Forest floor and soils in limed stands of substitute species in Klášterec nad Ohří forest district in the Krušné hory Mts.

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ABSTRACT: Forest ecosystems of the Krušné hory Mts. affected by long-term air pollution were finally disintegrated. The tree species composition has been changed in ecosystems disturbed in this way. Liming applied for the long-term revitalization of air-polluted areas partly decreased the effects of acid depositions on soil in spite of the reduction of air pollution; however, it did not cause any expected necessary changes yet. The aim of the paper is to evaluate the chemical composition of humus horizon H and organomineral horizon Ah (soil reaction, sorption complex, C/N ratio, available nutrients) in stands of substitute tree species differently affected by liming and site preparation in the area of Klášterec nad Ohří Forest District in the Krušné hory Mts. (Czech Republic). Based on our evaluations, we found out that pH values increased by 0.3–0.5, which was evident in stands with repeated liming at sites without soil preparation and with the site/soil preparation using an excavator or bulldozer. The majority of soils always showed an unsaturated base-exchange complex (< 50%). Increasing values of the sorption complex saturation were evident in stands with repeated liming, which is related to the favourable condition of pH in H and Ah horizons. C/N ratios in the H (Ah) horizon were always below a critical limit (< 24). The content of available nutrients in the H (Ah) horizon was insufficient. Among the particular elements phosphorus content decreased, that of magnesium reached optimum or even surplus, calcium was in surplus (optimum or even surplus), potassium in optimum (surplus). Forest management in the Krušné hory Mts. will be dependent on the effectiveness of the biological and chemical revitalization of soils also in the future.

Keywords: forest floor; Krušné hory Mts.; liming; soil; stands of substitute species

In forest ecosystems of the Krušné hory Mts., long-term air-pollution impacts became evident in the disturbed soil environment, forest disintegration and changes in the tree species structure (Slodičák et al. 2008). Negative changes in the soil environment were described by Němec (1952, 1958). Subsequently, Materna (1963, 1986), Sobotka (1964), Lochman (1976, 1981, 1986), Langkrammer and Lettl (1982), Lettl (1985, 1991), Jirgle (1986), Materna and Skoblík (1988), contributed to the knowledge of the development of chemistry and biological properties of soils at air-polluted mountain locations of the Krušné hory Mts. The obtained results initiated the use of ameliorative liming, which contributed to acceleration of revitalization processes of soils disturbed by long-term acidification. An area of 62 and 30 thousand ha was limed in the period 1978–1991 and 2000–2006, respectively (Kubelka et al. 1992;

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Šrámek et al. 2006a). A number of stands were limed repeatedly. At the same time, broadleaved stands (*Betula, Sorbus, Alnus, Fraxinus*) contribute to improvement of soil conditions (Ulbrichová, Podrázský 2002; Möllerová 2004; Podrázský et al. 2005) in contrast to extensive monocultures of blue spruce (*Picea pungens* Engelm.).

Forest floor and humus horizons represent the living space for soil and soil-forming fauna, the development of which is discussed in connection with ameliorative liming (Kula 2009; Kula, Menšík 2011). Forest floor affects the growth of forest stands (Němec 1928; Maňan, Káš 1948; Šály 1978; Waring, Running 1998), determines the cycle of carbon, nitrogen and other nutrients, dynamics of the decomposition of organic residues, quality of soil water and soil structure, accelerates the decomposition of harmful substances etc. (Stevenson 1994; Emmer 1999; Sparks 2003).

The aim of the present paper is to evaluate the chemical composition of humus horizon H and organomineral horizon Ah (soil reaction, sorption complex, C/N ratio, available nutrients) in stands of substitute species differently affected by liming and site preparation in the area of Klášterec nad Ohří Forest District in the Krušné hory Mts.

