Comparison of humus form state in the beech and spruce parts of the Žákova hora National Nature Reserve

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ABSTRACT: The paper summarises main ideas concerning the structure of natural forest ecosystems at middle altitudes and documents the changes of humus forms and their chemistry in the natural forest of Žákova hora National Nature Reserve, in typical selected parts with different tree species composition: European beech – Norway spruce. The species composition, age and spatial structure are discussed and analysis of the uppermost soil layer is done in particular parts of the natural forest regeneration cycle, of different stages respectively. We compared the amount and layer composition of surface humus and basic pedochemical characteristics of holorganic and upper mineral horizons. The results document changes in the character of humus forms as a consequence of the tree species change. On the contrary, a high portion of uncertainty as for the species, age and spatial structure follows from discussion about the structure of natural forests at middle altitudes.

Keywords: natural forest ecosystems; middle altitudes; species composition; age structure; humus forms; soil chemistry; Žákova hora Reserve

Studies of natural forest ecosystems represent a vital source of data and ideas concerning close-to-nature or ecologically based forest management. Their results are of great importance in different disciplines of forestry or natural sciences as well as for foresters, scientists and public education. On the contrary, only few forests under minor human influence were left in the cultural Czech landscape. Their conservation, protection and formation of the representative net in the ecological scale are of prime importance for forest ecology, forest economics and for the world natural heritage.

A wide range of problems is connected with this process:

- definition, delimitation of at least the main types of natural forests, formulation of ideas concerning their natural structure,
- establishment of a representative set of forest ecosystems of primary interest, description of their topical state and hemeroby (deviation from the natural state),
- delimitation of the areas of interest in particular forest complexes, destined for the natural, spontaneous development and delimitation of the buffer zone,
- definition of the forestry management of these areas and its impact on forest economics and function effectiveness including production function,
- compensation of costs at least in the case when the owner's aims differ from the State.

The objective of the present study is to document the changes of humus forms (layers) depending on a limited human impact (species composition) and natural dynamics on experimental results in the concrete case of the National Nature Reserve Žákova hora. Although the humus forms were the object of particular studies in the commercial and man-managed stands (overview see e.g. in Podrázský, Remeš 2005; Svoboda, Podrázský 2005), similar results from Czech conditions are totally missing.

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METHODS

National Nature Reserve Žákova hora is located in the summit part of the Žďárské vrchy Hills (x = 636,751.3021, y = 1,104,925.0056), close to the highest part, roughly 12 km N of the district town of Žďár nad Sázavou. The altitude ranges between 730 and 808 m a.s.l. It includes natural communities of mixed spruce-fir-beech forests, the rate of naturalness is relatively high despite of strong anthropic influences in the past (cutting, charcoal production). The main forest type groups are represented by: 6K, S, B, D. In the case of studied plots, the site conditions were more homogeneous – 6B and 6S (Průša 2001). The whole region is located in Natural Forest Area 16 – Českomoravská vrchovina Uplands.

To study the humus form, so called eco-series were determined, i.e. transects enabling the comparison of the natural state in the Nature Reserve (NR) with the human influenced ecosystems in its vicinity, or the comparison of different development stages of the natural ecosystems.

Series 1: beech thicket – growing-up stage – optimal stage (terminology according to Podlaski 2004), transect in the middle of the W border of the Reserve, in the horizontal direction, plots at a 50 m distance from each other;

Series 2: spruce maturing stand, beech maturing stand, optimal stage, break-up stage, mature spruce stand, in the uppermost part, W/E direction, plots at a 50 m distance. Although the whole stand is composed of a mixture of beech and sycamore, beech is growing in the broader vicinity of sampling sites, affecting the humus forms most dominantly. Parts without mixing, occupied by one species, were selected for sampling.

Sampling was done using a steel frame 25 × 25 cm in 4 replications, particular holorganic horizons were sampled separately. Moreover, the topmost mineral horizon was sampled too – not quantitatively (Green et al. 1993). Bulk samples were formed directly in the field by particular horizons, analyses were performed by standard pedochemical methods by laboratory Tomáš – based at the Forestry and Game Management Research Institute, Forest Research Station Opočno. These characteristics were determined: amount of DM of holorganic horizons, their content in total nutrients (N, P, K, Ca, Mg – mineralization by sulphuric acid and selenium, AAS), content of plant available nutrients in the 1%

Table 1. Comparison of humus form status in Series 1 – Žákova hora Mt.

