).

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Beech is one of the most abundant species in the potential natural vegetation of Central Europe. Dominant undergrowth species of the acidophilous beech stands of high elevations in Central Europe are mostly represented by the reed grass (*Calamagrostis villosa* (Chaix) J.F. Gmelin; plant nomenclature according to Kubát et al. (2002)), myrtle blueberry (*Vaccinium myrtillus* Linnaeus) and wavy hair grass (*Avenella flexuosa* (Linnaeus) Drejer) (Moravec 1999). Generally, the species show some differences in soil nitrogen requirements – reed grass can be considered as an indicator of very poor nitrogen content (Ellenberg et al. 1992). Furthermore, it is frequently mentioned as a species adversely affecting forest regeneration in the mountains (Madsen, Larsen 1997; Modrý et al. 2004). The knowledge of soil properties in relation to dominant species of the herb layer can improve understanding the plant-soil interactions and also help to interpret the prosperity of natural regeneration and of plantings during forest regeneration.

The aim of the paper is to evaluate whether the absence of forest floor and predominant species of the forest floor vegetation indicate different pedochemical characteristics of organic and upper mineral horizons (top soil horizons) under mature beech woods in the upper mountain conditions (6th and 7th forest vegetation zones according to the Czech forest site classification). The species tested were as follows: reed grass, wavy hair grass and myrtle blueberry, which are the most abundant species of the mountain beech woods of central Europe.

MATERIAL AND METHODS

Study area. The ridges of Jizerské hory Mountains at the northern border of the Czech Republic form a great barrier to the streams of humid and cold air from the ocean in the west and north-west, which is reflected in high precipitation amounts (Vacek et al. 2003). Annual precipitation amounts at higher mountain elevations may reach up to 1,700 mm, mean annual temperature is 4.4°C, mean January temperature can drop down to –7°C and the length of vegetation period is about 100 days (Plíva, Žlábek 1986). Similarly like many other parts of Europe, the region was affected by an air-pollution disaster in the 1970s and 1980s (Borůvka et al. 2005; Klimo et al. 2006). Mature beech stands occur mainly on northern steep slopes, ascending sporadically up to high plains surrounding the rock massifs Ptačí kupy and Ořešník.

In 2004, research was established in the summit part of the Jizerské hory Mts., which was focused on the monitoring of natural regeneration of beech, among other things with respect to the competition of ground vegetation (Špulák 2008). The research work was done on four partial research plots, each sized 0.5–1.0 ha (Table 1). Parent stands were dominated by beech with spruce admixture and with no shrub layer. The sites were acidic spruce and beech forest sites according to the Czech forest site classification (6K, 7K). Average height of the parent stand aged 150–170 years ranged from 20 to 25 m; the tree layer canopy was slightly disturbed. Parent rocks are granites and granodiorites, soils are Entic Podzols (soil taxonomy according to IUSS Working Group WRB 2015) and humus form is eumoder (Zanella et al. 2011).

Table 1. Basic data on the partial research plots

Plot	Altitude (m a.s.l.)	Aspect	Max. slope (°)	Species composition (%)		Basal area ($m^2 \cdot ha^{-1}$)
				Be	Sp	
P. k. I	890–920	NE	18	99	1	26.3
P. k. II	940–950	SW	10	97	3	23.8
P. k. III	880	SW	5	99	1	27.1
Ořešník	790–820	NW	15	98	2	24.2

P. k. – Ptačí kupy, Be – beech, Sp – spruce

Soil sampling. In the autumn of 2004, soil samples were taken from the four partial research plots. Sampling points were chosen at random under the following stands of the herb layer: myrtle blueberry (*Vaccinium myrtillus* – V), wavy hair grass (*Avenella flexuosa* – A) and reed grass (*Calamagrostis villosa* – C) at three levels of grass abundance (low – C_{low} (dry mass of 100–150 $g \cdot m^{-2}$), moderate – C_{mod} (180–230 $g \cdot m^{-2}$) and high – C_{high} (260–320 $g \cdot m^{-2}$)). Stand density of *C. villosa* was differentiated for being the most common weed species of Central European mountain forests with beech. Random sampling for each species was performed on places between the trees where the species was dominant at spots of 4 m^2 in size at least. The sampling localities showed a sporadically occurring initial stage of beech natural regeneration (average number of current year seedlings was 8.9 per m^2 – Špulák 2008). The control variants were covered only by beech litter without undergrowth (beech litter – B).

