CHANGES OF SOIL CHEMISTRY IN THE NORWAY SPRUCE FOREST ECOSYSTEMS OF THE MIDDLE ALTITUDES*

V. Podrázský, J. Remeš

Czech University of Life Sciences, Faculty of Forestry and Environment, Department of Silviculture, Prague, Czech Republic

Forest soil acidification represents an important topic concerning environmental considerations in the forestry. It is presented as a vital issue in the mountain areas; on the contrary, minimum interest has been paid to it in the middle and lower altitudes. The presented research results document the deficient data on changes in the soil chemistry in the middle altitudes, in the School Training Forest Kostelec nad Černými lesy (Czech University of Life Sciences), 30 km SE of Prague, the Czech capital. The research plots were established in the years 1965–1967, as a part of the commercial fertilization potential research. The soil samples were taken on the control variants, without fertilizer. They are located in the typical sites (*Luzulo-pilosse Abietum, Luzulo-Quercetum luzuletosum pilosae, Myrtillo-Abietum*) in the altitude 400–450 m a.s.l., in 100–120 years old spruce monocultures. The first sampling took place in 1967, re-sampling in the years 2002/2003. Only a limited set of pedo-chemical characteristics is available from the first sampling of three soil profiles. Results document a considerable soil acidification in the study period (1967–2002/2003). The pH (KCl) decreased more than by 1 unit, also the contents of the bivalent bases decreased in general. On the contrary, the contents of exchangeable Fe sesquioxides increased. The results indicate soil degradation also in the middle altitudes – the topic of discussion is whether is it the effect of air pollution only or also there is a contribution of the tree species change. But in any case, the nutrient depletion and extreme soil acidification can occur also outside of mountain border areas of the Czech Republic.

spruce forest; forest soils; acidification; soil degradation; nutrients

INTRODUCTION

The soil changes indicating the environment acidification are documented for many decades. They are described especially in higher and mountain localities (Pelíšek, 1983, 1984), in the last years they are considered as a relevant problem only in the mountain conditions (Hruška, Cienciala, 2001). Development of forest soils in the lower and middle altitudes was less the topics of research activities from this point of view. The studies were concentrated more on the comparison of forest soils in stands of particular tree species (Podrázský, Remeš, 2005; Podrázský, Viewegh, 2005) and on the evaluation of the soil degradation due to cultivation of coniferous monocultures (e.g. Podrázský, 2003; Podrázský, Remeš, 2002). Rarely, the degradation by inappropriate technologies was documented (Ulbrichová, Podrázský, 2003). The presented article documents the soil development, the soil reaction and plant available nutrients content respectively, on several localities in lower altitudes, where the site allochthonous stands of Norway spruce were established. The aim of the research is the evaluation of the soil chemistry dynamics since 1960ies and the evaluation of the soil chemistry development due to acid deposition and Norway spruce cultivation on not natural sites.

MATERIAL AND METHODS

The research plots were established on the territory of the School Training Forest in Kostelec nad Černými lesy. This area is located 25–30 km SE from Prague. It belongs to the geomorphological sub-system of the Mid-Bohemian colline region (Středočeská pahorkatina), connected with the Polabí (Elb lowland) region in the N and is a part of the Czech Cretaceous Plateau. It is a region mild-warm and sub-arid, with annual mean temperature 7.6 °C and mean annual precipitation 665 mm (meteo-station Ondřejov). The experiment, aimed at the study of commercial fertilization potential, was established in the years 1965–1966 on 41 permanent research plots.

Three plots were established on each study site: the full fertilization – NPKCa, nitrogen fertilization – N, control. On each study plot, a soil pit was dug to describe soil profile and basic soil characteristics. The analyses were performed by the laboratory of Forest and Game Research Institute (1967 – Strnady, 2002/2003 – VS Opočno). The area of particular research plots was 0.20 to 0.25 ha. The control plots were used for the presented research. The research was abandoned since the 1970s, and only a few of them were possible to evaluate in the 2000s. The soil samples were processed by several laboratories and institutions and only the limited number of results of analyses is available since 1967. It was possible to evaluate only three profiles to this moment.