Horizon	Thickness (cm)	Dry mass (g/m²)	pH H_2O	pH KCl	S (mval/100 g)	H (mval/100 g)	T (mval/100 g)	V (%)
Beech thicket								
L + F1	1.000	206.8	5.2	4.4	40.4	21.9	62.4	64.8
F2	2.375	1,562.8	5.0	3.9	31.7	37.7	69.4	45.7
H	3.250	7,060.0	4.1	2.7	14.4	55.4	69.9	20.7
Ah			4.7	3.0	3.3	19.7	23.0	14.3
Total	6.625	8,829.6						
Beech – growing-up stage								
L + F1	0.750	418.0	5.0	3.3	21.1	23.0	44.1	47.8
F2	2.250	1,765.2	4.7	3.1	0.4	48.1	48.5	0.9
H	3.375	5,532.4	4.4	2.4	4.5	68.2	72.7	6.2
Ah			4.7	3.1	4.3	18.9	23.2	18.6
Total	6.375	7,715.6						
Beech – optimal stage								
L + F1	1.000	427.6	5.1	4.3	28.5	21.6	50.0	56.9
F2	2.625	1,784.0	4.8	3.1	9.9	54.5	64.4	15.4
H	3.375	5,864.4	4.6	2.3	9.1	56.5	65.6	13.9
Ah			4.8	3.0	3.8	18.3	22.1	17.2
Total	7.250	8,076.0						

citric acid solution, pH (H_2O, 1 N KCl), soil adsorption complex characteristics according to Kappen (S – base content, H – hydrolytic acidity, T – cation exchange capacity, V – base saturation), exchangeable acidity, total humus content and total nitrogen content according to Kjeldahl. Bulk samples were formed in the field and so statistical evaluation is limited – the number of replications 4 is on the significance limit (Podrázský 1993).

RESULTS AND DISCUSSION

Series 1

Results obtained in the first series enable to compare the humus form state in the quasi-climax stand in the growing-up stage and in the optimal stage. This series is completed with the intensively growing planted beech thicket (Tables 1–3).

In this series, the variation of the surface humus amount during the forest development cycle shows considerable deviations. Maximum accumulation is documented in the optimal stage, owing to the maximum primary production, maximum canopy regulating the microclimatic conditions and slowed decomposition (Korpeľ 1991). This amount is reduced to the minimum during the break-up stage, consequently it is increased again during the next growing-up stage as the result of more intense canopy and biomass (necromass – litter) accumulation.

The very dense beech thicket represents also a locality with intense accumulation of litter with slower decay – beech thicket shows high values of surface humus accumulation, especially of more transformed matter (H layer). Both stands with more diversified structure exhibited higher ratios of surface humus in less transformed forms – accumulation amounts were relatively comparable. Dense canopy of young even-aged stages is probably more suitable for higher organic matter accumulation on the soil surface, management of even-aged stands causing considerable variations in the holorganic matter amounts (Heinsdorf et al. 1986).

The beech thicket also showed lower acidity (pH H_2O) in the horizons L and F. In the lower layers, the values decreased in the order: optimal stage, growing-up stage, thicket. This reflects the demands on the nutrition and base uptake, i.e. the maximum uptake and accumulation by the thicket, minimum one by the balanced mature stand. The pH (KCl) reflected longer-term trends of the minimum acidification in the beech thicket, higher in the optimum stage stand and the highest in the case of dynamic increase of the new forest generation.

The exchangeable base content was also the highest in the beech thicket, lower in the stand in the optimal stage and lowest in the stand of growing-up stage. This indicates together with the pH analysis considerably high demands of this development stage on soil nutrients. Similar trends were also

Table 2. Comparison of humus form status in Series 1 – Žákova hora Mt.

Horizon	Exch. acidity	Exch. H	Exch. Al	Total N	Total P	Total K	Total Ca	Total Mg
		(mval/kg)				(%)		
Beech thicket								
L + F1	30.0	17.0	13.0	1.81	0.31	0.14	0.58	0.034
F2	42.0	21.2	20.8	1.92	0.25	0.14	0.36	0.028
H	57.0	13.8	43.3	1.90	0.15	0.14	0.22	0.006
Ah	51.6	6.3	45.3					
Beech – growing-up stage								
L + F1	24.5	17.2	7.3	1.67	0.18	0.14	0.34	0.028
F2	49.2	19.1	30.1	2.12	0.15	0.12	0.22	0.012
H	99.0	16.5	82.5	2.11	0.17	0.14	0.08	0.012
Ah	64.0	7.8	56.3					
Beech – optimal stage								
L + F1	32.5	18.5	14.0	1.78	0.20	0.18	0.38	0.034
F2	47.5	15.7	31.8	1.96	0.13	0.12	0.20	0.018
H	86.8	13.1	73.7	1.82	0.16	0.22	0.12	0.012
Ah	61.1	4.6	56.5					

shown by the values of the hydrolytical acidity (H-values) and base saturation (V-values). Interesting is the trend of relatively high acidification in the Ah horizon of the beech thicket, this can be explained by its intense growth and nutrient uptake – a tendency contrary to the holorganic layers affected by the relatively rich litter (Table 1).