At each sampling point, the samples were taken from each organic horizon (litter (OL), fragmented (OF) and humus (OH)) and from the humic first mineral horizon (Ah). The soil horizons were distinguished according to the presence of diagnostic properties (e.g. Klinka et al. 1997; Zanella et al. 2011). The total number of soil pits was 111 (Table 2). The size of the soil pits corresponded to a sufficient amount of matter in each analysed horizon (25 × 25 cm in size minimally), the depth varied according to the

Table 2. The number of soil pits in the individual localities and variants ("weed species")

Variant of vegetation cover	Grass abundance	Ptačí kupy I	Ptačí kupy II	Ptačí kupy III	Ořešník	Total
Avenella flexuosa		6	5	1	5	17
	C_{low}	6	4	3	4	17
Calamagrostis villosa	C_{mod}	6	4	6	7	23
	C_{high}	4	4	3	6	17
Vaccinium myrtillus		6	3	4	4	17
Beech litter		7	3	4	6	20
Total		35	23	21	32	111

C_{high} – dry mass of 260–320 g·m^{-2}, C_{low} – dry mass of 100–150 g·m^{-2}, C_{mod} – dry mass of 180–230 g·m^{-2}, total – pits in each locality, each variant and all pits

total depth of analysed horizons. The Ah horizon depth varied from 2 to 5 cm. Soil acidity was classified according to Ulrich (1981), base saturation and available nutrient contents according to guidelines for the classification of forest soils published by Šáňka and Materna (2004).

Soil parameters analysed. The parameters of individual soil horizons (OL, OF, OH and Ah) subjected to analysis were as follows: active and exchangeable acidity, characteristics of the soil sorption complex according to Kappen (1929) (exchangeable bases – S, cation exchange capacity – CEC, hydrolytic acidity, base saturation – BS), total organic carbon (Springer-Klee method, e.g. Ciavatta et al. 1989) and nitrogen (Kjeldahl method, e.g. Kirk 1950) contents. Total carbon was multiplied by the mean coefficient (1.724; Nelson, Sommers 1996) to estimate the organic matter (OM) content. The contents of available nutrients were established from the extract of 1% citric acid (e.g. Jones, Brassington 1998) by the spectrophotometric method (P), flame photometry (K), Ca and Mg by using the method of atomic absorbance spectrophotometry. For the purpose of data presentation, the contents of oxides from the analyses were converted to the contents of individual nutrients. The organic horizons (OL, OF, OH) were also analysed for the total content of nutrients (N, P, K, Ca and Mg) after digestion with sulphuric acid and with selenium as a catalyst (Zbíral 2001).

Statistical analyses. For exploratory purposes, we performed the principal component analysis (PCA) of soil properties in organic horizons. The analysis and ordination diagram were performed in CANOCO 4.5 software (Microcomputer Power, Ithaca, USA; Ter Braak, Šmilauer 2002).

The differences in soil properties between particular variants in particular horizons were analysed by ANOVA, when a simple linear model was used (Eq. 1):

$$y = \beta_0 + \beta_1 \times t_i + \beta_2 \times b_k + \varepsilon_{ik} \quad (1)$$

where:

β_0, β_1, β_2 – coefficients,
t_i – particular variant,
b_k – particular block (locality),
ε_{ik} – normally distributed random errors.

We considered the mean value for a particular variant in a particular block as a quasi-experimental unit (6 × 4 = 24 experimental units), thus we calculated ANOVA with $(t-1) \times (b-1) = 15$ residual degrees of freedom. Moreover, we calculated the least significant differences (LSD) at 5% level from residual standard errors in ANOVA table. Planned linear contrasts for testing the particular differences of interest (Table 3) were used instead of more common but less testifying multiple comparison methods (Nelder 1971; Finney 1988; Mead et al 2012). Because of the semi-quantitative nature (ordinal

Table 3. Planned linear contrasts tested

Contrast	Subject of testing
L1	difference in soil properties between control and plant cover variants, B vs. mean of (A, V, C_{low}, C_{mod}, C_{high})
L2	difference in soil properties between blueberry and grass cover variants, V vs. mean of (A, C_{low}, C_{mod}, C_{high})
L3	difference in soil properties between hair grass and reed grass cover variants, A vs. mean of (C_{low}, C_{mod}, C_{high})
L4	linear relationship between density of reed grass and soil properties
L5	quadratic relationship between density of reed grass and soil properties

A – *Avenella flexuosa*, B – beech litter, C – *Calamagrostis villosa*, C_{high} – dry mass of 260–320 g·m^{-2}, C_{low} – dry mass of 100–150 g·m^{-2}, C_{mod} – dry mass of 180–230 g·m^{-2}, V – *Vaccinium myrtillus* scale) of reed grass cover categories, dummy variables were used in the statistical models of linear (L4) and quadratic (L5) contrasts. The analyses were performed in R software (R Development-Core Team 2015).

RESULTS

In the OL horizon, the first two principal (ordination) axes from PCA explain 65% of data variability (Fig. 1). The PCA ordination diagram shows the obviously increasing acidity and N content and the decreasing BS and K content with the decreasing density of reed grass stands. The highest acidity along with the lowest BS and the lowest K content was found in the stand covered exclusively with beech litter (B variant). The V variant was characterized by the highest Ca content and by the highest S and CEC values. The lowest contents of Ca and S were detected in the A variant.

In the OF horizon, the first two principal axes explain 67% of variability (Fig. 1). Similar to OL horizon, with decreasing density of reed grass the diagram indicates increasing acidity and also decreasing P content, however the differences in the ordination of variants are rather small. The B variant could be lower in BS and V higher in OM. The first two principal axes in OH horizon explain 69% of variability. The diagram indicates higher OM and CEC values in V variant, and lower values in A variant. Distribution of the other variants is close to each other.

