CHANGES IN THE QUANTITY AND CHARACTERISTICS OF SURFACE HUMUS AFTER THINNING TREATMENTS*

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Thinning operations affect the stability and growth dynamics of forest stands. Thinning also changes the forest stand environment and the processes of formation and transformation of surface humus. This layer of organic material is one of the most essential hydrologic components of the forest ecosystem. In addition to its considerable water retention capacity, surface humus also plays an important role in regulating the inflow and outflow of water from forested areas. We measured changes in humus forms on the Vrchmezí site in the higher elevations of the Orlické hory (mountains), where experimental thinning was begun approximately 30 years ago in an effort to stabilize young stands of Norway spruce in the presence of air pollution. We sampled organic horizons and the top layer of the mineral soil profile in control and thinned plots in autumn 2002 to determine the amount of surface humus and basic chemical characteristics of the soil. Our analysis showed statistically significant differences in the amount of organic material (58.51 t/ha in the thinned plot vs. 70.08 t/ha in the control plot), higher acidity and bases content on the control plot, and higher total Ca and Mg content on the thinned plot. We found no significant differences among treatment and control plots for other characteristics.

Norway spruce; Orlické hory Mts.; thinning; humus forms; forest soils

INTRODUCTION

Studies of forest stand thinning have tended to look at its effects more on forest productivity and stand dynamics than on the soil component. For example, researchers have investigated the impacts of harvesting, including mechanical thinning, changes in species composition or site amelioration treatments. In general, researchers have supposed that thinning, in contrast to other stand management activities, has only a slight impact on soil organic matter and soil dynamics. It is important, however, that we study how the quantity and quality of surface humus change after stand thinning as we seek to understand better the relationship between soil state and stand density. In addition, a clearer understanding of the effects of thinning on forest soils will help in studying the non-production values of the forest and in implementing sustainable forest management. The relationship between thinning and soil bases content, the carbon and nitrogen cycles may be expected to gain greater attention in forthcoming studies.

Thinning treatments and subsequent stand management affect the accumulation, transformation and mineralization of the organic litter in two ways, excluding effects on tree species mix. First, the changed volume and density of the canopy affects the litter amount (Binkley, 1986; Klimo, 1990; Šály, 1978, 1988). In intensively thinned stands, studies suggest that the amount of litter decreases, at least temporarily, as biomass is concentrated in the crown layer and litter production, especially from foliage, declines in the lower crown (Hager, 1988; Wright 1957).

The second factor is represented by changed micro-climatic conditions at the ground level, which are more favorable for organic matter transformation and mineralization in more open stands. Chroust (1954) described in detail the effects of thinning and tending treatments on the microclimate in oak and beech thickets. Nováková (1971) reported similar effects in spruce stands. Hager (1988) and Vyskot et al. (1962) described dramatic changes in microclimate resulting from thinning.

Past research has demonstrated that thinning and tending usually improve conditions for humus production and mineralization of the organic matter by changing both humidity and temperature. Increased soil moisture intensified cellulose decay in spruce stand soils in Denmark (Beier, Rasmussen, 1994). Šály (1988) observed that microflora responsible for cellulose and lignin decay were activated by raising the soil temperature above 0 and 7 degrees, respectively. Even small shifts in average temperature can change the transforma-

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tion of soil organic matter considerably or can prolong the activity of decomposers in forest ecosystems. Also important is increased air movement in the newly-opened stands and the resulting removal of metabolic waste products (i.e., carbon dioxide) from upper soil layers to prevent their self-suppression effects.

For Czech conditions, the most important of the few studies of silvicultural effects on soil are those by Šarman (1979, 1982, 1985, 1986), which deal with thinning effects in stands of the main climax species. From abroad, the publications of Naumann (1987), Richter, Richter (1990) and Wright (1957) appear to be the most relevant studies.

Research has shown that thinning and tending have various effects on the amount and quality of soil organic matter although these effects are more moderate than with other silvicultural treatments. This reduced impact is because thinning and tending result in less dramatic modification of the forest environment than other, more intensive treatments. As a result, there are less pronounced changes in litterfall and precipitation throughfall. In light of these presumed effects, our study investigated the state of humus in a thinning experiment in the submountain conditions of the Orlické hory.