The part of the stand in the growing-up stage shows slightly, but visibly increased values of the exchangeable acidity, determined especially by increased content of exchangeable aluminum. On the other hand, the relative enrichment with the total nitrogen of the holorganic profile was observed. Total phosphorus showed the trend of enrichment in the holorganic and impoverishment in the mineral soil layer of the beech thicket, total potassium was observed in the highest concentrations in the optimal stage stand, which is in temporal equilibrium with the soil. The content of total calcium was the highest in the beech thicket again, total magnesium in older stands showed the tendency of the movement into lower horizons, i.e. the signs of its leaching and of the soil acidification (Table 2).

The humus content in the beech thicket was the highest in the whole studied soil profile – this documents rapid humus transformation and relatively good mixing with the mineral soil. Total nitrogen determined by the Kjeldahl's method showed the same trend as was described above for nitrogen. The plant available phosphorus content was lowered in the deeper layers of the beech thicket and of the growing-up stage, so documenting the higher demands for this element. The beech thicket appeared as effectively recycling potassium in the plant available form, the growing-up stage was a little less effective. Similar results were observed as for plant available calcium and magnesium. The iron sesquioxide content was on the contrary the lowest in the beech thicket.

Evaluation of the results obtained in the study of Series 1 indicates high demands of the beech thicket and of the stand part in the growing-up stage. The beech litter affects the soil characteristics positively, signs of impoverishment are visible in the stand part in the growing-up stage. In the optimal stage, the forest soil compartment shows higher surface humus accumulation, on the other hand also the continual transformation processes without big changes. No studies of similar character are available, but analyses from other protected areas showed tendencies of surface humus accumulation, acidification and degradation in the stand parts composed of fast growing conifers (Podrázský et al. 2002).

Series 2

The humus form comparison in a large series includes the spruce and beech maturing stand,

Table 3. Comparison of humus form status in Series 1 – Žákova hora Mt.

Horizon	Humus	N (Kj.)	P_2O_5	K_20	CaO	MgO	Fe_2O_3
	(%)		plant available nutrients (mg/kg)				
Beech thicket							
L + F1	77.5	1.99	1,009	1,387	6,987	672	72
F2	59.8	2.09	791	673	3,333	283	24
H	51.6	2.03	356	620	2,693	171	264
Ah	13.5	0.51	134	142	393	33	663
Beech – growing-up stage							
L + F1	51.5	1.93	801	813	4,533	523	133
F2	48.7	2.16	875	713	2,827	277	72
H	50.7	2.32	179	287	800	139	176
Ah	12.8	0.58	137	127	173	38	833
Beech – optimal stage							
L + F1	42.6	1.91	1,040	1,000	5,947	688	104
F2	54.9	1.99	693	353	3,760	389	85
H	48.6	2.08	139	287	1,200	156	309
Ah	11.5	0.53	115	195	320	49	983

Table 4. Comparison of humus form status in Series 2 – Žákova hora Mt.

