PRACTICE FERTILIZATION AND STATE OF HUMUS FORMS IN THE AREA OF THE SCHOOL TRAINING FOREST KOSTELEC NAD ČERNÝMI LESY – THE MOŠTICE LOCALITY

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Abstract

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Long-term fertilization effects were evaluated including NPKCa and N application in the lower altitudes. The research plot Moštice was established on the Forest District Krymlov territory (Forest District Kostelec today) in the stand 638 b1 (today code 13 D11), at the altitude 400 m a.s.l. on a mild NW slope, forest type was determined as *Luzulo pilosae Abietum* (4O1). The soil (Luvisol) is loamy, with loess enrichment. At the age of sampling, the stand age was 108 years. Fertilizers were used in the period 1965–1976, evaluation of the soil state was done in 1967 (before) and 2002 years. After 25–35 years, only slight effects of fertilization are detectable in the humus forms and complex soil profile – surface humus accumulation, soil chemistry, as well as nutrient contents. Complex fertilization was reflected by higher site fertility in general, the N-fertilization only in the progress of acidification. During the period 1967–2002, a strong general trend of acidification is obvious caused both by the acid deposition and the Norway spruce monoculture-based forestry.

Key words: fertilization, Norway spruce, forest soils, humus forms, acidification, amelioration

Introduction

Last period represents a renaissance of the wood and timber as a multiple-use natural renewable resource, with an emphasis on its sustainable production and utilization. Temporary lack of the timber in the last centuries and decades led to study of opportunities of timber production increase respecting the above mentioned aspects (Binkley, 1986). The trends of solution of this economical as well as environmental problem were different: introduction of close-to nature principles in some cases (restoration of degraded sites), introduction of exotic species, tree breeding technologies and forest land extension (reforestation of marginal agriculture and range lands). Among them, the increase of site fertility and production played also important role – by improving soil state and nutrient supply. Nutrient loss by soil acidification represents another argument for the fertilization use, increased by the biomass removal and supported by the healthy status improvement of declining forest stands (Hüttl, 1987; Huettl, Zoettl, 1993; Podrázský, 2006; Podrázský et al., 2003).

Fertilization in forestry can be effectively used in different site conditions and at different forest stages: in forest nurseries, at reforestation, in plantations, at medium age of stands and also in the older stands with harvest perspective. In forest nurseries, it is *conditio sine qua non* for the soil fertility conservation. Fertilization of young plantations should accelerate their increase and improve vitality to shorten time necessary for intense care (weeding, fencing, re-planting – Podrázský, Remeš, 2006), to reduce mortality on unfavorable sites (Remeš et al., 2004). In the middle and older ages, it had production purposes too: volume growth increase, assortment changes, and soil improvement for the forest regeneration (Binkley, 1986). There is considerable higher number of data available for fertilization of young plantations, in Czech conditions is missing information on older stands treatments.

Fertilization influences not only the growth of forest trees, but also the soil state and chemistry, further it affects the tree vitality and resistance to particular damage factors. On the other hand, often changes in the forestry policy led to abandoning of many research plots, established in the past. Also on the territory of the School Training Forest Kostelec nad Černými lesy were established research plots with fertilization testing in 1965–1967. The aim of the former study was to quantify increment effect of particular fertilization methods in the maturing spruce stands on different sites. The plots were not studied between years 1980–2002. The aim of the presented study is to document the research results on one re-constructed plot set in this area: effects of the fertilization on the forest soil in the years 1967–2002 and soil changes in this period on the control plot on the locality Moštice. From other plot, Aldašín, the results were published (Remeš, Podrázský, 2006). Particular series of research plots are reconstructed, evaluated and the results are prepared for publication.

Material and methods

Several systems of permanent research plots (PRP) were established on the School Training Forest Kostelec nad Černými lesy territory. This area is located 25–50 km SE from Prague (Karnet, Malík, 2006). The climate is moderately warm and arid, mean year temperature is 7.6 °C, average year precipitation reaches 655 mm value (station Ondřejov). The soils are of Luvisol type, the established research plots are especially on the Fir-Beech sites. The research plot Moštice was established on the Forest District Krymlov territory (Forest District Kostelec today) in the stand 638 b1 (today code 13 D11), at the altitude 400 m a.s.l. on a mild NW slope, forest type was determined as *Luzulo pilosae Abietum* (4O1 by topical classification). The soil (Luvisol) is loamy, with loess enrichment. At the age of sampling, the age was 108 years.