The soil under all analysed stand variants was extremely acidic (Table 4). The lowest acidity (pH/H_2O) in OL horizon was recorded in the C_{high} variant. The exchangeable pH/KCl of the B variant was significantly lower than in the variants with herbaceous cover ($P = 0.02$) (Tables 4 and 7).

The cation exchange capacity of the analysed soil was in the category of very high values. In all horizons, the CEC value was significantly higher in the V variant than in the other variants of the herbaceous cover ($P < 0.001$, Tables 4 and 7), differences in S value were confirmed in OL horizon only. Analysing reed grass density, a negative linear relationship with CEC value and a positive relationship with base saturation were found. The Ah horizon values indicated very low base saturation (Table 4). In the OM content, the B variant showed significantly lower values in OL horizon compared to plant cover variants ($P = 0.02$, Table 7).

The content of total N was generally high (Table 5). With lower probability, in OL horizon it was higher in the V variant as compared with the other her-

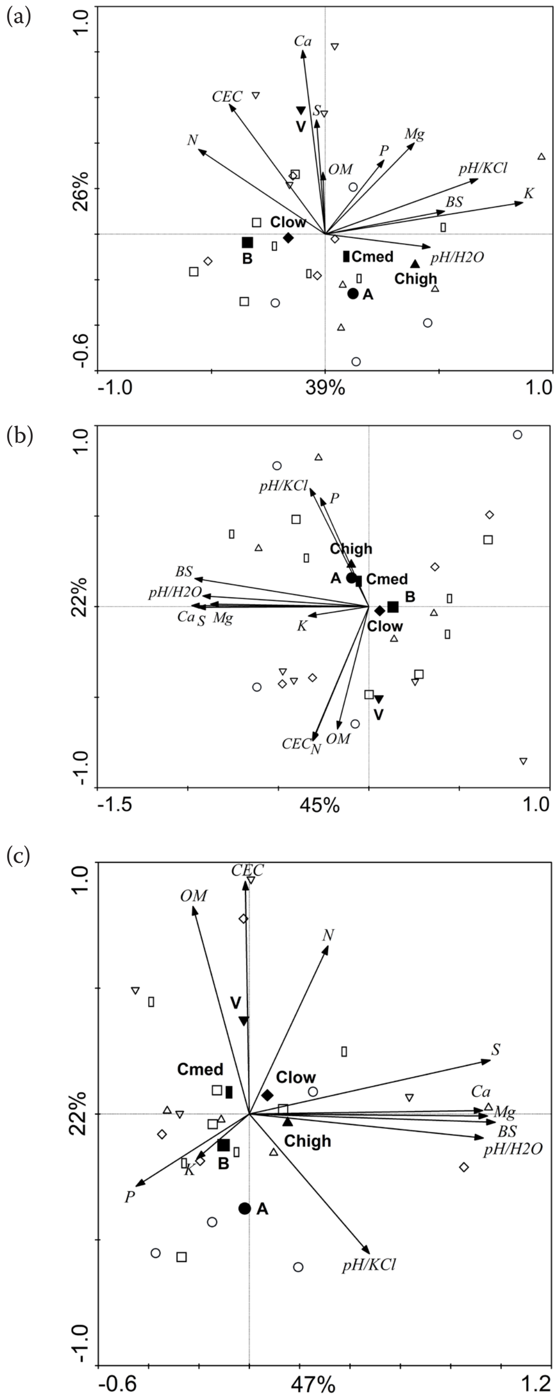

Fig. 1. Ordination diagrams from the principal component analysis (PCA) of litter (a), fragmented (b), humus (c) organic horizons. The percentages depict variability represented by the first and second principal axes. Open symbols denote particular units for particular variants. Solid symbols denoting centroids for particular variants are passively added to the diagram (they do not affect PCA anyhow)

A – *Avenella flexuosa*, B – beech litter, BS – base saturation, C – *Calamagrostis villosa*, C_{high} – dry mass of 260 to 320 g·m^{-2}, C_{low} – dry mass of 100–150 g·m^{-2}, C_{mod} – dry mass of 180–230 g·m^{-2}, CEC – cation exchange capacity, OM – organic matter content, S – exchangeable bases, V – *Vaccinium myrtillus*

Table 4. Soil acidity, soil sorption complex characteristics and organic matter (OM) content in the respective variants and horizons