Horizon	Thickness (cm)	Dry mass (g/m²)	pH H_2O	pH KCl	S	H	T	V (%)
					(mval/100 g)			
Spruce – maturing stand								
L + F1	1.250	920.4	5.1	3.4	2.0	28.6	30.6	6.5
F2	2.625	2,122.4	4.6	2.7	7.6	68.7	76.3	10.0
H	4.250	6,083.2	4.3	2.0	4.4	67.5	71.9	6.1
Ah			4.7	2.8	4.4	27.1	31.5	13.8
Total	8.625	9,126.0						
Beech – maturing stand								
L + F1	0.875	406.8	5.1	4.0	41.5	34.4	75.9	54.7
F2	2.125	996.4	5.1	3.5	26.9	50.2	77.1	34.9
H	2.375	2,073.6	4.4	2.4	15.7	65.9	81.6	19.2
Ah			4.9	3.0	6.8	33.6	40.4	16.7
Total	5.375	3,476.8						
Optimal stage								
L + F1	0.875	277.2	5.2	4.0	34.8	35.0	69.8	49.9
F2	1.250	1,444.4	5.0	3.2	19.9	51.5	71.4	27.9
H	1.625	3,170.8	4.3	2.5	9.7	57.8	67.4	14.3
Ah			4.7	3.0	5.6	29.1	34.7	16.0
Total	4.125	4,892.4						
Breaking-up stage								
L + F1	0.500	177.2	5.3	4.0	39.2	31.0	70.2	55.9
F2	1.000	915.6	5.2	3.3	19.8	52.5	72.3	27.4
H	1.000	1,397.2	4.2	2.6	14.3	54.0	68.3	21.0
Ah			4.8	3.1	7.8	27.4	35.2	22.2
Total	2.500	2,490.0						
Spruce – mature stand								
L + F1	0.875	494.8	5.4	3.5	1.6	24.2	25.8	6.2
F2	2.000	2,904.4	4.6	2.6	4.0	51.7	55.7	7.2
H	2.375	2,182.8	4.5	2.4	0.5	51.1	51.6	1.0
Ah			5.0	3.1	5.3	19.4	24.8	21.5
Total	5.250	5,582.0						

beginning optimal stage, breaking-up stage and mature spruce stand (Tables 4–6). These results also indicate considerable spatial variability of the surface humus characteristics in the forest stand life cycle. Contrary to Series 1, the maximum humus accumulation is not observed in the late optimal stage, but in younger even-aged stands – maturing monocultures. The even-aged forest parts show a tendency of higher surface humus accumulation (Table 4), due to both greater litter production and more conservative stand environment. The spruce stand accumulated a higher amount compared to the beech one, this trend is determined by different litter production and its bio-degradability. A decrease in the surface humus amount is also observable in the spruce stand at the higher age that is connected with the canopy lowering and beginning of regeneration. This natural regeneration is conditioned by the humus changes. Similar differences and trends were documented for beech and spruce also by Šarman (1982a) and Školek and Bublinec (1981).

In the late regeneration phase, a steep decrease in the surface humus amount is obvious; as this phenomenon was not documented in other cases, verification is necessary. The humus amount changes are of greater extent compared to data reported by other authors for commercial forests (Heinsdorf et al. 1986; Šarman 1982b, 1985, 1986, 1987), managed even by the clear-cutting.

The soil reaction (H_2O) does not show any visible trends contrary to pH (KCl). The highest acidification of the soil profile was documented in the younger spruce stand with strong bio- as well as necromass accumulation. A lower trend of this type was documented in the older spruce monoculture (Table 4). A more favourable situation was documented in the stand part in the optimal stage, then in the breaking-up stage and in the younger beech stand – an increase in the pH value was observed in these cases.

In the pure spruce stands, the critical base content and base saturation decreases to extremely low values were documented. Diversified structures and especially the beech presence improved the soil condition considerably.

Similarly, in the pure spruce stands, the characteristics of exchangeable acidity were the highest (Table 5), more pronounced in the older stand. They were the lowest in the pure beech maturing stand. The total nitrogen content was the lowest in the older spruce stand with high accumulation of biomass as well as with losses from the soil compartment. It was low also in the younger spruce stand. Medium values were observed in the stand of optimal stage, also

Table 5. Comparison of humus form status in Series 2 – Žákova hora Mt.

Horizon	Exch. acidity	Exch. H	Exch. Al.	Total N	Total P	Total K	Total Ca	Total Mg
	(mval/kg)			(%)				
Spruce – maturing stand								
L + F1	22.7	14.7	8.0	1.65	0.11	0.12	0.44	0.026
F2	54.0	18.7	35.3	1.78	0.07	0.10	0.18	0.018
H	86.9	21.9	65.1	1.64	0.03	0.14	0.18	0.006
Ah	71.2	9.3	61.9					
Beech – maturing stand								
L + F1	35.5	23.5	12.0	1.91	0.22	0.12	0.62	0.050
F2	31.7	16.0	15.7	2.07	0.03	0.10	0.46	0.036
H	59.0	12.0	47.0	2.06	0.03	0.16	0.30	0.012
Ah	70.3	6.6	63.6					
Optimal stage								
L + F1	30.7	17.5	13.2	1.96	0.08	0.12	0.54	0.056
F2	34.7	15.0	19.7	1.90	0.04	0.10	0.32	0.046
H	85.2	13.3	71.9	1.71	0.04	0.16	0.18	0.006
Ah	77.6	6.3	71.3					
Breaking-up stage								
L + F1	35.7	18.7	17.0	1.93	0.06	0.16	0.58	0.048
F2	34.2	14.2	20.0	1.99	0.02	0.12	0.46	0.026
H	51.4	11.4	40.1	2.00	0.02	0.16	0.32	0.006
Ah	62.5	6.8	55.7					
Spruce – mature stand								
L + F1	21.2	10.0	11.2	1.64	0.04	0.10	0.30	0.022
F2	69.5	14.3	55.2	1.67	0.02	0.12	0.20	0.010
H	95.0	7.9	87.1	1.56	0.04	0.22	0.12	0.006
Ah	84.7	4.9	79.8					

