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Humus conditions of stands with different proportion of Douglas fir in the Hůrky Training Forest District and Křtiny Training Forest Enterprise

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ABSTRACT: The paper presented evaluates reserves and chemical composition of forest floor of three stands of Douglas fir, spruce and spruce with beech at acid sites (3K) in the Hůrky Training Forest District (TFD) and at a mesotrophic site (4H) in the Křtiny Training Forest Enterprise (TFE). The aim of the study was to evaluate: (*i*) reserves of forest floor, (*ii*) soil reaction, (*iii*) total content of carbon and nitrogen for the forest floor layers, (*iv*) C/N ratio, and (*v*) the content of dissolved organic carbon (DOC). The lowest reserve occurs in the Douglas fir stand at a mesotrophic site (25.0 t/ha), the highest accumulation occurs in the spruce stand and in the spruce/beech stand at an acid site (79.4–79.6 t/ha). The soil reaction is strongly acid to acid. The most favourable values of pH for forest floor and soil at acid (4.6 ± 0.4) and mesotrophic sites (5.2 ± 0.4) occur in the Douglas fir stand. It also corresponds to C/N ratio (23–26). The highest reserve of carbon in forest floor occurs at the acid site 34.7 t/ha (1.3 t/ha nitrogen). The lowest reserve of carbon in forest floor at the mesotrophic site amounts to 8.5 t/ha (0.4 t/ha nitrogen). The higher content of DOC in stands at acid sites can result in a higher risk of soil acidification.

Keywords: species composition; soil; forest floor reserves; pH; carbon and nitrogen; C/N ratio; DOC

A long-term deviation from the natural species composition of our forests resulted in marked changes in the relative tree species composition where coniferous species began to predominate in the species composition at the expense of broadleaved species. The changes mostly affected the natural distribution of beech, the proportion of which decreased from the original 40.2% to the present 6.9%. On the other hand, the proportion of spruce increased from the original 11.2% to the present 52.8% (MZE 2008).

Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco) is evidently rightly considered to be the most important and perspective introduced species in the Czech Republic. It is given by more than 150-year tradition of its growing in this country and its potential to grow up very well at acid, mesotrophic and gleyed sites of the 2nd to the 5th forest vegetation zone. As a rule, Douglas fir also naturally regenerates there creating mixtures with a number of autochthonous species. For its dynamic intensive growth (Bušina 2007) it is an optimum species for repair or enrichment planting already at an early age. Above all, it is necessary to stress its quite exceptional production potential markedly exceeding all domestic conifers

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(Čermák et al. 2007; Kantor 2008). At present, however, only about 4,400 ha of Douglas fir stands are recorded in the Czech Republic (0.18% forests in the CR), which is e.g. 50% less than mountain pine stands and 3× less than stands of blue spruce or robinia (MZE 2008).

In the modern conception of forest ecology and forest soil science, forest floor and humus horizons are important parts of the forest ecosystem from the aspect of preserving the element cycle in forest ecosystems and maintaining their ecological stability. The condition and forms of humus in forest management are among crucial factors affecting the condition and growth of forest stands. In the course of the last century, this fact was mentioned by prominent authors in the field of forest pedology, such as Němec (1928), Mařan and Káš (1948), Pelíšek (1964), Šály (1977, 1978). Humus represents a place of the main accumulation of carbon in the majority of terrestrial ecosystems. Because it remains unoxidized for centuries there, it becomes an important long-term reservoir of carbon in an ecosystem (Waring, Running 1998). It is considered to be the source of carbon and nitrogen for plants and soil organisms, which is the role of dissolved organic carbon (Magill, Aber 2000) as well as the reservoir of carbon and nitrogen, which enters into soil from forest floor (Yano et al. 2000).

The function of forest floor within the soil profile can be considered as fundamental. The decomposition of plant and animal material and subsequent release of nutrients into the soil environment take place there. Thus, the result of humification is the differentiation of forest floor horizons – forest litter, mull and soil skeleton where particular processes of decomposition, mineralization and humification take place (Sparks 2003). The decomposition of dead rhizosphere (or soil biota) and organic excrements takes place in the organo-mineral horizon. Further, synthesized humus substances from surface layers penetrate there (Samec, Formánek 2007). Forest floor is separated from lower layers of mineral soil both parts of soil being, however, further divided (Waring, Running 1998). Under the purely organic forest floor, a surface humus horizon occurs where the organic part is inseparably mixed and fixed with the mineral component of soil (Ah horizon) (Green et al. 1993).

The forest floor is important particularly in the forest soil hydrology where it functions as a regulator of runoff rainfall water, decreases the hazard of floods in piedmont and lowland regions, intercepts large amounts of rainfall water penetrating through crowns of stands and releases the water into underlying soil layers to increase ground water reserves, decides on runoff, evaporation and groundwater flow (Kantor, Šach 2008). It also regulates temperature conditions in such a way that through the increased content of air it acts as an insulator reducing temperature fluctuations in soils between day and night and in the particular seasons (Pelíšek 1964).

The aim of the study was to evaluate the reserves and chemical composition of forest floor (soil reaction, content and reserves of total carbon and nitrogen, C/N ratio and the content of DOC) in Douglas fir, spruce and spruce/beech stands at acid sites (3K) in the Hůrky Training Forest District (TFD) and at a mesotrophic site (4H) in the Křtiny Training Forest Enterprise (TFE).

MATERIAL AND METHODS

Site and stand description

The Hůrky TFD ranks among South-Bohemian basins, viz the NW part of the Budějovice basin, orographic subregion Kestřaňsko-Vodňanská basin. The region topography is upland, mildly undulating, divided by longitudinal and transverse ravines. Research plots in the Hůrky TFD are situated 5 km south of Písek at an altitude of about 430 m, mean annual temperature 7.5 to 7.7°C and mean annual total precipitation 550 to 575 mm (Quitte 1971). The bedrock of TFD Hůrky is built of migmatite of orthogneiss appearance. The soil type is modal oligotrophic Cambisol (KAmd´) (Němeček et al. 2001). Potential growth conditions were standardized by the Institute for Forest Management Planning as 3K – *Querceto-Fagetum acidophilum* (acid sites – series).