MATERIAL AND METHODS

Site and stand description

From the archival documentation of aerial liming (2.5–3 $t \cdot ha^{-1}$) of stands of substitute species (*Betula, Sorbus, Alnus, Picea pungens*) in the area of Klášterec nad Ohří Forest District (1986–2002) 49 stands were selected. This group is differentiated by the time (1986–2002) and frequency of liming (0–4 times) in the interval of 5–6 years and site conditions (altitude 740–960 m, tree and shrub vegetation, forest type group /FTG/ 6S, 6K, 7K). Based on general characteristics, *Piceeto-Fagetum acidophilum* (6K) and *Piceeto-Fagetum mesotrophicum* (6S) are typical sites for locations at an altitude of 650–950 m, mean annual temperature 4.5–5.5°C, total annual precipitation 900–1,050 mm, growing season 115–130 days and the natural species composition of *Picea abies* [L.] Karst., *Fagus sylvatica* L. and *Abies alba* Mill. (Průša 2001).

Sampling procedure

Samples of forest floor and soil (H and Ah horizons down to the depth of 3–4 cm, i.e. about 10% of the total soil depth) according to Němeček et al. (2001) were taken in October 2008 always from three places in a stand. From each of the horizons, a composite sample was created (Σ49 + 49 samples). Values of active (pH H_2O) and exchangeable (pH KCl) soil acidity were determined by potentiometry using a digital pH meter (Zbíral 1995). From air-dried soil samples free of coarse particles, total nitrogen and carbon were determined after fine grinding or comminution (Zbíral et al. 1997). Using the method of Kappen (1929), soil exchangeable sorption and the degree of saturation of the sorption colloid complex by basic cations were measured (Zbíral 1995; Rejšek 1999). Available nutrients (P, Mg, K and Ca) in a humus horizon (H) were determined after extraction using the method of Göhler (Soukup et al. 1987) and in an organomineral horizon (Ah) after extraction using the method of Mehlich III (Mehlich 1984; Zbíral et al. 1997). Sulfur (S) in H horizon was determined gravimetrically (Zbíral 2002). Sulphate-sulfur ($S\text{-}SO_4$) in Ah horizon was determined after extraction of the extract according to ISO 110481 (1995).

Existing limit values for forest soils are given in Table 1.

Processing the statistical values

Soil characteristics (soil reaction, base-exchange complex, carbon content, nitrogen content, C/N ratio, available nutrients – P, Mg, K and Ca) were statistically evaluated in the Statistica programme (StatSoft Inc., Tulsa, USA) and one-factor analysis ANOVA and Tukey's test for the detection of differences between groups were used (StatSoft, 2007). Significance was tested at a level $\alpha = 0.05$ (Meloun et al. 2005).

Note: In the paper, particular variants of stands are designated by letters A–G [A – stands without liming and site preparation ($n = 4$); B – stands limed once without site preparation ($n = 13$); C – stands limed once and with the "excavator" site preparation /using an excavator for site preparation/ ($n = 10$); D – stands limed once and with "bulldozer" site preparation /using a bulldozer for site preparation/ ($n = 3$); E – stands limed 2–3 times and without site preparation ($n = 6$), F – stands limed 2–3 times and with "excavator" site preparation ($n = 5$), G – stands limed 2–3 times and with "bulldozer" site preparation ($n = 4$)].

RESULTS AND DISCUSSION

Soil reaction

Actual (exchangeable) pH reached the value of 4.1–4.9 (3.3–3.9) in the H horizon and 3.9–4.7

Table 1. Limit values (criteria) for the evaluation of forest soil quality (Šály 1978; Rejšek 1999; Sáňka, Materna 2004)

Soil reaction	Extremely acid	Very heavily acid	Heavily acid	Acid
pH (H_2O)	< 3.5	3.5–4.5	4.5–5.5	5.5–6.5
pH (KCl)	< 3.0	3.0–4.0	4.0–5.0	5.0–6.0
Sorption complex	very low, low	medium	high (very high)	
T (mmol·kg^{-1})	(< 80) 80–130	130–240	240–300 (> 300)	
S (mmol·kg^{-1})	< 120	120–180	> 180	
Sorption complex saturation	very low, low	medium	Higher	high (very high)
V (%)	(< 5) 15–30	30–50	50–70	70–85 (>85)
Content of available nutrients*	very low, insufficient	optimum	excessive (very high)	
P (mg·kg^{-1})	(< 5) 5–10	10–30	30–60 (> 60)	
Mg (mg·kg^{-1})	(< 20) 20–40	40–60	60–80 (> 80)	
Ca (mg·kg^{-1})	(< 150) 150–300	300–500	500–800 (> 800)	
K (mg·kg^{-1})	(< 20) 20–50	50–90	90–140 (> 140)	

*Criteria of the evaluation of available nutrients are determined according to analyses using the procedure of Mehlich II, III.