MATERIAL AND METHODS

Research was conducted on the Vrchmezí research site in the Orlické hory. The research site was established in 1970 by planting Norway spruce at different spacings with a density of approximately 4,000 individuals per hectare. At the age of 15 years, the density was lowered to 2,500 stems/ha by a heavy negative selection from below. Two 0.04-ha plots were established in 1988 at the stand age 18 years. One plot was left without further treatments as the control plot. On the second one, density was initially reduced to 1,600 stems/ha by negative selection from below. A second and final thinning, again by negative selection from below, was conducted in 1999 at the age of 30 years, decreasing density to 1,150 stems/ha. Damage from several snowfalls reduced stand density to 1,075 stems/ha on the thinned plot and 1,775 stems/ha on the control plot. Growth processes and foliage health conditions were investigated continually on both plots.

The stand is located at altitude 880 m a.s.l. The slope is 6 degrees with a north-western exposure. The geological bedrock is formed by mica-schists. Soil type was determined to be Cambisol to entic Podzols (Spodosols), with skeletic entic Podzol prevailing on the plot. The forest type was determined to be 6K1 (upper limit) – acid spruce-beech stand (*Piceto-Fagetum acidophilum – Avenella flexuosa*).

On each plot, samples of humus form layers were taken: L + F1, F2, H and Ah. Sampling was done in 4 replications in 2002. Layer determination was based on Green et al. (1993). Typical sampling sites were selected for each plot. The holorganic horizons, but not the mineral Ah horizon, were sampled quantitatively using a 25 x 25-cm steel frame.

Soil samples were processed in the laboratory at the Research Station at Opočno by standard methods: the dry mass of holorganic layers at 105 degrees C, pH in water and 1 N KCl, soil adsorption complex characteristics by Kappen (S – bases content, H – hydrolytic acidity, T – cation adsorption capacity, V – base saturation), plant-available nutrient content (P, K, Ca, Mg, Fe sesquioxides) using AAS and spectrophotometry in 1% citric acid solution, total nutrient content in holorganic layers using mineralization by selene and sulfuric acid and AAS (K, Ca, Mg) and spectrophotometry (P). Statistical evaluation used analysis of variance at the 95% confidence level.

RESULTS AND DISCUSSION

Thinning caused a decrease in the surface humus amount (Table 1). The statistically significant decline in the H-humification layer considerably influenced the total quantity of surface organic matter. The soil reaction (H_2O) was similar on both the thinned and control plots. The slightly higher values on the thinned plot are within the range of laboratory error. Both plots had similar pH values (KCL), with the exception of the Ah horizon, where pH values were significantly higher on the thinned plot despite a low absolute difference of 0.1.

In contrast, the bases content (S-value) was higher on the control plot, with an exception of the uppermost layer; the difference was statistically significant in the mineral horizon. Hydrolytic acidity (H-value) changed sharply on the two types of plots without visible trend. Cation exchange capacity (T-value) was similar on both plots. Only in the litter the exchange capacity was higher on the thinned plot than on the control. The base saturation (V-value) showed a pattern similar to that of the base content. Lower base content and loss of basic nutrients would be expected on the thinned plot. The exchangeable acidity also decreased on the thinned plot (Table 1).

On the thinned plot, lower total humus quantities and LOI values were measured, with an exception of the uppermost horizon (Table 2). Reflecting the more intense mineralization processes on thinned plots, this difference is of ecological importance, especially in the mineral horizon. Total nitrogen content showed a similar difference. Nitrogen losses and leaching can be connected with the decrease of exchangeable bases content described above, and opening the canopy can open nutrient cycles as well.

Although differences in the plant-available phosphorus (expressed in oxide form) content were not statistically significant, these differences were visible as an increase in the holorganic horizons in the treated plot. In contrast, plant-available contents of potassium decreased in the uppermost and lowest horizons (L + F1, Ah) of the thinned plot. Plant-available calcium values on the treated plot increased in holorganic horizons and decreased in the mineral one.

Available magnesium levels decreased in general after thinning, with the exception of the F2 layer. Total phosphorus content was higher in the humus layers of the

Table 1. Effect of thinning on the basic pedo-chemical characteristics on the Vrchmezí research plot