The experiments were established in the period 1965–1967 as a part of a large project, abandoned in the 1980ies. The size of individual subplots was 0.20–0.25 ha, the position and dendrometric parameters were determined for individual trees. Three basic variants were defined at each particular research plot:

– control one, without fertilizers application,
– full fertilization, NPKCa,
– nitrogen application, N.

NPKCa: commercial fertilizer, 150–200 kg of pure N/ha, 50–100 kg pure P/ha, 100 kg pure K/ha, 100–400 kg pure Ca/ha.

N: 180–200 kg pure N/ha in the ammonium nitrate form. All application was done manually to ensure even fertilizer distribution. The experiment was stopped in 1970ies, abandoned in 1980ies, re-stored in 2002 (remeasurement, soil sampling). Only part of the plots was conserved.

Sampling of holorganic layers was done using steel frame 25x25 cm in 4 replications, particular 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 in the Opočno Research Station – fa Tomáš – laboratory. It was determined: amount of DM of holorganic horizons at 105 °C, their content in total nutrients (N, P, K, Ca, Mg – mineralization by sulphuric acid and selene, AAS), content of plant available nutrients in the 1% citric acid solution, pH (H_2O, 1 N KCl), soil adsorption complex characteristics by Kappen (S – bases content, H – hydrolytic acidity, T – cation exchange capacity, V – bases saturation), exchangeable acidity, total humus content and total nitrogen content by Kjeldahl. Number 4 of replications is on the significance limit (Podrázský, 1993).

Mineral horizons were sampled using the soil borer, in 4 replications and bulk samples preparation as well, sampling done by particular pedogenetic horizons, comparable with 1967 sampling layers. In the first sampling term, only limited set of characteristics was determined, so the comparison possibilities are restricted.

Results and discussion

There was not visible trend in the surface humus accumulation among variants with an exception of slightly higher amount of its D.M. in the complex fertilized stand (Table 1). Also the total nitrogen content was not different between variants. The effect of the complex fertilization was visible (not significantly) in the total phosphorus as well as potassium contents, probably due to the stability of the P-constituents (Binkley, 1986) and re-cycling of the K-ions. The contents of bivalent cations were very similar, the variations did not show any visible trends. The effects of the fertilization were not significantly detectable in spite of the total nutrients content among particular variants – they are probably covered by the forest stand dynamics including the humus forms. Comparing the plot Moštice with the formerly studied Aldašín plot (Remeš, Podrázský, 2006), on the other plot the complex fertilization accelerated the humus turnover, the N-fertilization slowed it on the contrary. Moreover, on the Aldašín locality, the N-application caused visible N-enrichment and Ca and K losses.

It was possible to core the soil to the depth up to 60 cm on the Moštice locality by the soil borer. This research plot represented the most rich site among studied localities (Remeš, Podrázský, 2006), which was reflected both by the depth of the soil profile, both by depth of the Ah horizon (Tables 2 and 4).

Values of the active pH are very equal among variants, slightly higher pH in the complex variant and lower in the N-one are only indicative, without significant support. The differences in the order of 0.2 pH units are in the error frame (Podrázský, 1993). As for the pH KCl, the results showed insignificantly, but visible higher values in both fertilized variants in the non transformed and slightly transformed layers (L + F1), lower value in the H horizon of the N-variant, and higher pH (KCl) in mineral horizons of both fertilized variants. The fertilization effect could be considered as positive as for the soil reaction. On the compara-

T a b l e 1. Amount of surface humus and total nutrients content in the hologanic horizons on the Moštice locality.

Subplot	Horizon	Dry mass t/ha	N	P	K %	Ca	Mg
1	$L + F_1$	5.56	1.35	0.08	0.08	0.48	0.034
	F_2	18.24	1.64	0.07	0.06	0.12	0.034
NPKCa	H	44.676	1.61	0.10	0.20	0.02	0.062
Total		**66.476**					
2	$L + F_1$	3.884	1.25	0.06	0.06	0.64	0.036
	F_2	19.520	1.68	0.07	0.06	0.14	0.034
N	H	33.956	1.48	0.07	0.12	0.02	0.042
Total		**59.360**					
3	$L + F_1$	6.712	1.36	0.06	0.06	0.40	0.034
	F_2	15.976	1.71	0.07	0.08	0.16	0.050
Control	H	38.924	1.46	0.06	0.12	0.02	0.044
Total		**61.612**					

T a b l e 2. Soil reaction and soil adsorption complex characteristics on the Moštice locality.