Research plots in TFE Masaryk Forest Křtiny are situated 2 km south of Rudice in Forest Natural Region 30, the Drahanská vrchovina Upland, altitude ca 520 m, mean annual temperature 7.9°C and mean annual total precipitation 596 mm (375 mm in the growing season). Maximum and minimum precipitation was recorded in July and February, respectively. Northern and western air flow is prevailing (Truhlář 1996). Climatic data were recorded by the nearest meteorological station at Olomučany. The bedrock of research plots in the Křtiny TFE consists of shale, greywacke and "singing" sediments of limestone. The soil type of research plots is modal mesotrophic Cambisol (KAmm´) (Němeček et al. 2001). Potential growth conditions have been standardized by the Institute for Forest Management Planning as 4H – *Fagetum illimerosum trophicum* (mesotrophic sites – series).

Sampling procedure

Samplings of forest floor for the reserve determination and subsequent analyses were carried out always at the end of the growing season, in autumn, after the leaf fall in 2007. Particular samples were taken by a standard method using the metal frame of a known area (0.1 m^2). In each of the six stands, 10 samplings of particular layers (L, F and H) were carried out. Each sample was taken separately. After transport to the laboratory, the samples were dried up at 60°C to a constant weight in an oven, weighed and mean dry weight was calculated and reserves of forest floor per ha were calculated from it.

Samples of the organo-mineral horizon (Ah horizon) were taken in all stands in autumn 2007. Pedological ditches were dug at five places in each of the variants and Ah horizon was taken from them with a shovel and knife or a soil probe. Horizons from each replication were taken separately into a paper or plastic bag. Values of active and exchangeable soil acidity were determined by a potentiometer method (Zbíral et al. 1997) using an OP-208/1 digital pH-meter (Radelkis Budapest, Hungary). Basic nutrients, i.e. carbon and nitrogen, were determined from samples devoid of coarse particles after fine grinding or comminution on a LECO TruSpec analyzer (MI USA) (Zbíral et al. 1997).

Dissolved organic carbon (DOC) of soil samples was determined by a modified method according to Robertson et al. (1999). Then, the content of DOC was determined using a Shimadzu TOC-$V_{CSH/CSN}$ analyzer (Shimadzu Corporation, Japan). Mensurational characteristics of stands were determined by standard procedures.

Processing the statistical values

Statistical analyses were carried out in the Statistics Program (StatSoft Inc., Tulsa, USA). Single-factor analysis ANOVA was used and Tukey's test was applied for the detection of differences between groups. Significance was tested at the level $\alpha = 0.05$.

RESULTS

Forest floor reserves

The surface humus accumulation was determined in L, F and H layers. The reserves fluctuate in particular horizons and variants (Fig. 1). The total depth of the forest floor layers (L, F, H) ranged from 4 to 8 cm. The forest floor supply in horizon L ranged from 2.4 to 8.6 t/ha. No statistically significant differences in the supply of forest floor were determined at the significance level $\alpha = 0.05$ in horizon L at an acid site. At a mesotrophic site, however, highly significant differences were found between the spruce stand and the spruce/beech stand at the significance level $\alpha = 0.01$. Comparing the particular sites, significant differences were found at the significance level of both $\alpha = 0.05$ and 0.01 between the Douglas fir stand and the spruce/beech stand at a mesotrophic site and all stands at an acid site.

The accumulation of humus in horizon F was determined to range from 14.6 to 37.1 t/ha. In horizon F, a statistically significant difference was determined between the Douglas fir stand and spruce stands ($\alpha = 0.01$) and spruce/beech stand ($\alpha = 0.05$) at an acid site. At a mesotrophic site, no statistically sig-

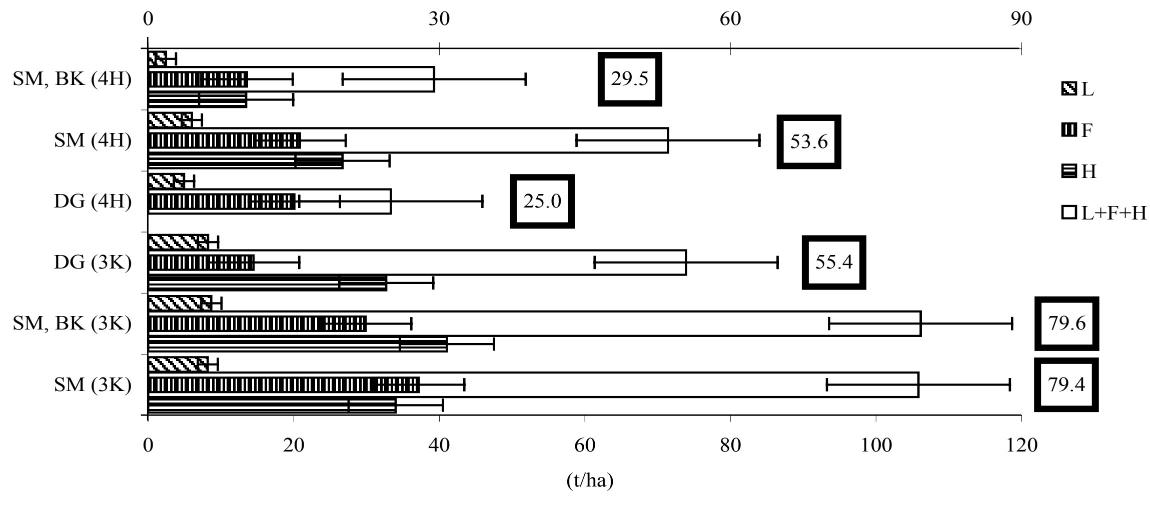

Fig. 1. Reserves of forest floor in different forest stands (I – confidence interval [0.95], lower *x*-axis – reserves of the separate layers [L, F, H] of forest floor, upper *x*-axis – total accumulation of surface humus [L+F+H])