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The first study site (No. 1, 2, 3) at area of 0.20 ha 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*. The soil (Luvisol) is loamy, with loess enrichment, the locality code is **Moštice**. Today, age is 108 years.

The next set of plots (Nr. 25, 26, 27) is located on the Forest District Jevany, in the stand 331 d1 (today code 442 D11), at the altitude 400 m a.s.l. again, on very mild SE slope, the forest type is *Luzulo-Quercetum luzuletosum pilosae*. The soil is sandy-loamy, on permo-carbonian arcosas, the locality code is **Aldašín**. Its age is 113 years today.

The last evaluated locality was sampled the second year (2003 – Nr. 13, 14, 15), on the Forest District Krymlov in the stand 737 a2, on the flat terrain at the altitude 445 m a.s.l. The forest type was determined as *Myrtillo-Abietum*. The soil is of the Luvisol type, loamy, with loess enrichment. The locality has code **Radlice**. The age is assumed 118 years today.

The samples were taken from the soil pit (1967) and with soil borer (2002/2003), in many replications (4–8). The bulk samples were prepared in the field, so the statistical evaluation was limited.

RESULTS AND DISCUSSION

The results are summarized in Tables 1 to 3. The soil pH in H_2O in the years 1967–2002/2003 was not changed significantly, in the uppermost horizon, the slight increase of pH values was observed on plots Moštice and Aldašín. Tendency of a small increase of the pH in the uppermost part of the B horizon prevailed, lower, the stable state or pH decrease was observed. This characteristic reflects more the soil solution state. Only on the poorest site (Radlice locality) the significant decrease was observed. This phenomenon is probably caused by the low buffer capacity of this poor site in the range of exchangeable buffer (Ulrich, 1986a, b, c).

The soil reaction potential (pH in 1 N KCl) showed significant decrease in the whole observed soil profile, to the C (weathered bedrock) horizon. The shift reached 0.6 to 1.0 pH degree at richer sites, 1.0 to 1.25 pH degree at the poor one. Changes of similar extent are not documented in majority of other studies and they confirmed significant acidification in the middle altitudes, considered as less endangered by the soil degradation.

The plant available phosphorus contents showed considerable increase in the studied period, of the order extent in similar cases. The effect of the laboratory change is not clear, as well as of the acidification causing higher P availability can play a role (Šály, 1978). Decreased uptake can be also considered (Binkley, 1986).

The plant available potassium content was not changed much on the locality Moštice, it increased slightly in upper horizons (locality Aldašín), or increased more prominently (locality Radlice). The decreased demand of particular forest stands contributed probably to the lesser uptake after the period of intense growth.

On the other hand, the content of bivalent cations decreased dramatically during the observation period, or it showed the signs of translocation. The calcium content increased in the A horizons as a consequence of the biological mobilisation by forest trees, only at the Radlice locality; it was increased also in B horizons. All other B horizons showed a large decrease in the Ca contents.

Similar trend was documented for the plant available magnesium too. On the other hand, the content of Fe sesquioxides increased significantly, with the exception of the upper mineral profile at the Aldašín locality. There are not results available from similar localities in the region, which could be compared with our data. In the next period, the problem should be solved, whether the trends observed are the result of the acid deposition only, or also the cultivation of coniferous monocultures contributed to the changes observed (Podrázský, 2003; Podrázský, Remeš, 2002).

CONCLUSIONS

The results gained document the considerable acidification of forest soils in the middle and lower altitudes in the past decades. The observed sites are typical for large areas of the Middle Bohemia, where more significant acidification and site degradation was not assumed. According to our results, also in these conditions, the soil changes connected with acidification and nutrient losses

Table 1. Dynamics of soil chemistry in the period 1967–2002 on plots 1–3 (Moštice locality)

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	1120		387	80	560	940	
MgO mg/kg	32	75	237	237		85	41	135	219	
Fe_2O_3 mg/kg	1144	572	762	572		1688	775	1099	886	

Table 2. Dynamics of soil chemistry in the period 1967–2002 on plots 25–27 (Aldašín locality)