(3.0–3.8) in the Ah organomineral horizon. Statistically significant differences (α = 0.05) were not determined in any horizon. Soil reaction is acid to very acid in both horizons. In spite of ameliorative liming, the marked improvement of pH did not become evident.

The chemical conditions of upper layers of soil were also affected by technical measures applied over the last years, above all by piling the forest floor (using an excavator or bulldozer for site/soil preparation) and also by changes in the soil moisture regime (Kulhavý et al. 2008). With respect to the insufficient extent of liming and continuous acidification (Šrámek et al. 2008a) the revitalization of soil proceeds slowly. Values of pH for beech humus are given at a level of 5.3–6.6 and spruce humus 3.7–4.5 (Mařan, Káš 1948), for the leaf litter 5.0–6.5 and needle litter 4.0–5.0 (Šály 1978).

The most favourable values of active and exchangeable pH for the H horizon of forest floor were determined in repeatedly limed stands (Fig. 1). Favourable values were noted in stands with one application and minimum site disturbance. The positive pH reaction in the Ah horizon is associated with repeatedly limed stands exceptionally also disturbed by the "bulldozer" site preparation (Fig. 1). Insignificant differences in pH between both horizons show evidence of the relative sufficiency of basic cations in the uppermost soil layers (Ulrich 1983). According to the pH horizon, stands can be included in the buffering zone (Ulrich 1981) where the increased input of hydrogen ions is compensated by basic cations from the soil sorption complex and the buffer zone of aluminium. Ah horizons remain in the Al buffering zone where inorganic compounds of Al are released into the soil solution (Ulrich 1981). After liming of forest stands, active and hydrolytic acidity of forest floor decreases, which can become evident after two (Nihlgård et al. 1988; Erstad et al. 1993; Podrázský 1993a,b; Kreutzer 1995; Formánek, Kulhavý 2001) or even 8–12 years since the application of limestone (Schuller 1995; Geary et al. 1996).

A decrease in soil acidity was determined in the H horizon of stands with one liming in contrast to stands without liming. Mareš (1992) reported an increase in soil acidity by 0.4 (active) or 0.3 (exchangeable) after 2.5 years since liming. A similar increase in the pH value was observed in stands with repeated liming (Fig. 1).

Active and exchangeable acidity in mineral soil after liming was reported to decrease mostly with time delay (Nömmik et al. 1984; Nihlgård et al. 1988; Abrahamsen 1994; Schuler 1995; Geary et al. 1996). Maximum changes in the soil reaction were noted 8–10 years after liming in surface layers of forest floor (F) and even deeper (H layer and mineral horizon A) after 10 to 15 years (Podrázský 2006). At some limed sites, the expected change of pH values has not become evident yet. It is caused by the fact that the evaluated group of stands was limed in 1986–2002. Ameliorative liming carried out in the past was reported as partly eliminated by the ongoing air-pollution impact (Šrámek et al. 2008b). It is possible to expect that ameliorative