Table 1. Brief characteristics of forest stands

Variant	Age	Species composition	Soil	Forest typology
SM (3K) – TFD Hůrky	65	spruce 100	Modal oligotrophic Cambisol*	3K – *Querceto-Fagetum acidophilum* (acid sites – series)***
SM, BK (3K) – TFD Hůrky	65	spruce 80, beech 20	Cambisols (CM)**	
DG (3K) – TFD Hůrky	65	Douglas fir 100		
DG (4H) – TFE Křtiny	60	Douglas fir 100	Modal mesotrophic Cambisol*	4H – *Fagetum illimerosum trophicum* (mesotrophic sites – series)***
SM (4H) – TFE Křtiny	60	spruce 100	Cambisols (CM)**	
SM, BK (4H) – TFE Křtiny	60	spruce 70, beech 30		

*Soil taxonomy by Němeček et al. (2001), **WRB 2006, ***taxonomy by FMI (Forest Management Institute, Brandýs nad Labem, Plíva 1987)

nificant differences were found between the stands. Statistically highly significant differences ($\alpha = 0.01$) were found between the spruce stand at an acid site and all stands at a mesotrophic site and further between stands of spruce with beech at both sites at the significance level ($\alpha = 0.01$).

The accumulation of humus in horizon H was determined from 13.5 to 41.0 t/ha. In horizon H at an acid site and significance level $\alpha = 0.05$, no statistically highly significant differences were found, however, at a mesotrophic site and significance level $\alpha = 0.01$, statistically significant differences were found between the spruce stand and the Douglas fir stand. Comparing the sites, statistically highly significant differences were found between the Douglas fir stand and the spruce/beech stand at a mesotrophic site and all stands at an acid site. Highly significant differences were also found between spruce stands at both sites ($\alpha = 0.01$).

The total accumulation of surface humus shows an increasing tendency (Fig. 1). The surface humus

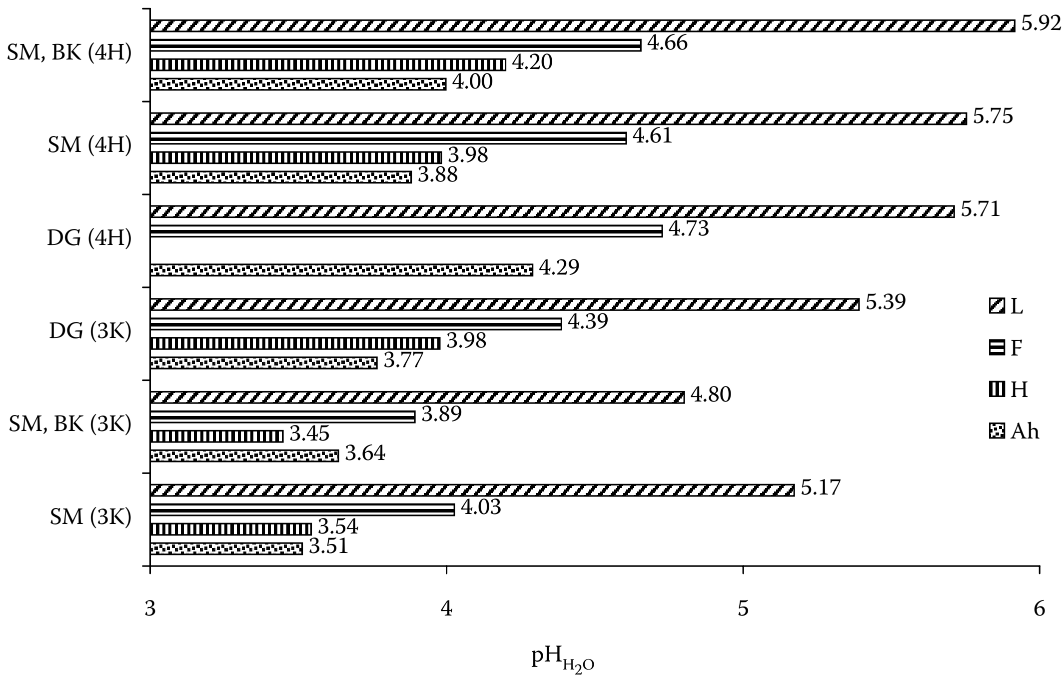

Fig. 2. Distribution of pH_{H_2O} in layers of forest floor and organo-mineral horizon in different forest stands (value of a mixed sample – 10 samplings of particular layers [L, F, H]; 5 samplings of a particular horizon Ah and a stand)

Table 2. Statistically significant differences in the total reserve of forest floor

Stand	SM (3K)	SM, BK (3K)	DG (3K)	DG (4H)	SM (4H)	SM, BK (4H)
Reserves in horizon L						
SM (3K)	X	NS	NS	*	NS	**
SM, BK (3K)	NS	X	NS	**	NS	**
DG (3K)	NS	NS	X	**	NS	**
DG (4H)	*	**	*	X	NS	NS
SM (4H)	NS	NS	NS	NS	X	**
SM, BK (4H)	**	**	**	NS	**	X
Reserves in horizon F						
SM (3K)	X	NS	**	**	**	**
SM, BK (3K)	NS	X	*	NS	NS	**
DG (3K)	**	*	X	NS	NS	NS
DG (4H)	**	NS	NS	X	NS	NS
SM (4H)	**	NS	NS	NS	X	NS
SM, BK (4H)	**	**	NS	NS	NS	X
Reserves in horizon H						
SM (3K)	X	NS	NS	**	**	**
SM, BK (3K)	NS	X	NS	**	NS	**
DG (3K)	NS	NS	X	**	**	**
DG (4H)	**	**	**	X	NS	NS
SM (4H)	**	NS	NS	**	X	NS
SM, BK (4H)	**	**	**	NS	NS	X
Reserves of forest floor – horizons L+F+H						
SM (3K)	X	NS	**	**	**	**
SM, BK (3K)	NS	X	**	**	**	**
DG (3K)	**	**	X	**	NS	**
DG (4H)	**	**	**	X	**	NS
SM (4H)	**	**	NS	**	X	**
SM, BK (4H)	**	**	**	NS	**	X