	Variant of vegetation cover	OL			OF			OH			Ah		
		Mean	SEM	LSD	Mean	SEM	LSD	Mean	SEM	LSD	Mean	SEM	LSD
pH/H_2O	A	4.9	0.13	0.39	4.0	0.08	0.24	3.7	0.06	0.18	3.7	0.06	0.19
	C_{low}	4.7			3.9			3.7			3.6		
	C_{mod}	4.8			3.9			3.6			3.6		
	C_{high}	5.0			3.9			3.8			3.7		
	V	4.8			3.8			3.6			3.7		
	B	4.7			3.9			3.7			3.7		
pH/KCl	A	4.1	0.07	0.22	3.3	0.09	0.26	3.3	0.05	0.16	3.2	0.07	0.21
	C_{low}	4.1			3.2			3.2			3.2		
	C_{mod}	4.2			3.3			3.2			3.1		
	C_{high}	4.2			3.4			3.3			3.3		
	V	4.1			3.2			3.2			3.2		
	B	4.0			3.3			3.2			3.2		
BS (%)	A	58.2	1.73	5.21	25.6	1.32	3.96	17.3	1.27	3.82	16.0	1.00	3.00
	C_{low}	56.3			24.2			17.9			15.0		
	C_{mod}	58.2			25.6			15.8			16.0		
	C_{high}	63.3			27.8			18.4			17.0		
	V	58.6			21.6			14.9			14.0		
	B	55.0			21.9			14.8			15.0		
CEC (meq·100 g^{-1})	A	45.5	2.20	6.62	74.8	2.52	7.61	54.9	1.80	5.43	34.0	1.40	4.20
	C_{low}	54.9			72.0			60.8			41.0		
	C_{mod}	49.3			71.9			61.8			36.0		
	C_{high}	46.6			69.8			59.2			37.0		
	V	61.4			82.2			67.1			41.0		
	B	56.3			78.9			59.3			36.0		
S (meq·100 g^{-1})	A	26.7	1.44	4.35	19.6	1.35	4.06	9.2	0.64	1.94	5.0	0.40	1.20
	C_{low}	31.1			18.1			10.6			6.0		
	C_{mod}	28.9			18.5			9.8			6.0		
	C_{high}	29.9			18.9			10.9			6.0		
	V	36.0			18.2			10.1			6.0		
	B	30.8			16.9			8.8			5.0		
OM (%)	A	59.0	1.60	4.83	54.4	1.68	5.07	47.4	1.41	4.26	30.0	2.30	6.80
	C_{low}	62.5			58.6			49.4			37.0		
	C_{mod}	59.7			57.2			49.6			32.0		
	C_{high}	61.3			58.1			48.2			31.0		
	V	62.2			59.6			51.9			37.0		
	B	56.6			56.6			46.8			34.0		

A – *Avenella flexuosa*, Ah – humic first mineral horizon, B – beech litter, BS – base saturation, C – *Calamagrostis villosa*, C_{high} – dry mass of 260–320 g·m^{-2}, C_{low} – dry mass of 100–150 g·m^{-2}, C_{mod} – dry mass of 180–230 g·m^{-2}, CEC – cation exchange capacity, LSD – least significant difference, OF – fragmented organic horizon, OH – humus organic horizon, OL – litter organic horizon, S – exchangeable bases, SEM – standard error of the mean, V – *Vaccinium myrtillus*

Table 5. Nitrogen content according to Kjeldahl and the contents of available nutrients in the respective variants and horizons

	Variant of vegetation cover	Horizons											
		OL			OF			OH			Ah		
		Mean	SEM	LSD	Mean	SEM	LSD	Mean	SEM	LSD	Mean	SEM	LSD
N (%)	A	1.595			1.888			1.693			1.060		
	C_{low}	1.678			1.868			1.786			1.110		
	C_{mod}	1.540	0.069	0.208	1.908	0.048	0.145	1.789	0.056	0.170	1.080	0.071	0.215
	C_{high}	1.480			1.895			1.847			1.090		
	V	1.725			1.943			1.778			1.120		
	B	1.698			1.868			1.746			1.180		
P (mg·kg^{-1})	A	276			133			166			156		
	C_{low}	214			129			166			125		
	C_{mod}	248	34.8	105.0	167	18.5	55.7	186	14.2	42.9	143	11.1	33.4
	C_{high}	252			163			163			141		
	V	250			112			142			134		
	B	238			144			163			145		
K (mg·kg^{-1})	A	1,806			519			205			117		
	C_{low}	1,578			382			176			117		
	C_{mod}	1,576	236.5	712.8	540	88.6	267.1	196	18.5	55.9	119	11.0	33.3
	C_{high}	2,030			572			191			112		
	V	1,570			399			174			120		
	B	1,239			379			189			117		
Ca (mg·kg^{-1})	A	4,068			1,961			243			128		
	C_{low}	4,450			2,031			485			164		
	C_{mod}	4,441	188.9	569.5	2,241	198.0	596.9	366	104.5	315.0	169	25.7	77.5
	C_{high}	4,129			2,046			475			157		
	V	5,699			1,988			364			124		
	B	4,662			1,622			245			140		
Mg (mg·kg^{-1})	A	614			560			117			69		
	B	588			274			97			63		
	C_{low}	579	45.3	136.5	433	62.6	188.7	195	45.5	137.1	61	7.1	21.4
	C_{mod}	666			412			138			68		
	C_{high}	686			442			194			58		
	V	726			392			151			50		
	B	588			274			97			63		

A – *Avenella flexuosa*, Ah – humic first mineral horizon, B – beech litter, C – *Calamagrostis villosa*, C_{high} – dry mass of 260–320 g·m^{-2}, C_{low} – dry mass of 100–150 g·m^{-2}, C_{mod} – dry mass of 180–230 g·m^{-2}, LSD – least significant difference, OF – fragmented organic horizon, OH – humus organic horizon, OL – litter organic horizon, SEM – standard error of the mean, V – *Vaccinium myrtillus*