Table 6. Comparison of humus form status in Series 2 – Žákova hora Mt.

Horizon	Humus	N Kj.	P_2O_5	K_20	CaO	MgO	Fe_2O_3
	(%)		(mg/kg)				
Spruce – maturing stand							
L + F1	68.8	1.64	791	1,000	3,787	293	80
F2	72.9	1.78	365	507	2,720	197	160
H	58.0	1.64	127	173	1,107	100	328
Ah	17.8	0.70	124	130	287	45	652
Beech – maturing stand							
L + F1	58.1	1.87	935	1,167	7,147	648	104
F2	61.5	1.88	801	507	4,667	387	147
H	56.4	2.04	206	250	2,013	172	245
Ah	24.5	0.81	133	140	253	51	605
Optimal stage							
L + F1	53.2	1.98	1,225	1,260	5,493	536	99
F2	54.5	1.95	856	607	4,347	389	133
H	50.9	1.94	249	453	1,560	231	476
Ah	21.7	0.85	131	157	233	83	1,136
Breaking-up stage							
L + F1	56.0	1.98	1,037	1,893	6,240	491	171
F2	58.9	1.95	869	833	5,760	448	152
H	57.4	1.89	366	700	2,587	233	255
Ah	23.4	0.95	134	193	533	91	741
Spruce – mature stand							
L + F1	47.4	1.41	546	630	2,560	251	83
F2	67.8	1.64	166	247	1,227	136	304
H	45.7	1.71	153	383	693	137	787
Ah	13.3	0.48	121	77	120	69	2,114

with high values of biomass accumulation and with high canopy. In the breaking-up stage, the N-mineralisation increases again, enrichment with this element is observed in the humus layer. The nitrogen content of the humus form is positively affected by the beech presence, even its dominance in the species stand composition.

The total phosphorus content was comparable and low in stands with high biomass amount. The highest values were documented in the young beech stand. Dynamics of total potassium indicates its movement to lower layers again, and it was the most obvious in the mature spruce stand – similar trends were documented for total Ca and Mg. Differentiation of the stand structure and the beech presence showed positive effects on the base content.

The humus content (Table 6) was also different for particular horizon types. In the holorganic horizons, the contents were highly comparable. On the other hand, its content increased in the order: spruce stands – beech stand – diversified stand – breaking-up stage showing the highest ones. This indicates on-going soil changes based on intense decomposition processes.

The plant available phosphorus content was the lowest in the humus forms of the older spruce stand, it was a little higher in the younger spruce one. Also in the younger beech stand, the intense fixation of this nutrient was registered. The highest and at the same time similar contents were determined in both differentiated stands. A similar tendency was observed in the case of the plant available potassium, indicating highly increased content in the stand of breaking-up stage. Intense decomposition processes, structural as well as soil ones, lead to potential losses of this macronutrient. A similar situation was determined for plant available calcium with the difference that the highest concentrations were determined for the younger beech stand – this was similar like in plant available magnesium. The highest contents of iron sesquioxides were determined in the older spruce stand, similarly like in other cases.

Pure spruce monocultures have degradation effects in the given conditions; this can be documented in the case of soil acidity and particular nutrient content of different forms. Beech admixture as well as higher spatial diversity work as ameliorative factors. Higher canopy loosening can increase nutrient losses from the forest ecosystem, especially of nitrogen and bases. The values of the pedo-chemical characteristics are comparable to other data (Vrška et al. 1999) from the area of interest, larger differences were observed in the case of pH and of total nitrogen (we observed higher values).

CONCLUSIONS

The results showed considerable variability of the humus forms in the homogeneous site conditions, depending on the development stage of the forest stand, on its space heterogeneity, structure and species composition. Natural and close-to-nature forest stands exhibit also high dynamics of the surface humus, in many cases comparable to that of commercial forests.