*Statistically significant differences (α < 0.05), **statistically highly significant differences (α < 0.01), NS – not significant

reserves (Fig. 1) ranged from 25.0 to 79.6 t/ha. The lowest reserve occurred in the Douglas fir stand at a mesotrophic site, namely only 25.0 t/ha. On the contrary, the highest accumulation occurred in the spruce stand and the spruce/beech stand at an acid site, namely 79.4–79.6 t/ha. Statistically highly significant differences (α = 0.01) in the total reserve of forest floor were found at an acid site between the Douglas fir stand and the spruce stand and the spruce/beech stand. Further, at a mesotrophic site, between the Douglas fir and spruce/beech stands and the spruce stand (α = 0.01). Comparing the particular sites, statistically highly significant differences were found between the Douglas fir and the spruce/beech stand at a mesotrophic site and all stands at an acid site. Further, between the spruce stand at a mesotrophic site and spruce and spruce/beech stands at an acid site. Always, it was a highly significant difference (α = 0.01). The survey of statistically significant differences in the total reserve of forest floor is given in Table 2.

A humus form "moder" was found in all stands at acid sites (3K) and in the spruce stand. In the

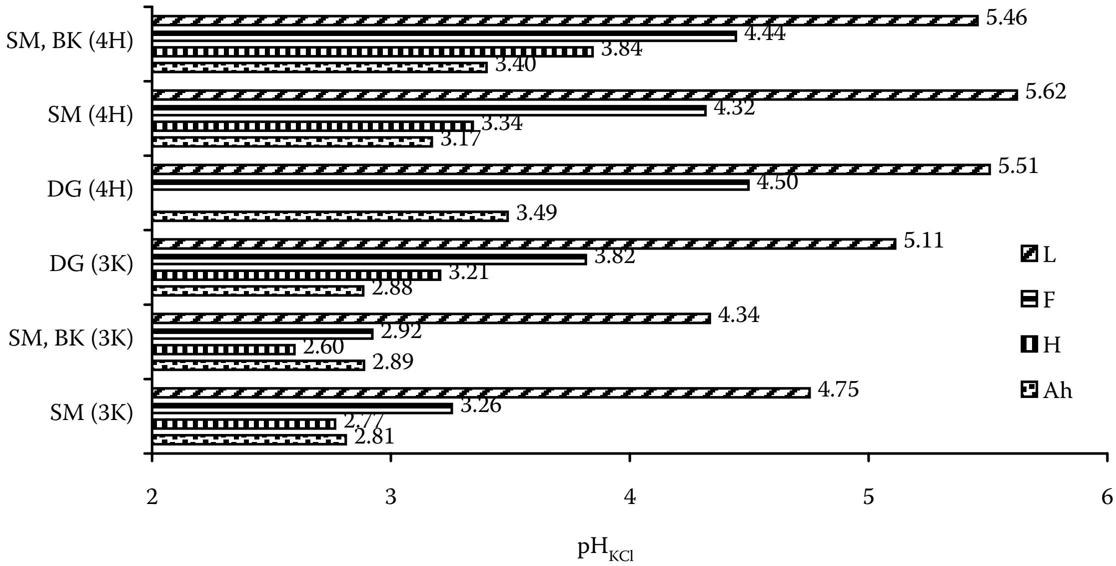

Fig. 3. Distribution of pH_{KCl} in layers of forest floor and organo-mineral horizon in different forest stands (value of a mixed sample – 10 samplings of particular layers [L, F, H]; 5 samplings of a particular horizon Ah and a stand)

mixed stand of spruce, Douglas fir and beech at a mesotrophic site (4H), the humus form "mull-moder" was not found. In the Douglas fir stand at a mesotrophic site, the humus form "mull" was found (according to Němeček et al. 2001).

Soil reaction

Both actual (in H_2O) and exchangeable (in nKCl) pH was determined. In surface humus, values of actual and exchangeable pH decrease with increasing depth in all stands. Values of pH were determined in horizon L in stands at an acid site (4.8–5.2) and at a mesotrophic site (5.7–5.9). In F horizon in stands at an acid site, pH values ranged from 3.9 to 4.0 and at a mesotrophic site from 4.6 to 4.7. In H horizon at an acid site, pH values ranged from 3.4 to 4.0 and at a mesotrophic site, from 3.9 to 4.2. In Ah horizon, the soil reaction was 3.5–3.7 at an acid site and 3.9–4.2 at a mesotrophic site.