Table 6. Total contents of nutrients in the respective variants and horizons (in %)

	Variant of vegetation cover	Horizons								
		OL			OF			OH		
		Mean	SEM	LSD	Mean	SEM	LSD	Mean	SEM	LSD
P	A	0.060	0.006	0.018	0.090	0.007	0.021	0.130	0.010	0.031
	C_{low}	0.060			0.080			0.120		
	C_{mod}	0.070			0.100			0.130		
	C_{high}	0.070			0.100			0.140		
	V	0.060			0.100			0.110		
	B	0.060			0.090			0.120		
K	A	0.270	0.031	0.093	0.230	0.013	0.040	0.305	0.016	0.048
	C_{low}	0.230			0.170			0.255		
	C_{mod}	0.240			0.190			0.293		
	C_{high}	0.300			0.210			0.273		
	V	0.210			0.180			0.243		
	B	0.190			0.200			0.293		
Ca	A	0.580	0.059	0.177	0.040	0.035	0.105	0.004	0.002	0.007
	C_{low}	0.510			0.090			0.009		
	C_{mod}	0.520			0.060			0.007		
	C_{high}	0.460			0.090			0.006		
	V	0.660			0.090			0.004		
	B	0.520			0.060			0.006		
Mg	A	0.090	0.006	0.017	0.060	0.023	0.069	0.025	0.006	0.018
	C_{low}	0.080			0.070			0.023		
	C_{mod}	0.090			0.080			0.019		
	C_{high}	0.090			0.060			0.024		
	V	0.090			0.110			0.024		
	B	0.080			0.050			0.025		

A – *Avenella flexuosa*, B – beech litter, C – *Calamagrostis villosa*, C_{high} – dry mass of 260–320 g·m^{-2}, C_{low} – dry mass of 100–150 g·m^{-2}, C_{mod} – dry mass of 180–230 g·m^{-2}, LSD – least significant difference, OF – fragmented organic horizon, OH – humus organic horizon, OL – litter organic horizon, SEM – standard error of the mean, V – *Vaccinium myrtillus*

baceous variants (P = 0.07) and a negative linear relationship between N and reed grass density was also indicated (P = 0.06, Table 8).

Comparing total nutrient contents (Table 6), in OH horizon significantly lower P and K contents were found in V variant compared to the other plant cover variants (Table 9). On the other hand, V variant was higher in Ca content (P = 0.05).

As to available nutrients, a higher content of Ca was found in the litter of the V variant in OL horizon (P < 0.001), and the B variant was lower in Mg content in OF horizon (P = 0.02). A lower K content in the OL horizon of the B variant was only suggested (P = 0.09; Tables 5 and 8).

DISCUSSION

Metabolism within the plant-soil system occurs both through the uptake of soil solution by plants and through the litterfall of dead plant residues and their humification (Singer, Munns 1996). A range of factors can characterize litter quality as well as features of individual soil horizons. Many works are focused on studying the effect of woody plants on the formation and properties of the forest floor (e.g. Augusto et al. 2003; Ritter et al. 2003; Hagen-Thorn et al. 2004; Pérez-Bejarano 2010; Kacálek et al. 2013; Ulbrichová et al. 2014). Studies dealing with herbaceous species beneath forest stands are scarce, mostly concerning the species abundance in relation to tree layer parameters (e.g. Martinák et al. 2014). However, the fact that differences in ground vegetation communities of stands even of similar structure can address different soil properties (Mataji et al. 2010) is a basis for forest site quality classifications.

Differences in the nutrient contents of some dominant herbaceous species were studied in various stands (e.g. Peřina, Květ 1975; Svoboda et al. 2006; Kuklová, Kukla 2008; Andreasson et al. 2012). For example Peřina and Květ (1975) found in spruce stands a conspicuously higher content of Ca^{2+} in the vegetative organs of myrtle blueberry as

Table 7. Tests of planned linear contracts for soil acidity, soil sorption complex characteristics and organic matter (OM) content