Development stages determined by high net primary production accumulated also a relatively higher amount of surface organic matter and showed a tendency of strong nutrient uptake and biological mobilisation – leading to the site acidification.

On the other hand, more intense canopy lowering in the breaking-up stage resulted in the acceleration of decomposition and mineralisation activities of soil and in some revitalisation.

Spruce was confirmed to be a species promoting more extreme soil development – surface humus accumulation, beginning of acidification.

The results document missing data on the natural forest ecosystem dynamics and can serve as a comparison basis for further studies. This part of development of the natural forest ecosystems has been totally neglected until now.

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Srovnání humusových forem v bukových a smrkových porostech NPR Žákova hora

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ABSTRAKT: Příspěvek shrnuje hlavní myšlenky týkající se struktury přírodních lesních ekosystémů ve středních nadmořských výškách a dokumentuje vliv strukturálních změn lesních porostů na stav humusových forem a jejich chemismus v pralese NPR Žákova hora. Studie byla provedena v typických podmínkách této lokality a zachycuje různá vývojová stadia přirozených lesů a změny druhové skladby, především střídání hlavních dominant – smrku a buku. Srovnáváno bylo: množství a morfologické vlastnosti povrchového humusu a základní pedochemické vlastnosti holorganických horizontů a nejsvrchnějšího horizontu minerálního. Výsledky doložily značné změny humusových forem jako důsledku změny druhové skladby porostů a rovněž značné změny (s velkou mírou neurčitosti) v důsledku postupu jednotlivých vývojových stadií přírodních a přirozených lesů.

Klíčová slova: přírodní lesy; střední polohy; druhové složení; věková struktura; humusové formy; půdní chemismus; NPR Žákova hora

Přírodní a přirozené lesy a jejich dynamika představují základ pro přírodě blízké lesní hospodářství a lesnictví založené na ekologické bázi. Studium posledních zbytků podobných porostů tak má mimořádný význam. Jednu z nejstarších, nezachovalejších a zároveň nejvíce prozkoumaných lokalit představuje Národní přírodní rezervace Žákova hora ve vrcholové části Českomoravské vrchoviny (Žďárské vrchy). Toto chráněné území reprezentuje typické stanoviště smíšených buko-jedlo-smrkových lesů. Příspěvek dokumentuje aktivity spojené s analýzou nejsvrchnější části půdy v porostních částech s různým stupně vývoje, prostorovou strukturou a druhovým složením i v částech s různou intenzitou antropogenního vlivu.

Humusové formy, tj. holorganické vrstvy a nejsvrchnější část minerálního půdního profilu, byly studovány ve dvou sériích:
– Série 1: buková mlazina, stadium dorůstání, stadium optima v rámci přirozeného vývojového cyklu;
– Série 2: smrková nastávající kmenovina, buková nastávající kmenovina, stadium optima, stadium rozpadu, dospělá smrková kmenovina.

Bylo stanoveno:
– tloušťka a zásoba nadložního humusu ve vrstvách L + F1, F2, H,
– obsah celkových živin v holorganických vrstvách,
– půdní reakce aktivní a potenciální, charakteristiky půdního sorpčního komplexu podle Kappena, charakteristiky výměnné acidity, obsah celkového humusu, dusíku, a přístupných živin (P, K, Ca, Mg, Fe) ve výluhu kyselinou citronovou v holorganických horizontech a v horizontu Ah.

Výsledky (tab. 1–6) dokládají značnou variabilitu humusových forem i v rámci jednoho stanovištního typu v závislosti na stadiu vývoje, prostorové a druhové struktuře lesního ekosystému. Přírodní a přirozené porosty vykazují značnou dynamiku povrchového humusu, často srovnatelnou s hospodářskými lesy.

Vývojová stadia s vysokou čistou primární produkcí akumulují zároveň relativně vysoká množství povrchového humusu a fixují v něm a ve své biomase vysoká množství živin. Na druhé straně se stadia spojená s obnovou lesa zároveň vyznačují intenzivnější dekompoziční aktivitou a mineralizací organické hmoty.

Smrk přispívá k extrémnějšímu stavu půdního chemismu a stavu humusové formy, obecně k akumulaci povrchového humusu a ke zvýšení acidity.

Získané výsledky uvádějí údaje dosud nepublikované jinými autory, přitom nezbytné pro zvážení důsledků lesopěstebních opatření. Jsou významné při posuzování důsledků přírodě blízkého lesního hospodářství.

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