Horizon	L + F_1	F_2	H	Ah	L + F_1	F_2	H	Ah
	Thinning				Control			
				Total				Total
Dry mass (t/ha)	6.688	19.648	32.176 *	58.512*	5.744	19.248	45.088*	70.080*
pH H_2O	4.20	4.05	3.88	3.82	4.08	4.12	3.78	3.72
pH KCl	3.68	3.18	2.98	2.85*	3.58	3.15	2.80	2.75*
S (mval/100g)	9.30	17.8	8.82	3.9*	6.28	22.40	11.6	6.3*
H (mval/100g)	22.6	50.6	56.0*	16.6	16.4	49.3	66.2*	13.7
T (mval/100g)	31.8*	68.4	64.8	20.5	22.7*	71.7	77.8	20.7
V (%)	28.7	25.2	13.5	19.1*	27.6	30.4	14.5	32.3*
Acidity ex. (mval/kg)	19.4	42.8	93.2	75.8	21.6	45.4	104.0	81.0
H^+ ex. (mval/kg)	7.6*	11.4	9.4	4.7	6.0*	12.2	18.9	6.3
Al^{3+} ex. (mval/kg)	11.8	31.4	83.8	71.1	15.8	33.2	85.1	74.7

* statistically significant differences among corresponding horizons of particular plots ($p < 0.05$)

Table 2. Effect of thinning on the nutrients content on the Vrchmezí research plot

Horizon	L + F_1	F_2	H	Ah	L + F_1	F_2	H	Ah
Variant	Thinning				Control			
Humus (Springel-Klee) (%)	55.4*	55.5	55.0	22.2	42.4*	58.6	56.8	30.8
Lost of Ignitron – LOI (%)	95.1	88.9	77.1	28.5	86.3	91.5	80.5	41.8
N (Kjeldahl) (%)	1.50	1.88	1.68	0.20*	1.60	1.82	1.79	0.30*
P_2O_5 (mg/kg) – plant avail. – PA	866	759	524	321	612	465	368	322
K_2O (mg/kg) – PA	1,050	636	401	170	1,185	500	399	219
CaO (mg/kg) – PA	4,946	4,036	1,627	243	3,373	2,813	1,427	300
MgO (mg/kg) – PA	537	307	190	64	647	260	224	83
Fe_2O_3 (mg/kg) – PA	132	2,454	1,430	2,769	94	360	1,111	3,099
P (%) – total	0.15	0.18*	0.16	n.d.	0.17	0.12*	0.15	n.d.
K (%) – total	0.110	0.115	0.420	n.d.	0.105	0.100	0.265	n.d.
Ca (%) – total	0.430	0.075	0.02	n.d.	0.325	0.050	0.02	n.d.
Mg (%) – total	0.055	0.038	0.044	n.d.	0.058	0.032	0.036	n.d.

* statistically significant differences among corresponding horizons of particular plots ($p < 0.05$), n.d. – no determined

thinned plot with the exception of the litter layer. Total potassium and total calcium content increased in general after the treatment. Total magnesium content remained virtually stable in the whole holorganic profile. The clear and in some cases statistically significant changes in humus characteristics on the treated plot extends observations about changes in soil after other thinning experiments (Podrázský, Moser, 2003).

CONCLUSIONS

Study results confirmed the hypothesis that thinning impacted soil characteristics. Lower surface humus accumulation was observed on the thinned stand, indicating more rapid transformation and mineralization of the litter. These processes were linked with the lowering of soil acidity and conversely with increased losses of nitrogen and connected bases. Differences in pedochemical characteristics were not large in absolute value, but in some cases they were statistically significant. Thinning has been demonstrated to cause considerable changes in forest soil characteristics. In selecting silvicultural treatments, forest managers must take into account the ways thinning changes properties of the organic and mineral layers of the soil, as well as the whole soil-forest environment.

REFERENCES

BEIER, C. – RASMUSSEN, L.: Organic matter decomposition in an acidic forest soil in Denmark as measured by the cotton strip assay. Scand. J. For. Res., *9*, 1994: 106–114.

BINKLEY, D.: Forest Nutrition Management. New York, J. Wiley 1986. 289 pp.

GREEN, R. N. – TROWBRIDGE, R. L. – KLINKA, K.: Towards a taxonomic classification of humus forms. Forest Sci., *39*, 1993, Monograph Nr. 29, Supplement 1. 49 pp.

CHROUST, L.: Projekt diferencované porostní výchovy (The project of differentiated stand tending). Lesnický průvodce No. 3, Jíloviště-Strnady, VÚLHM 1976. 69 pp.

HAGER, H.: Stammzahlreduktion. Die Auswirkungen auf Wasser-, Energie und Nährstoffhaushalt von Fichtenjungwüchsen. Wien, Universität für Bodenkultur 1988. 189 pp.

KLIMO, E.: Lesnická pedologie (Forest pedology). Brno, VŠZ 1990. 256 pp.

NAUMANN, G.: Bodenbeeinflussung durch waldbauliche Massnahmen. Allg. Forstzeitschrift, *42*, 1987: 122–124.