Subplot	Horizon	pH H_2O	pH KCl	S	H mval/kg	T	V %
1	$L + F_1$	4.40	3.80	19.4	26.8	46.2	42.1
	F_2	4.60	3.60	25.3	30.0	55.4	45.8
NPKCa	H	4.30	3.10	20.8	52.7	73.6	28.3
	Ah	4.60	3.40	3.3	13.1	16.3	20.0
	B1	4.60	3.90	2.6	5.9	8.6	30.9
	B2	4.40	3.90	4.2	4.0	8.2	51.5
	B3	4.50	4.00	7.2	4.3	11.5	62.4
2	$L + F_1$	4.30	3.70	18.2	17.8	36.0	50.6
	F_2	4.70	3.50	22.9	31.8	54.7	41.9
N	H	3.70	2.90	19.2	54.6	73.8	26.0
	Ah	4.60	3.40	2.3	13.9	16.2	14.4
	B1	4.90	3.90	0.7	6.6	7.3	9.6
	B2	4.30	4.00	1.9	6.3	7.2	26.1
	B3	4.50	4.00	8.4	3.2	11.5	72.7
3	$L + F_1$	4.30	3.20	22.8	19.4	42.2	54.0
	F_2	4.70	3.70	29.0	26.6	55.6	52.1
K	H	4.10	3.00	19.8	51.7	71.5	27.7
	Ah	4.50	3.20	2.3	16.0	18.4	12.6
	B1	4.90	3.80	2.0	6.8	8.8	22.6
	B2	4.40	3.80	3.9	4.9	8.8	44.3
	B3	4.70	3.40	8.7	3.9	12.6	69.3

T a b l e 3. Exchangeable titration acidity and plant available nutrients content on the Moštice locality.

Subplot	Horizon	Exchangeable			Plant available nutrients – 1% citric acid				
		acidity	hydro-gen	alumi-num	P_2O_5	K_2O	CaO	MgO	Fe_2O_3
		mval/kg			mg/kg				
1	L + F_1	20.2	9.7	10.5	481	437	4.747	371	115
	F_2	16.6	6.3	10.4	233	147	3.067	213	211
NPK Ca	H	47.9	4.8	43.1	130	107	1.627	147	519
	Ah	62.6	1.8	60.8	671	63	300	82	1.253
	B1	40.1	1.0	39.1	151	44	253	51	915
	B2	30.0	1.1	28.9	124	66	607	107	1.172
	B3	36.0	1.3	34.8	29	90	713	154	550
2	L + F_1	20.0	9.4	10.6	553	576	4.000	381	77
	F_2	20.4	5.0	15.4	235	147	2.933	253	205
N	H	58.9	8.4	50.6	124	168	2.053	219	563
	Ah	72.4	1.4	71.0	55	28	140	57	790
	B1	55.3	1.3	54.0	59	19	67	31	675
	B2	50.2	1.1	49.1	48	33	373	102	919
	B3	38.5	1.4	37.2	39	56	1.013	223	859
3	L + F_1	32.7	12.5	20.2	417	425	4.507	376	104
	F_2	18.8	6.8	12.0	381	199	4.160	291	200
K	H	46.4	6.4	40.0	163	201	3.200	261	712
	Ah	78.1	1.8	76.3	145	44	387	85	1.688
	B1	62.2	1.4	60.8	60	25	80	41	775
	B2	44.1	1.4	42.8	49	38	560	135	1.099
	B3	31.6	1.5	30.2	29	53	940	219	886

tive Aldašín plot (Remeš, Podrázský, 2006), the N-variant showed more significant value decline. Similar effects of the pure N-application indicated also Popovic (1984).

The state of the adsorption complex characteristics was not significantly different among variants, the N-fertilized variant showed in the upper B-horizons more visible tendency to the exchangeable bases content and base saturation decrease. This acidification effect of the fertilization with nitrogen (also confirmed by Remeš, Podrázský, 2006) was also not significant. The nitrate leaching can probably cause these trends.

The next Table 3 documents the exchangeable acidity characteristics and plant available macroelements content on particular variants of the experiment. The plots did not differ with an exception of the acidity and aluminum content decrease on the variant with complex fertilization.

T a b l e 4. Dynamics of soil chemistry on the Moštice locality in the period 1967–2002.