	Con-	OL			OF			OH			Ah		
	trast	Diff	SED	*P*	Diff	SED	*P*	Diff	SED	*P*	Diff	SED	*P*
pH/H_2O	L1	0.15	0.140	0.314	0.02	0.089	0.842	0.01	0.064	0.838	–0.04	0.068	0.577
	L2	0.06	0.143	0.662	0.13	0.091	0.176	0.06	0.065	0.407	–0.08	0.070	0.296
	L3	–0.07	0.148	0.634	–0.10	0.094	0.295	–0.06	0.067	0.348	–0.04	0.072	0.586
	L4	0.27	0.181	0.156	0.07	0.115	0.537	0.09	0.082	0.303	0.10	0.088	0.267
	L5	0.07	0.157	0.684	0.01	0.099	0.931	0.11	0.071	0.150	0.09	0.076	0.265
pH/KCl	L1	0.19	0.079	***0.028***	0.00	0.094	1.000	0.05	0.060	0.446	–0.01	0.078	0.870
	L2	0.00	0.080	0.982	0.09	0.096	0.375	0.05	0.061	0.443	–0.02	0.079	0.814
	L3	0.08	0.083	0.326	–0.03	0.099	0.741	–0.09	0.063	0.153	0.00	0.082	0.994
	L4	0.16	0.101	0.147	0.14	0.121	0.266	0.09	0.077	0.238	0.12	0.100	0.233
	L5	–0.04	0.088	0.636	0.00	0.105	0.981	0.08	0.067	0.273	0.11	0.087	0.213
BS (%)	L1	3.89	1.894	*0.058*	3.09	1.441	***0.049***	2.07	1.390	0.157	0.50	1.095	0.658
	L2	0.42	1.933	0.831	4.14	1.470	***0.013***	2.38	1.418	0.114	2.22	1.118	*0.065*
	L3	1.03	1.997	0.615	0.29	1.519	0.850	0.11	1.465	0.941	–0.13	1.154	0.914
	L4	7.03	2.446	***0.012***	3.53	1.860	*0.078*	0.53	1.794	0.773	2.22	1.414	0.137
	L5	1.61	2.118	0.458	0.44	1.611	0.790	2.29	1.554	0.161	0.12	1.224	0.924
CEC (meq·100 g^{-1})	L1	–4.75	2.406	*0.067*	–4.79	2.765	0.104	1.42	1.972	0.483	1.57	1.542	0.325
	L2	–12.28	2.456	***< 0.001***	–10.11	2.822	***0.003***	–7.90	2.013	***0.001***	–3.72	1.574	***0.032***
	L3	4.73	2.537	*0.082*	–3.62	2.915	0.234	5.71	2.079	***0.015***	3.82	1.626	***0.033***
	L4	–8.30	3.107	***0.017***	–2.23	3.570	0.542	–1.57	2.546	0.546	–4.27	1.991	***0.049***
	L5	1.50	2.691	0.585	–1.04	3.092	0.742	–1.76	2.205	0.438	3.31	1.724	*0.074*
S (meq·100 g^{-1})	L1	–0.32	1.580	0.845	1.79	1.476	0.244	1.31	0.705	*0.083*	0.36	0.432	0.414
	L2	–6.80	1.613	***0.001***	0.58	1.507	0.705	–0.01	0.719	0.990	0.23	0.441	0.614
	L3	3.23	1.665	*0.071*	–1.06	1.556	0.507	1.19	0.743	0.130	0.45	0.455	0.337
	L4	–1.15	2.040	0.581	0.85	1.906	0.662	0.32	0.910	0.729	–0.10	0.557	0.857
	L5	1.55	1.766	0.394	0.03	1.651	0.988	0.95	0.788	0.249	0.38	0.483	0.445
OM (%)	L1	4.35	1.754	***0.026***	1.03	1.843	0.586	2.50	1.548	0.127	–1.17	2.476	0.642
	L2	–1.57	1.790	0.395	–2.53	1.881	0.198	–3.26	1.580	*0.057*	–4.36	2.527	0.105
	L3	2.14	1.849	0.265	3.53	1.943	*0.090*	1.64	1.632	0.331	3.81	2.609	0.165
	L4	–1.18	2.264	0.611	–0.53	2.379	0.828	–1.18	1.999	0.565	–6.18	3.196	*0.072*
	L5	2.24	1.961	0.272	1.16	2.061	0.581	–0.84	1.731	0.633	2.62	2.768	0.359

Ah – humic first mineral horizon, BS – base saturation, CEC – cation exchange capacity, Diff – difference, L1–L5 – see Table 3, OF – fragmented organic horizon, OH – humus organic horizon, OL – litter organic horizon, S – exchangeable bases, SED – standard error of the difference, *P*-values lower than 0.1 are in italics, *P*-values lower than 0.05 are in bold italics

compared with the organs of wavy hair grass. Also Svoboda et al. (2006) reported higher Ca and Mg but lower P contents in the leaves and annual shoots of myrtle blueberry as compared with wavy hair grass and reed grass in the same spruce forest stands. In line with this finding, our results confirmed higher Ca content in the litter horizon under myrtle blueberry as compared with the other variants (Tables 5 and 6). As compared with the other herbaceous variants, the myrtle blueberry litter was specific also in other parameters (Tables 6–9). In spite of that, the differences in the chemical composition of litter did not persist in deeper horizons.

Andreasson et al. (2012) found out differences in soil parameters beneath two beech stands, the one with homogeneous monospecific undergrowth of *A. flexuosa* and the other with *Anemone nemorosa* Linnaeus. In their study spots without vegetation had the lower pH of the top soil, which corresponds with our outcomes (Table 4). In the *A. flexuosa* stand they also found a higher content of organic matter than under places without ground flora. Studying the effect of beech litter and myrtle blueberry undergrowth on the chemistry of humus horizons in central Italy also Levi-Minzi et al. (2000) revealed higher contents of organic carbon and nitrogen in humus horizons under blueberry stands. The higher contents of nitrogen correspond with the observed values in organic horizons under the V and B variants in our study (Table 4). In line with our study, differences in the other chemi-