Thus, the soil reaction can be described as strongly acid to very strongly acid. The most favourable values of both active and exchangeable pH for forest floor and soil at acid and mesotrophic sites occur in the

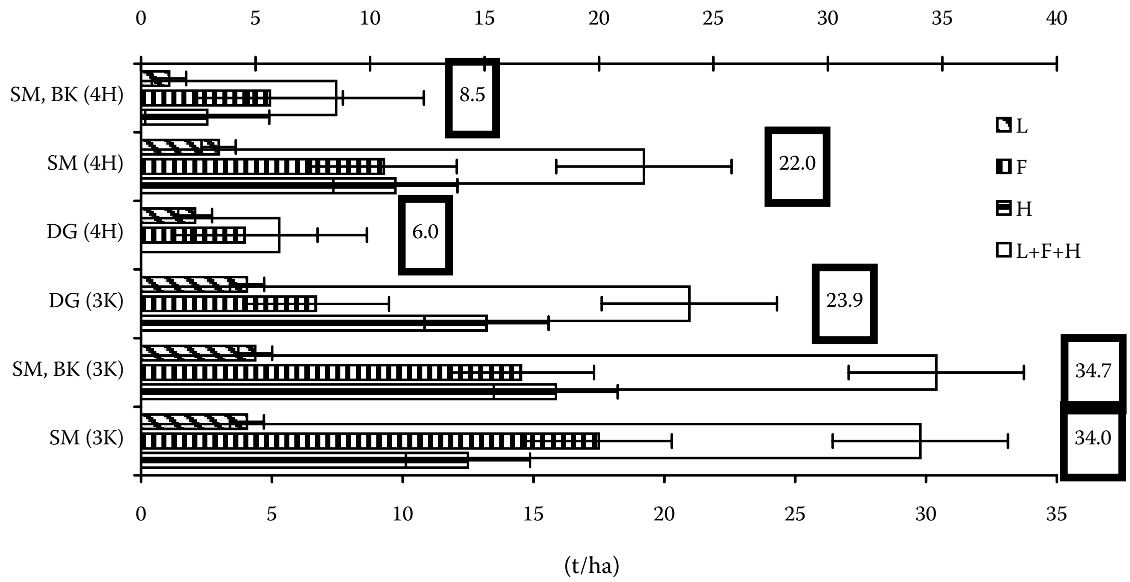

Fig. 4. Carbon reserves in forest floor in different forest stands (I – confidence interval [0.95], lower x-axis – reserves of the carbon separate layers [L, F, H] of forest floor, upper x-axis – total accumulation of carbon in surface humus [L+F+H])

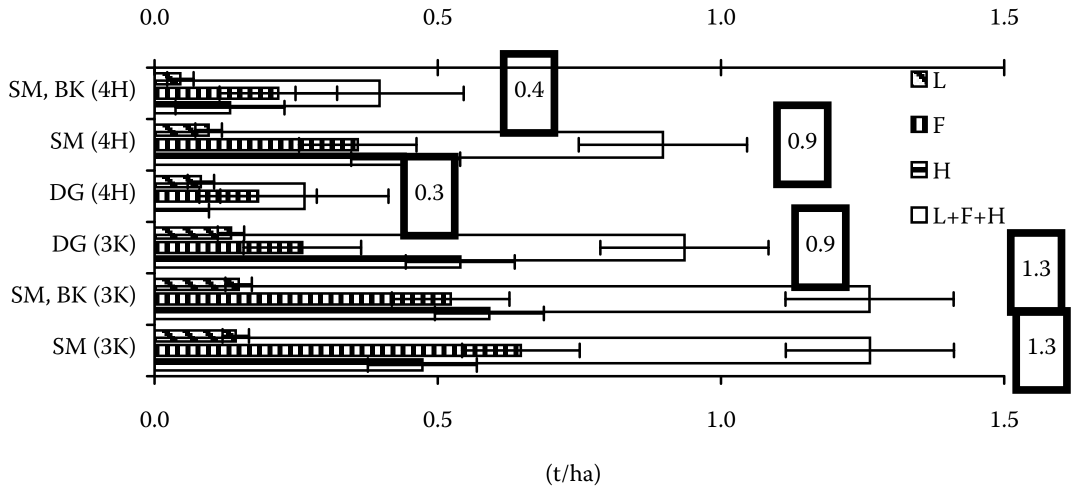

Fig. 5. Nitrogen reserves in forest floor in different forest stands (I – confidence interval [0.95], lower x-axis – reserves of the nitrogen separate layers [L, F, H] of forest floor, upper x-axis – total accumulation of nitrogen in surface humus [L+F+H])

Douglas fir stand. Favourable values at a mesotrophic site were also measured in spruce and spruce/beech stands. Less favourable values occur in spruce and spruce/beech stands at an acid site.

Carbon, nitrogen, C/N ratio

In 2007, the content of total carbon ranged in particular stands from 41.9 to 50.3% for horizon L, from 36.3 to 48.6% for horizon F and from 18.8 to 40.4% for horizon H. In the organo-mineral horizon Ah, the content of total carbon ranged from 2.9 to 15.9%. The content of total nitrogen ranged from 1.6 to 1.9% for horizon L, 1.6–1.8% for horizon F and 1.0–1.7% for horizon H. In the organo-mineral horizon Ah, it ranged from 0.2 to 0.6%.

The highest supplies of carbon (Fig. 4) in forest floor occur in the spruce and spruce/beech stands at acid sites, viz 34.0 and 34.7 t/ha, respectively (1.3 t/ha nitrogen in forest floor – Fig. 5). Medium reserves of carbon 22.0–23.9 t/ha (0.9 t/ha nitrogen

Table 3. Statistically significant differences in reserves of carbon and nitrogen in forest floor

Stand	SM (3K)	SM, BK (3K)	DG (3K)	DG (4H)	SM (4H)	SM, BK (4H)
Carbon reserves in forest floor – horizons L+F+H						
SM (3K)	X	NS	**	**	**	**
SM, BK (3K)	NS	X	**	**	**	**
DG (3K)	**	**	X	**	NS	**
DG (4H)	**	**	**	X	**	NS
SM (4H)	**	**	NS	**	X	**
SM, BK (4H)	**	**	**	NS	**	X
Nitrogen reserves in forest floor – horizons L+F+H						
SM (3K)	X	NS	*	**	*	**
SM, BK (3K)	NS	X	*	**	*	**
DG (3K)	*	*	X	**	NS	**
DG (4H)	**	**	**	X	**	NS
SM (4H)	*	*	NS	**	X	**
SM, BK (4H)	**	**	**	NS	**	X