Year	1967					2002				
Horizon	Ah	B1	B2	B3	C	Ah	B1	B2	B3	C
Depth cm	0–6	6–30	3–60	60 +		0–6	6–30	3–60	60 +	
pH H_2O	4.30	4.65	4.80	5.10		4.50	4.90	4.40	4.70	
pH KCl	3.90	4.40	4.30	4.40		3.20	3.80	3.80	3.40	
P_2O_5 mg/kg	30	20	23	43		145	60	49	29	
K_2O mg/kg	53	24	39	47		44	25	38	53	
CaO mg/kg	299	313	881	1,120		387	80	560	940	
MgO mg/kg	32	75	237	237		85	41	135	219	
Fe_2O_3 mg/kg	1.144	572	762	572		1.688	775	1.099	886	

The plant available phosphorus content was higher in the litter layer for both fertilized variants, the pattern being more variable deeper. At the variant with complex fertilization including the phosphorus one, the content of plant available P was higher comparing to the control, which documents the stability of this bioelement in the soil (Binkley, 1886). The nitrogen fertilization was reflected on the contrary slightly negative, i.e. mild decrease was documented. This can be caused by the uptake by more intensively growing trees. Less pronounced, but corresponding trend is showed also for the content of total nutrients in the holorganic horizons (Table 1).

Also the content of the plant available potassium increased in both fertilized variants in the litter layer, L + F1 respectively. It was lower comparing to the control variant in the deeper holorganic horizons. Its content was considerably higher in the variant with complex fertilization in the mineral horizons as the result of P-supply as well as K^+ cations leaching in the lower horizons. On the N-fertilized variant, the losses connected with nitrate leaching have to be considered.

Similar dynamics among variants was documented in the case of the plant available calcium and even more in the case of the plant available magnesium. Many deviations were observed in particular horizons. Complex fertilization shows slight tendency to content increase, n-fertilization to decrease.

In the plant available content, different dynamics was documented for holorganic and mineral horizons. In the surface humus layers the decrease of nutrients content is documented as a consequence of accelerated uptake, the enrichment is observed on the contrary in the mineral horizons. This is conditioned especially by the limiting of the physiological soil profile on the surface layers with maximum offer of the available nutrients (Wesemael, 1992). The application of the nitrogen is reflected by the higher losses of bivalent bases in the nitrate form.

The spectrum of studied soil chemistry characteristics was considerably limited in 1967, and the results of the humus form analyses are not available too, but the disposable data enable some reasonable conclusions as for the soil chemistry dynamics in the period 1967–2002 (Table 4). The active soil reaction showed different trends in the upper and lower layers. In the Ah and B1 horizons, slightly higher values were detected in 2002 (by 0.2–0.25 pH units), the acidity considerably increased lower (0.4 pH units). The potential soil reaction determined in the 1N KCl showed relatively dramatic decrease by 0.4–1.0 pH unit – the plots reflect considerable soil acidification. This can be caused by acid deposition, acidification effects of spruce even-aged monocultures on the former beech-oak-fir sites, as well as by other factors.

The plant available phosphorus content was slightly increased, with an exception of the deepest horizon, the potassium content did not show visible changes. Excepting the uppermost horizon, the contents of available Ca and Mg highly decreased – with the pH decrease it documents the ongoing acidification of studied forest soils. This conclusion is supported by the increase of the iron content in the leachable form.

Conclusion

The objects of research were the effects of the fertilization on the status of forest soils in the unique set of study plots on the territory of the School Training Forest. They were studied after application of complex as well as nitrogen fertilizers in the period 1967–2002. The preliminary research contributed the following knowledge:

– the effects of the fertilization are detectable even after 35 years, despite the characteristics shifts are not big,
– there were not great differences in the surface humus accumulation, despite slight higher accumulation on the complex fertilized variant. The amount of total nutrients was affected by the supply by fertilization. On the nitrogen variant, the decrease of bases in the total form was apparent,
– the nutrient addition including the bases was reflected in the shift of basic pedo-chemical characteristics (complex variant), as well as the acidification effect of the nitrogen addition was detectable. The changes were not dramatic in any case,
– the acidification effect is visible in the period 1967–2002, plant available nutrient content did not show any prominent dynamics.

Besides the general acidification trend, the cultivation of demanding spruce monocultures is in charge probably, connected with limiting of the root systems on the uppermost, prevailingly holorganic layers. The more detailed research is needed with more complex sampling and analyses, able to be evaluated statistically. Also the growth reaction has to be studied.

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