Table 8. Tests of planned linear contracts for nitrogen content and contents of available nutrients

	Con-	OL			OF			OH			Ah		
	trast	Diff	SED	*P*	Diff	SED	*P*	Diff	SED	*P*	Diff	SED	*P*
N (%)	L1	−0.094	0.076	0.232	0.033	0.053	0.547	0.033	0.062	0.605	−0.090	0.078	0.271
	L2	−0.152	0.077	*0.068*	−0.053	0.054	0.339	0.000	0.063	0.995	−0.030	0.080	0.676
	L3	−0.029	0.080	0.719	0.003	0.056	0.965	0.114	0.065	*0.099*	0.040	0.083	0.661
	L4	−0.198	0.098	*0.061*	0.028	0.068	0.692	0.061	0.080	0.457	−0.020	0.101	0.838
	L5	0.039	0.084	0.653	−0.026	0.059	0.662	0.027	0.069	0.697	0.022	0.088	0.805
P ($mg\cdot kg^{-1}$)	L1	10.2	38.16	0.794	−3.2	20.25	0.877	1.3	15.59	0.937	−5.2	12.14	0.674
	L2	−2.3	38.95	0.953	36.0	20.67	0.102	28.4	15.91	*0.094*	7.4	12.39	0.558
	L3	−38.4	40.22	0.355	20.3	21.35	0.356	6.3	16.43	0.709	−19.8	12.80	0.142
	L4	38.3	49.26	0.450	34.0	26.14	0.213	−3.5	20.12	0.864	16.2	15.68	0.318
	L5	−15.6	42.66	0.719	−20.5	22.64	0.380	−21.8	17.43	0.231	−9.4	13.58	0.501
K ($mg\cdot kg^{-1}$)	L1	473.1	259.03	*0.088*	103.8	97.06	0.302	−0.3	20.32	0.988	0.1	12.09	0.993
	L2	176.9	264.37	0.514	103.8	99.06	0.311	18.4	20.73	0.389	−4.2	12.34	0.740
	L3	−78.4	273.04	0.778	−20.6	102.31	0.843	−17.5	21.41	0.427	−1.6	12.74	0.902
	L4	452.3	334.40	0.196	189.3	125.30	0.152	14.8	26.23	0.582	−5.2	15.60	0.743
	L5	228.1	289.60	0.443	−63.1	108.51	0.569	−13.1	22.71	0.572	−4.8	13.51	0.728
Ca ($mg\cdot kg^{-1}$)	L1	−104.5	207.00	0.621	431.5	216.92	*0.065*	141.9	114.47	0.234	8.1	28.17	0.779
	L2	−1427.6	211.20	< ***0.001***	81.8	221.39	0.717	28.0	116.83	0.814	30.0	28.75	0.313
	L3	271.9	218.20	0.232	144.8	228.65	0.536	198.7	120.66	0.120	35.3	29.70	0.253
	L4	−321.2	267.20	0.248	14.8	280.04	0.959	−9.8	147.78	0.948	−7.5	36.37	0.841
	L5	−151.6	231.40	0.522	−202.9	242.52	0.416	113.9	127.98	0.388	−8.3	31.50	0.795
Mg ($mg\cdot kg^{-1}$)	L1	66.6	49.60	0.200	173.3	68.56	***0.023***	62.0	49.83	0.233	−2.1	7.77	0.787
	L2	−89.6	50.63	*0.097*	69.1	69.97	0.339	10.3	50.86	0.843	13.9	7.93	0.101
	L3	29.5	52.29	0.581	−131.5	72.27	*0.089*	59.3	52.53	0.276	−6.5	8.19	0.442
	L4	107.5	64.04	0.114	9.0	88.51	0.920	−0.8	64.33	0.991	−2.9	10.03	0.780
	L5	−33.0	55.46	0.561	25.5	76.65	0.744	56.4	55.71	0.328	−8.9	8.69	0.320

Ah – humic first mineral horizon, Diff – difference, L1–L5 – see Table 3, OF – fragmented organic horizon, OH – humus organic horizon, OL – litter organic horizon, SED – standard error of the difference, *P*-values lower than 0.1 are in italics, *P*-values lower than 0.05 are in bold italics

cal composition of top soil layers recorded by Levi-Minzi et al. (2000) were not confirmed.

Bonifacio et al. (2008) studied the effect of different vegetation on the content of organic carbon in the OH horizon in a spruce stand in the Krkonoše Mountains. Different vegetation affected carbon content as well as the content of humic acids, however with statistically nonsignificant differences between the species *V. myrtillus* and *A. flexuosa*. Mařan and Káš (1948) informed that the species of the genus *Vaccinium* feature a very slow decomposition of litter, which then accumulates. Slow decomposition can be the reason why the specific properties of *V. myrtillus* litter did not directly affect the properties of deeper soil horizons in our study.

Peřina and Květ (1975) reported an intensive withdrawal of all nutrients by the reed grass. The accumulation of nutrients in the reed grass biomass and the elimination of adverse processes connected with soil acidification by reed grass stands were confirmed also in open forests and on a clear-cut area (Fiala et al. 2005; Mládková et al. 2005). On the other hand, the statistical tests in our study showed no differences in the chemistry of top soil horizons between the reed grass and wavy hair grass variants. However, the BS parameter was significantly increasing with the increasing reed grass stand density.