*Statistically significant differences ($\alpha < 0.05$), **statistically highly significant differences ($\alpha < 0.01$), NS – not significant

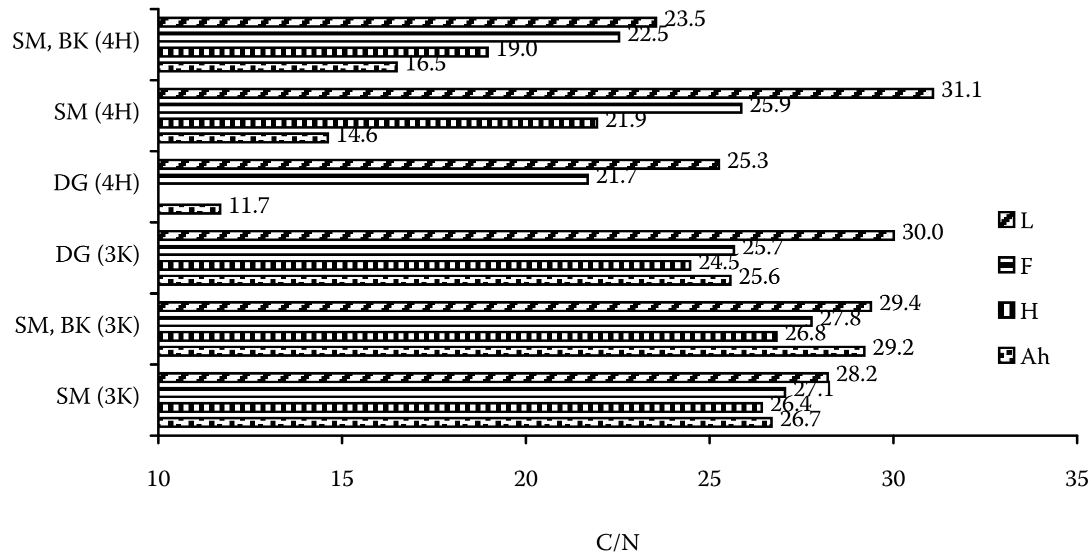

Fig. 6. C/N ratio in forest floor in different forest stands (value of a mixed sample – 10 samplings of particular layers [L, F, H]; 5 samplings of a particular horizon Ah and a stand)

in forest floor) were found in the spruce stand at a mesotrophic site and in the Douglas fir stand at an acid site. The lowest reserves of carbon in the Douglas fir and spruce/beech stands were 8.5 and 6.0 t/ha, respectively (0.4 or 0.3 t/ha nitrogen in forest floor). Statistically significant differences were found in carbon and nitrogen reserves in forest floor at the significance level $\alpha = 0.05$ as well as 0.01. The survey of statistically significant differences is given in Table 3.

The C/N ratio in horizon L in stands at an acid site is 29.2–30.0 and 23.5–31.1 at a mesotrophic site. In F horizon in stands at an acid site, the C/N ratio amounted to 25.7–27.8 and 21.7–25.9 at a mesotrophic site. In H horizon, it was 24.4–26.8 at an acid site and 19.0–21.9 at a mesotrophic site. In Ah horizon, the C/N ratio at an acid site ranged from 25.6 to 29.2 and at a mesotrophic site from 11.7 to 16.5. The lowest C/N ratio in forest floor in horizon H (Fig. 6) was found in the spruce/beech stand (19) and in the spruce stand (22) at a mesotrophic site while the highest C/N ratio was found in the spruce/beech stand and in the spruce stand (identically 26) at an acid site. The Douglas fir stand at an acid site shows the C/N ratio 24.5. The C/N ratio in the organo-mineral horizon Ah is lowest in the Douglas fir stand at a mesotrophic site (12). On the contrary, the highest values were found in stands at acid sites (26–29).

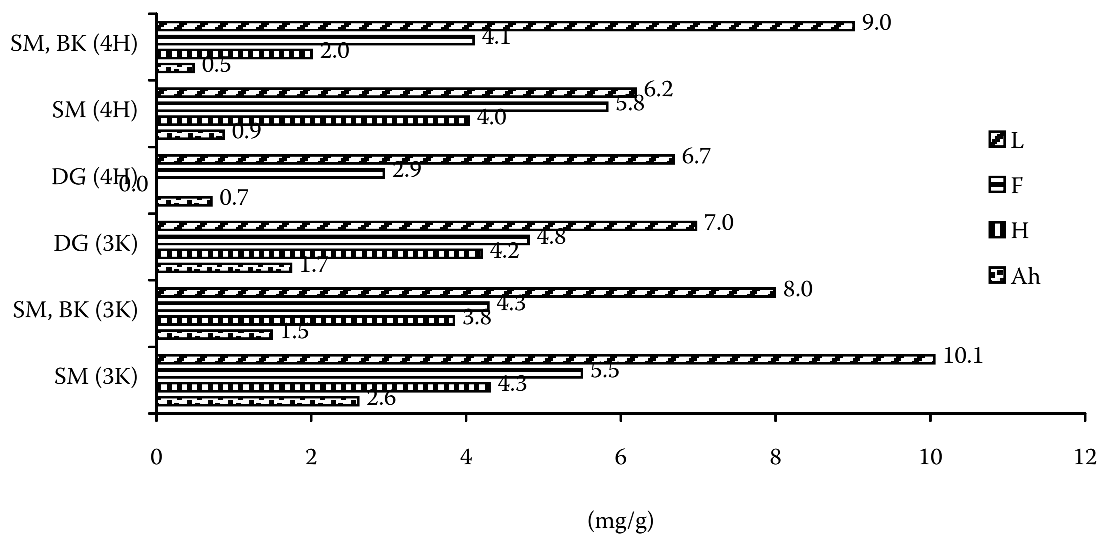

Fig. 7. The content of dissolved organic carbon (DOC) in forest floor in different forest stands (value of a mixed sample – 10 samplings of particular layers [L, F, H]; 5 samplings of a particular horizon Ah and a stand)

Dissolved organic carbon (DOC)

The determination of DOC content (Fig. 7) in samples of forest floor and soil horizons showed a trend of gradual decrease from L horizon to Ah horizon in all stands. In L horizon, the content of DOC ranged from 7.0 to 10.1 mg/g in stands at acid sites and from 6.2 to 9.0 mg/g at a mesotrophic site. In F horizon in stands at an acid site, the values of DOC content ranged from 4.3 to 5.5 mg/g, at a mesotrophic site from 2.9 to 5.8 mg/g. In H horizon, the DOC content ranged from 3.8 to 4.3 mg/g at an acid site and 2.0–4.0 mg/g at a mesotrophic site. In Ah horizon, the DOC content was 1.7–2.6 mg/g at an acid site and 0.5–0.9 mg/g at a mesotrophic site.