NOVÁKOVÁ, M.: Vliv silných výchovných zásahů na mikroklima ve smrkových mlazinách (The effect of strong tending interventions on microclimate in spruce young stands). Sborník VŠZ Brno, *40*, 1971 (3): 187–200.

PODRÁZSKÝ, V. V. – MOSER, W. K.: Vliv výchovných zásahů na stav humusových forem (The effect of tending interventions on the condition of humus forms). In: Vliv hospodářských zásahů a spontánní dynamiky porostů na stav lesních ekosystémů (The effect of silvicultural interventions and spontaneous dynamics of stands on the condition of forest ecosystems). Kostelec n. Č. lesy, ČZU FFE, 20.–21. 11. 2003: 4.

RICHTER, I. E. – RICHTER, T. A.: Formirovanije lesnoj podstilki v kuľturach sosny raznoj gustoty. Lesoved. i les. choz., *25*, 1990: 20–23.

SLODIČÁK, M., 1992. Výchova smrkových porostů pod vlivem imisí v Orlických horách – výsledky pokusu (The tending of spruce stands as influenced by immissions in the Orlické Hory Mts). Lesnictví – Forestry, *38*, 1992: 783–792.

ŠÁLY, R.: Pôda, základ lesnej produkcie (The soil, the basis of forest production). Bratislava, Príroda 1978. 235 pp.

ŠÁLY, R.: Pedológia a mikrobiológia (Pedology and microbiology). Zvolen, VŠLD 1988. 378 pp.

ŠARMAN, J.: Vliv pěstebního zásahu na stav povrchového humusu v jedlovém porostu (The effect of silvicultural intervention on the condition of surface humus in fir stand). Lesnictví, *25*, 1979: 595–604.

ŠARMAN, J.: Vliv probírky na povrchový humus ve smrkovém porostu (The effect of thinning on the surface humus in spruce stand). Lesnictví, *28*, 1982: 31–42.

ŠARMAN, J.: Vliv probírky na humusový profil v bukovém porostu (The effect of thinning in humus profile in the beech stand). Lesnictví, *31*, 1985: 341–349.

ŠARMAN, J.: Vliv různé intenzity prořezávky v dubové mlazině na některé půdní vlastnosti (The effect of different intensity of juvenile thinning in oak young stand on some soil properties). Lesnictví, *32*, 1986: 637–644.

TESAŘ, V.: Prvé výsledky z výchovy smrkových tyčovin ovlivněných imisemi (The first results from tending of spruce pole-stage stands influenced by immissions). Práce VÚLHM, *48*, 1976: 55–76.

VYSKOT, M. et al.: Probírky (Thinnings). Praha, SZN 1962. 303 pp.

WRIGHT, T. W.: Some effects of thinning on soil of a Norway Spruce plantation. Forestry, *30*, 1957: 123–133.

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Změny množství a charakteru nadložního humusu v důsledku výchovných zásahů.

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Výchovné zásahy ovlivňují zásadním způsobem porostní stabilitu a růstovou dynamiku. Ovlivňují také prostředí porostu a proces formace a transformace nadložního humusu. Ten představuje jeden ze základních faktorů lesního ekosystému i z hlediska hydrických funkcí lesa. Kromě nezanedbatelné retenční kapacity hraje tato složka lesního ekosystému důležitou roli v transformaci zásaku a odtoku ze zalesněného území. Předkládaný příspěvek dokumentuje změny humusových forem na lokalitě Vrchmezí v Orlických horách, ve vyšších nadmořských výškách. Experiment s výchovnými zásahy byl založen zhruba před 30 lety a jeho cílem byla stabilizace smrkových porostů proti biotickým faktorům a imisím. Vzorky jednotlivých holorganických horizontů a nejsvrchnější vrstvy minerální zeminy byly odebírány na kontrolní a vychovávané variantě na podzim roku 2002, bylo sledováno množství a základní pedochemické charakteristiky. Výsledky dokumentovaly významné rozdíly mezi variantami (58,51 povrchového humusu t/ha na variantě s výchovou, 70,08 t/ha na variantě kontrolní), dále vyšší aciditu a obsah bází na kontrolní variantě, vyšší obsah Ca a Mg na variantě s výchovou. Rozdíly u těchto sledovaných charakteristik byly vesměs méně výrazné, třebaže byly v několika případech potvrzeny statistickou analýzou.

smrk; Orlické hory; výchovné zásahy; humusové formy; lesní půdy

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