Year	1967					2002				
Horizon	Ah	B1	B2	B3	C	Ah	B1	B2	B3	C
Depth cm	0–4	4–34	34–52	52–73	73 +	0–4	4–34	34–52	52–73	73 +
pH H_2O	3.80	4.50	4.80	4.70	4.80	4.10	4.30	4.40	4.70	4.60
pH KCl	3.60	4.30	4.25	4.20	4.30	3.00	3.50	3.70	3.40	3.50
P_2O_5 mg/kg	40	40	30	23	30	87	117	38	53	57
K_2O mg/kg	32	17	41	54	42	47	39	24	41	44
CaO mg/kg	75	90	313	821	582	367	67	240	700	860
MgO mg/kg	22	43	97	97	97	55	21	78	169	188
Fe_2O_3 mg/kg	1263	620	524	477	381	940	376	550	679	622

Table 3. Dynamics of soil chemistry in the period 1967–200 on plots 13–15 (Radlice locality)

Year	1967				2002			
Horizon	Ah	B1	B2	C	Ah	B1	B2	C
Depth cm								
pH H_2O	4.10	4.25	4.30	4.65	3.40	3.60	3.70	4.00
pH KCl	4.05	4.20	4.20	4.30	2.80	3.20	3.20	3.30
P_2O_5 mg/kg	8	53	37	40	169	66	49	25
K_2O mg/kg	47	28	36	57	73	86	51	108
CaO mg/kg	90	60	104	418	113	93	100	393
MgO mg/kg	11	22	86	129	51	33	43	170
Fe_2O_3 mg/kg	2002	1763	405	572	2553	1773	833	1035

have to be taken into account. The forest policy concept has to take care for these results not only in the mountain regions, but also in lower elevations. As prevention, the cultivation of stands with more diversified stand and species structure, as well as the chemical amelioration in some cases, can be recommended.

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Změny půdního chemismu ve smrkových lesních ekosystémech ve středních polohách.

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Acidifikace lesních půd představuje stále významný problém vývoje životního prostředí a lesnictví. Prozatím byla uvažována jako kritický jev v horských oblastech, naopak v nižších polohách byla těmto půdním změnám věnována mnohem menší pozornost. Předkládané výsledky dokumentují výsledky sledování změn půdního chemismu v nižších nadmořských výškách, na území ŠLP Kostelec nad Černými lesy (ČZU v Praze), 30 km JV od Prahy. Výzkumné plochy byly založeny v letech 1965–1967 jako součást výzkumu vlivu hnojení lesních porostů na jejich produkci. Půdní vzorky byly odebírány na kontrolních variantách, bez aplikace hnojiv. Plochy byly založeny v reprezentativních stanovištních podmínkách (*Luzulo-pilosse Abietum, Luzulo-Quercetum luzuletosum pilosae, Myrtillo-Abietum*), v nadmořské výšce 400–450 m n. m., v době založení v 70letých smrkových porostech (dnes 100–120 let). První odběr byl proveden v roce 1967, druhý v letech 2002/2003. Z první etapy se dochovala jen část výsledků analýz, takže je možno doložit vývoj jen u omezeného počtu pedochemických charakteristik. Výsledky dokládají výraznou acidifikaci lesních půd v období 1967–2002/2003. Půdní reakce (potenciální) klesla o více než jeden stupeň a obecně poklesl i obsah dvojmocných bází. Naproti tomu vzrostla koncentrace sesquioxidů železa. Šetření prokázalo půdní degradaci v nižších polohách – otázkou zůstává, nakolik k tomuto jevu došlo vlivem kyselé depozice a nakolik k tomu přispělo i pěstování smrkových porostů. V každém případě je třeba počítat s tím, že k výrazné acidifikaci a ke ztrátám živin dochází i mimo horské polohy hraničních českých pohoří.

smrkové porosty; lesní půdy; acidifikace; degradace půd; živiny

Contact Address:

Prof. Ing. Vilém P o d r á z s k ý , CSc., Česká zemědělská univerzita v Praze, Fakulta lesnická a environmentální, katedra pěstování lesů, Kamýcká 129, 165 21 Praha 6-Suchdol, Česká republika, tel.: +420 224 383 403, e-mail: podrazsky@lf.czu.cz, remes@lf.czu.cz