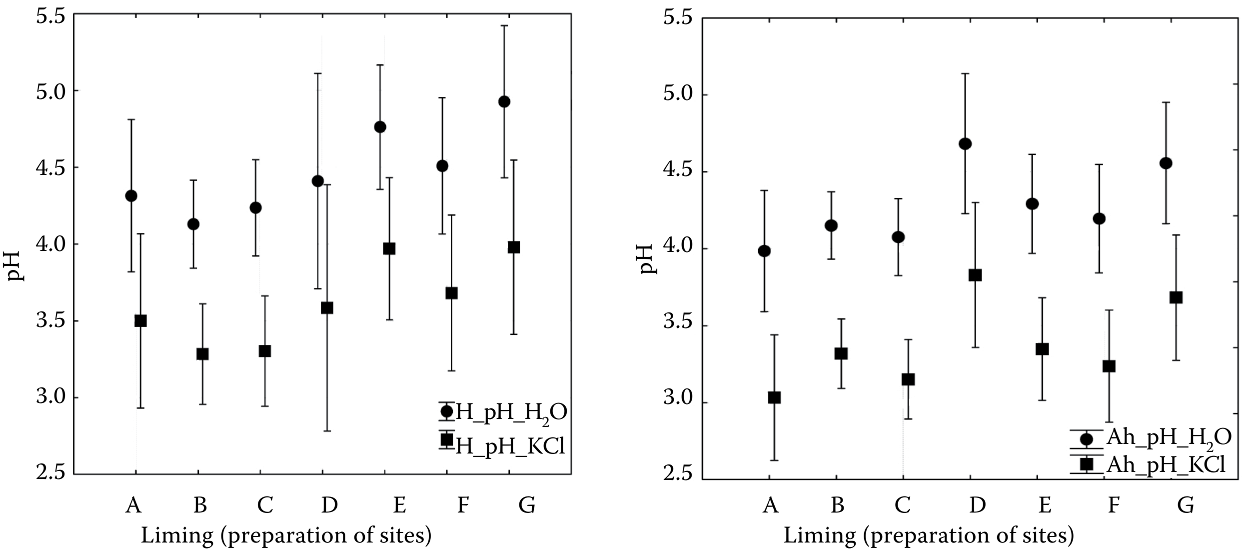

Fig. 1. Actual soil acidity pH (H2O) and exchangeable soil acidity pH (KCl) in the H horizon of surface humus (left) and in the Ah organomineral horizon (right) of stand variants

A – stands without liming and site preparation; B – stands once limed without site preparation; C – stands once limed and with the "excavator" site preparation (using an excavator for site preparation); D – stands once limed and with "bulldozer" site preparation (using a bulldozer for site preparation); E – stands 2–3 times limed and without site preparation, F – stands 2–3 times limed and with "excavator" site preparation, G – stands 2–3 times limed and with "bulldozer" site preparation

liming carried out at present will be more effective due to the reduction of air pollution.

Sorption complex

Total (maximum) cation exchange capacity (CEC) in the H (Ah) horizon 269–866 mmol·kg^{-1} (168–287 mmol·kg^{-1}) partly differed site from site (Fig. 2).

In the humus horizon, except the repeatedly limed stand with the "excavator" site preparation (G), CEC was very high (Fig. 2) while it decreased to a "high" and "intermediate" level in the organomineral horizon.

The values 150–200 mmol·kg^{-1} can be considered to be optimal in forest soils (Šály 1978; Sáňka Materna 2004). Statistically significant differences ($\alpha = 0.05$) were determined in CEC in the H horizon between stands A and G ($P = 0.0214$), B and G ($P = 0.0050$), C and G ($P = 0.0216$) and between stands D and G ($P = 0.0220$) (Fig. 2). We did not find out any statistically significant differences in the Ah horizon. The amount of absorbed bases (S) in the H and Ah horizon reached 92–170 mmol·kg^{-1} and 19–75 mmol·kg^{-1}, respectively. Sulphur occurred at a low and medium level in the humus horizon H (Fig. 2). However, the level of S in the organomineral horizon Ah was low in all variants of stands (Fig. 2). Differences in sulphur content in the H horizon between stands E and G ($P = 0.0478$) were statistically significant at $\alpha = 0.05$ (Fig. 2).

Total CEC changes were not marked due to liming (Hruška, Cienciala 2003). Changes in the total sorption capacity showed the same dynamics after liming as the content of organic substances. The CEC increase in the humus horizon was due to the effect of improving the humification processes (Fig. 2). It was contrariwise in mineral horizons (Fig. 2). Liming stimulated mineralization of an organic fraction, which resulted in the reduction of CEC (Derome et. al 1986). Marschner and Wilczynski (1991) also reported the reduction of CEC as a result of humus mineralization.