Bruelheide and Udelhoven (2005) compared the soil properties of samples taken at a depth of 5 cm beneath ground vegetation species in beech forest on acid soil types and in accordance with our findings in OF, OH and Ah horizons, they stated a low contribution of top soil parameters to explaining the floristic variation of ground vegetation. Due to vegetation dynamics there can be a delay in the indicative value of the plant community (Kopp 1987; Konopatzky 1995).

We recorded a high content of total nitrogen in the locality that is likely to be related to the generally increased deposition of nitrogen due to combustion of fossil fuels and use of fertilizers (Janssens et al. 2010). The monitored plant species are considered as species indicating low to very low nitrogen content (e.g. Ellenberg et al. 1992). However,

Table 9. Tests of planned linear contracts for the total contents of nutrients (in %)

	Contrast	OL			OF			OH		
		Diff	SED	*P*	Diff	SED	*P*	Diff	SED	*P*
P	L1	0.003	0.007	0.660	0.003	0.007	0.741	0.007	0.011	0.541
	L2	0.004	0.007	0.591	–0.009	0.008	0.236	0.024	0.011	***0.049***
	L3	0.008	0.007	0.255	–0.003	0.008	0.754	< 0.001	0.012	0.945
	L4	0.008	0.009	0.398	0.015	0.010	0.139	0.013	0.014	0.400
	L5	0.001	0.007	0.869	–0.008	0.008	0.381	–0.001	0.013	0.922
K	L1	0.056	0.034	0.119	–0.002	0.015	0.893	–0.019	0.018	0.296
	L2	0.048	0.035	0.184	0.019	0.015	0.215	0.039	0.018	***0.047***
	L3	–0.013	0.036	0.731	–0.037	0.015	***0.028***	–0.032	0.019	0.108
	L4	0.070	0.044	0.130	0.040	0.019	*0.052*	0.018	0.023	0.452
	L5	0.023	0.038	0.561	< 0.001	0.016	1.000	–0.029	0.020	0.164
Ca	L1	0.030	0.064	0.654	0.018	0.038	0.647	< 0.001	0.003	0.968
	L2	–0.141	0.066	***0.048***	–0.024	0.039	0.541	0.003	0.003	0.313
	L3	–0.085	0.068	0.300	0.036	0.040	0.389	0.004	0.003	0.231
	L4	–0.055	0.083	0.518	–0.001	0.049	0.988	0.004	0.003	0.257
	L5	–0.038	0.072	0.610	0.029	0.043	0.501	< 0.001	0.003	0.824
Mg	L1	0.010	0.006	0.155	0.023	0.025	0.375	–0.002	0.007	0.749
	L2	–0.007	0.007	0.305	–0.038	0.026	0.159	–0.001	0.007	0.837
	L3	0.001	0.007	0.903	0.006	0.027	0.819	–0.003	0.007	0.718
	L4	0.010	0.008	0.241	–0.017	0.033	0.619	0.001	0.008	0.906
	L5	–0.003	0.007	0.729	–0.010	0.028	0.740	0.005	0.007	0.542

Diff – difference, L1–L5 – see Table 3, OF – fragmented organic horizon, OH – humus organic horizon, OL – litter organic horizon, SED – standard error of the difference, *P*-values lower than 0.1 are in italics, *P*-values lower than 0.05 are in bold italics

they seem to be tolerant to its content because they are still a dominant constituent of the herbaceous layer. Nevertheless, this might also be related to the above-mentioned vegetation dynamics. Delay until the ground vegetation changes can be caused e.g. by a potentially missing seed reservoir of better adapted species.

Validated differences in some top soil parameters beneath the analysed dominant species of the mountain beech forest floor vegetation can specify roles of the species in forest site quality mapping systems. From the chemical point of view of the OL layer, at least myrtle blueberry and reed grass deserve to be differentiation species of mountain site units of Central European forest site quality mapping systems. Considering reed grass, distinguishing at least two densities of the stand would also be effective, but hardly applicable in forest practice.

CONCLUSIONS

Our research of the relation between the dominant species of ground vegetation and some characteristics of the forest organic floor and Ah horizon in mountain beech stands with open canopy revealed differences between the analysed variants mostly at the level of OL horizon. Beech litter in the variant without herbaceous cover exhibited significantly lower pH/KCl and potassium contents as compared to the variants with vegetation. The most conspicuous differences were found between the myrtle blueberry variant and the assessed variants of grasses as shown for example by the significantly higher content of exchangeable bases and the maximum sorption capacity given by higher calcium and magnesium contents under the blueberry stand. A positive relationship between the base saturation in the OL horizon and the reed grass stand density was also recorded.

The studied variants of dominant ground vegetation under the beech stand markedly affected the OL horizon chemistry; their impact on the other organic horizons and the upper organomineral horizon was limited, though. Our research documents that in the mountain beech forests the effect of the herb layer species on the soil chemistry is small.

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