DISCUSSION

The most important factors at the creation of forest floor are: topography, climatic and microclimatic conditions, edaphon, soil chemistry and the composition of forest stands or phytocoenoses (Pelíšek 1964). The study deals with soil characteristics in relation to the composition of forest stands, particularly of Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco). As for soil characteristics, the following indicators were selected: forest floor reserves, soil reaction, total carbon and nitrogen, C/N ratio and DOC.

The highest supply and depth of forest floor was found in the spruce stand and in the mixed spruce/beech stand at an acid site (3K). In the spruce stand at a mesotrophic site (4H), the form of forest floor consisted of moder (according to Němeček et al. 2001). At acid and mesotrophic sites in the stands mentioned above, the highest reserves occurred in horizons F and H. This soil condition was probably a result of rather poorly decomposable coniferous litter containing small amounts of nutrients (Zlatník 1976; Van Breemen, Finzi 1998) and potentially increasing acidification particularly at an acid site throughout the soil profile (Hruška, Cienciala 2003). Thus, the retardation of decomposition processes and the nutrient cycle deceleration can occur in these stands.

The lowest forest floor reserves occur in the Douglas fir stand and in the spruce/beech stand at a mesotrophic site (4H). The mull form of forest floor was detected in the Douglas fir stand and the mull-moder form in the spruce stand (according to Němeček et al. 2001). Mull originates under very favourable conditions for the decomposition and transformation of organic residues. It is mainly formed under broadleaved and mixed stands in temperate and warm climate under balanced conditions of water regime, on sufficiently deep and well aerated soils supplied with nutrients (Průša 2001).

The schematic division of the forest floor forms can serve only for a rough comparison of the carrying capacity of soils because it often fails under concrete conditions (Pastor et al. 1984; Binkley, Giardina 1998). Based on this evaluation we can conclude that Douglas fir stands at both sites show positive effects on the condition and reserves of forest floor.

The soil reaction (pH) is another important factor to evaluate forest floor and soil. The soil reaction can be described as strongly acid (pH 4.5–5.5) to very strongly acid (pH 3.5–4.5). Mařan and Káš (1948) reported pH values for beech humus within the limits 5.3–6.6 and for spruce within the limits 3.7–4.5. Similarly Šály (1978) reported pH values for the litter of broadleaves within the limits 5.0–6.5 and for conifers 4.0–5.0. Thus, the most favourable pH values for exchange and active acidity of forest floor and soil at acid and mesotrophic sites occur in the Douglas fir stand. Favourable values at a mesotrophic site occur also in the spruce stand and in the spruce/beech stand.

Less favourable values occur in the spruce and spruce/beech stands at an acid site. Stands at an acid site show pH values lower than stands at a mesotrophic site, which can be another factor pointing out the soil profile acidification. Exchangeable soil reaction has a similar course as active reaction. Rather small differences between active and exchangeable pH values show evidence of the relative sufficiency of basic cations in upper soil horizons (Ulrich 1983; Kulhavý 1997).

According to pH values, soils at all localities can be classified at the border of the cation exchange capacity where the increased input of hydrogen ions is compensated for basic cations from an adsorbing complex and buffer zone of aluminium. Thus, compensation occurs there of the increased input of hydrogen ions by the creation of Al^{3+} ions from polymeric Al compounds (Ulrich 1989). It is localized in soils where there are disproportions between basic cations released at the weathering of feldspars and inputs of H^+. Under these conditions, protons could be immobilized on exchange sites on clay minerals as a rule by the sorption of Al^{3+}. Aluminium ions act as a weak acid and partly also as toxic factors inhibiting the mycorrhiza. Therefore, the compensation of acid inputs within this zone occurs particularly thanks to basic cations fixed on exchange sites on organic colloids.

The main indicator of the biomass decomposition rate is just the content of nitrogen and the C/N ratio, which is given by the close relationship between the C/N ratio and soil transformations of nitrogen (Cote et al. 2000). In forest soils of Europe, the C/N ratio ranges between 10 and 100 while the majority of the C/N ratio values in the organic horizon is within the limits 20 to 40, in mineral horizons within the limits 10 to 30.

Evaluation of the C/N ratio is not, however, so unambiguous and differs in particular authors (Vitousek et al. 1982; Binkley, Giardina 1998; Cote et al. 2000; Prescott et al. 2000; Puhe, Ulrich 2001). In broadleaved and mixed stands, no boundary value has been determined yet to generalize assessing the C/N ratio to forest stands (Hruška, Cienciala 2003). The C/N ratio has to be assessed comprehensively within all analyses. The lowest C/N ratio in forest floor was found in the spruce/beech stand and in the spruce stand at a mesotrophic site, the highest one occurred in the spruce/beech stand and in the spruce stand at an acid site. The C/N ratio in the organo-mineral horizon Ah was lowest in the Douglas fir stand at a mesotrophic site, the highest value was found in stands at an acid site. From the aspect of decomposition conditions, Douglas fir stands at mesotrophic and acid sites and spruce/beech stands at mesotrophic sites appear to be most favourable. Emmett et al. (1998) reported the value of about 24 as the critical value of C/N ratio in coniferous stands. At a ratio > 24, less than 10% of nitrogen is washed out from the ecosystem. Nevertheless, at the C/N ratio < 24, the amount of washed out nitrogen is more than 10% of the total nitrogen in the ecosystem.