The sorption complex saturation (V) reached a level of 14.9–33.2% and 7.3–35.7% in the H and Ah horizon, respectively. Soils were extremely sorption-unsaturated in all stands with the exception of unsaturated variant E in H and Ah horizons (Fig. 2. – statistically significant differences were not determined there). The unsaturated sorption complex is characteristic of the increased content of H-ions, which is typical of acid soils (Šály 1978). The course of the humus-clay complex unsaturation consists in the increased formation of raw humus and the creation of acid simpler less dehydrated humic and fulvic acids (Šály 1978; Stevenson 1994; Sparks 2003). In the majority of papers, effects of liming on the sorption complex are

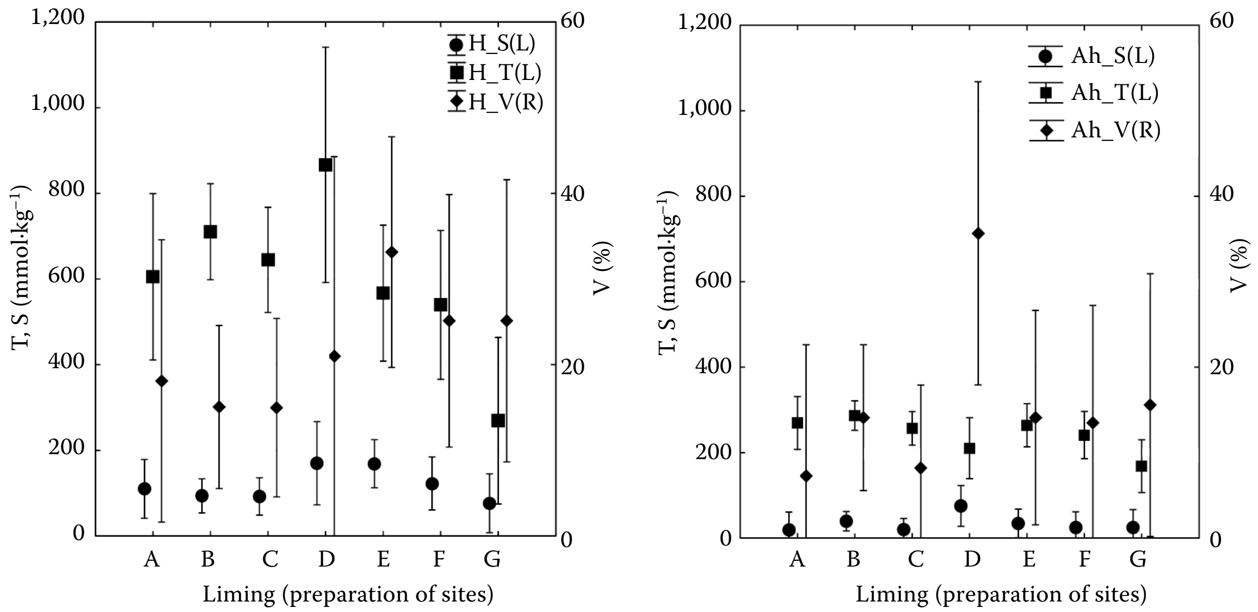

Fig. 2. Maximum sorption capacity (T, KVK, CEC), momentary content of exchangeable basic cations (S) and the sorption complex saturation (V) in the H horizon of surface humus (left) and in the Ah organomineral horizon (right) of stand variants (Legend, see Fig. 1)

assessed as favourable (Hruška, Cienciala 2003). The sorption complex saturation increased as a result of liming. These changes are often very marked; the sorption complex saturation takes place, namely with Ca cations. Based on results of Swedish experiments, this favourable effect persists for a long time. Limed areas (5 t·ha^{-1} $CaCO_3$) showed 10% higher saturation of sorption complex in all profiles even after 68 years as compared with the control plot (Nihlgård, Popovič 1984). Derome et al. (1986) reported the increased saturation of sorption capacity by 15% in a humus horizon and by 5% in a mineral horizon. It is evident in stands where liming was carried out compared to unlimed stands.

Carbon, nitrogen, C/N ratio

The content of total carbon was 6.1–28.6% and 2.8–6.4 % in the H and Ah horizon, respectively. Only stands marked as H differed in the decreased carbon level in both horizons. The content of nitrogen ranged between 0.4% and 1.5% and from 0.3% to 0.4% in the H and Ah horizon, respectively, corresponding with carbon characteristics (Fig. 3).

Statistically significant differences (α = 0.05) were determined in the content of carbon (nitrogen) only in the H horizon between stands A and G (P = 0.0011; P = 0.002), B and B (P = 0.0009; P = 0.009), C and G (P = 0.0042; P = 0.045), D and G (P = 0.0047; P = 0.062), E and G (P = 0.0057; P = 0.016), F and G (P = 0.0183; P = 0.0126).

The main indicator of the rate of biomass decomposition is the C/N ratio, which is closely associated with the soil transformation of nitrogen (Cote et al. 2000). C/N ratios in the H horizon were balanced (15.7–19.5). In the organomineral horizon Ah, the ratio was at a level of 11.3–16.8. In monitored horizons, no statistically significant differences in the C/N ratio were detected. Although the C/N ratio is 10–100 in forest soils of Europe, it reaches generally the value of 20–40 in the H horizon and 10–30 in the Ah horizon. Determined differences in the C/N ratio were not significant in monitored variants in H and Ah horizons. Nevertheless, it is possible to reach a slight increase in the C/N ratio in forest floor (Podrázský 1993a) or in the layer of forest litter (Formánek, Kulhavý 2001) through liming. Simultaneously, there are data on a possible decrease in C/N ratio after forest soil liming on the ground of nitrogen accumulation into soil organic matter (SOM) (Persson 1988; Míchal 1994; Andersson 1999) or the change does not occur (Mareš 1992; Podrázský 1993b; Formánek, Kulhavý 2001). After the application of calcic substances, changes occur in forest soils in the processes of mineralization, humification and nitrification, which is reflected in the increased dynamics of nitrogen and carbon (Hruška, Cienciala 2003).

If the C/N ratio is < 20, humus horizons have good conditions for biological decomposition and increased dynamics of the nutrient cycle (Kulhavý et al. 2008). On the other hand, at the lower C/N ratio, the leaching of nitrogen can occur. Emmett et