The values from forest floor in coniferous stands at acid sites do not fall below the limit. On the contrary, at mesotrophic sites, the C/N ratio is under the critical limit as reported by Emmett et al. (1998). However, nitrogen accumulation is the highest in F and H layers at both sites, at the same time being also the most intense in all stands in given layers.

Forest floor shows an important role in the dynamics of carbon and nitrogen of a forest ecosystem. It is considered to be the source of carbon and nitrogen for plants and soil microorganisms as well as the reservoir of carbon and nitrogen, which enters the forest floor (Yano et al. 2000). The highest accumulation of carbon in forest floor occurred in the spruce and spruce/beech stands at an acid site. The lowest accumulation of carbon was observed in the Douglas fir and spruce/beech stands at a mesotrophic site. Berger et al. (2002) also came to similar results. They found the higher accumulation of carbon under a pure spruce stand than under a mixed beech/spruce stand. Dissolved forms of carbon become reputable for their importance in the forest nutrient cycle. The role of DOC as the source of energy for the metabolism of microbes is of particular importance (Magill, Aber 2000). The highest amounts of DOC were found in forest floor and soil horizons at acid and mesotrophic sites. It conforms to findings which were presented by Michalzik et al. (2001) that the highest content of DOC was noted in forest floor (the highest proportion of organic substances) and then in Ah horizon (the proportion of organic substances markedly decreases) (Šály 1977). Thus, the higher content of DOC in stands at acid sites bears evidence of the sufficiency of substrates available to soil organisms but it also means a higher risk of soil acidity (Lesná, Kulhavý 2003).

CONCLUSION

The presented study evaluates reserves of forest floor and the chemical composition of forest floor in three stands of Douglas fir, spruce and spruce with beech at an acid site (3K) in Hůrky TFD and in three stands of Douglas fir, spruce and spruce with beech at a mesotrophic site (4H) in Křtiny TFE.

Based on the results obtained so far it is possible to conclude:

– The lowest reserves of forest floor occurred in the Douglas fir stand at a mesotrophic site, only 25.0 t/ha; on the contrary, the highest accumulation occurred in the spruce and spruce/beech stands at an acid site, 79.4–79.6 t/ha (statistically significant difference).
– In spruce and spruce/beech stands at an acid site, the increased accumulation of organic matter can result in the deceleration of decomposition processes as well as retardation of the nutrient cycle.
– Under these conditions, the soil reaction is heavily acid to acid. The most favourable active and exchange pH values for forest floor and soil at acid and mesotrophic sites were recorded in the Douglas fir stand. Favourable values at a mesotrophic site occur also in the spruce and spruce/beech stands. Less favourable values are in the spruce and spruce/beech stands at an acid site. In comparison with pure spruce stands, Douglas fir acts on pH values favourably both in forest floor and Ah horizon.
– The largest reserve of carbon in forest floor occurred in the spruce and spruce/beech stands at an acid site, namely 34.0 and 34.7 t/ha, respectively (identically 1.3 t/ha nitrogen). The lowest reserve of carbon occurred in the Douglas fir and spruce/beech stands, 8.5 and 6.0 t/ha, respectively (0.4 and 0.3 t/ha nitrogen, respectively). Statistically significant differences were found in carbon

and nitrogen reserves in forest floor (statistically significant difference).
- The lowest C/N ratio in forest floor in H horizon was found in the spruce/beech and (19) and spruce stands (22) at a mesotrophic site, the highest ratio was found in the spruce/beech and spruce stands (identically 26) at an acid site.
- The higher content of DOC in stands at acid sites can mean a higher risk of soil acidification.

The results of this study can be used for the transformation of spruce monocultures to forests close to the potential natural composition.

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Humusové poměry porostů s rozdílným zastoupením douglasky tisolisté na ŠP Hůrky a ŠLP Křtiny

ABSTRAKT: Studie hodnotí zásobu nadložního humusu a chemické složení nadložního humusu tří porostů douglasky, smrku a smrku s bukem na kyselém stanovišti (3K) na školním polesí Hůrky a tří porostů douglasky, smrku a smrku s bukem na živném stanovišti (4H) na ŠLP Křtiny. Cílem studie bylo zhodnotit: (*i*) zásobu nadložního humusu, (*ii*) půdní reakci, (*iii*) obsah a zásobu celkového uhlíku a dusíku pro vrstvy nadložního humusu, (*iv*) poměr uhlíku a dusíku a (*v*) obsah rozpustného organického uhlíku (DOC). Nejnižší zásoba je v porostu DG na živném stanovišti (25,0 t/ha), nejvyšší akumulace je v porostu smrku a porostu smrku s bukem na kyselém stanovišti (79,4 až 79,6 t/ha). Půdní reakce je silně kyselá až kyselá. Nejpříznivější hodnoty pH pro nadložní humus i půdu jsou na kyselém (4,6 ± 0,4) i živném stanovišti (5,2 ± 0,4) v porostu douglasky. Tomu odpovídá i poměr C/N (23–26). Největší zásoba uhlíku v nadložním humusu na kyselém stanovišti je 34,7 t/ha (1,3 t/ha dusíku). Nejnižší zásoba uhlíku v nadložním humusu na živném stanovišti je 8,5 t/ha (0,4 t/ha dusíku). Vyšší obsah DOC v porostech na kyselých stanovištích může znamenat větší riziko pro okyselování půdy.

Klíčová slova: dřevinná skladba; půda; zásoba nadložního humusu; pH; uhlík a dusík; poměr C/N; DOC

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