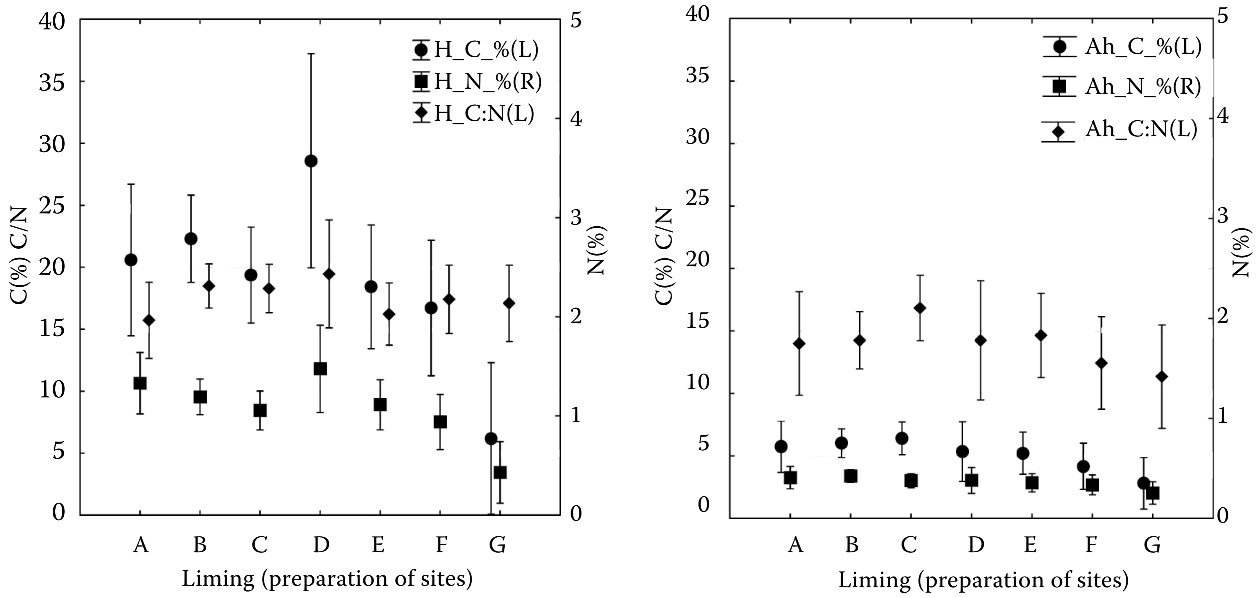

Fig. 3. Carbon content (C%), nitrogen content (N%) and C/N ratio in the H horizon of surface humus (left) and in the Ah organomineral horizon (right) of stand variants (Legend see Fig. 1)

al. (1998) considered the value of 24 to be the critical C/N ratio in coniferous stands while Nömmik (1979) and Persson (1988) considered the value of 30 to be critical. At the C/N ratio < 24, the amount of leached nitrogen is higher than 10% out of the total nitrogen in an ecosystem. Thus, the critical limit of the C/N ratio remains always disturbed in all monitored variants and stands in both horizons. Similarly, Huettl and Zoettl (1993) also reported in the summary of findings obtained with liming in Germany that the risk of mineralization is higher on areas where the C/N ratio is smaller than 30.

These conclusions confirm a hypothesis that mineralization in consequence of liming can be expected on areas with a good supply of nitrogen. In the monitored area, nitrogen deposition under crowns was always high ranging from 15 to 30 kg·ha^{-1}·year^{-1} and, at the same time, critical rates for nitrogen were also exceeded (Hůnová et al. 2008; Šrámek et al. 2008b; Ågren 2009; Boháčová et al. 2009). In the results by the FGMRI (Boháčová et al. 2009), the closest value is presented in Lasy, where maximal deposition of nitrogen is 27 kg·ha^{-1}·year^{-1}. In the region of Horní Blatná, total nitrogen deposition in the last three years ranged about 20 kg·ha^{-1}·year^{-1}, in the eastern part, near Moldava, it was up to 15 kg·ha^{-1}·year^{-1}.

Available nutrients

The content of available phosphorus in the H horizon was insufficient (1.0–7.4 mg·kg^{-1}) while it was sufficient in the Ah horizon (10.7–31.0 mg·kg^{-1}) (Fig. 5, no significant difference was determined among particular variants). The P content was low in the H horizon, being affected by soil acidity (the uptake of phosphorus is blocked in acid soils). This was explained earlier as a result of the formation of hardly available aluminium and iron phosphates (Lomský 2006). This can also be due to the fact that it is released from the surface humus layer into the Ah horizon where it is promptly accepted by plants. The optimum content of available phosphorus in the Ah horizon can be given by the bond of phosphorus in the biomass of microorganisms, which prevents losses (through leaching) or by immobilization to the soil sorption complex (Šimek 2003). With respect to the relatively fast life cycles of soil microorganisms, large amounts of available phosphorus are released after their death. Phosphorus is immediately taken up by plants before being immobilized or leached (Šimek 2003). However, coniferous species can take up phosphorus from hardly available forms, particularly on heavily acid soils by means of soil mycorrhizae (Lomský 2006). The obtained results are in compliance with the statement of Kulhavý et al. (2008) that in the H and Ah horizons, nearly two thirds of the area of the Krušné hory Mts. are below a limit of 10 mg·kg$^{-1.}$ Fiala and Reininger (2000) also reported similar conclusions, namely that low values of phosphorus (< 2.39 mg·kg^{-1}) occur in the whole area of the Krušné hory Mts. including Klášterec Forest District.

Magnesium is the most important element, the increase of which was targeted in connection with liming (Kula 2009). The content of avail-

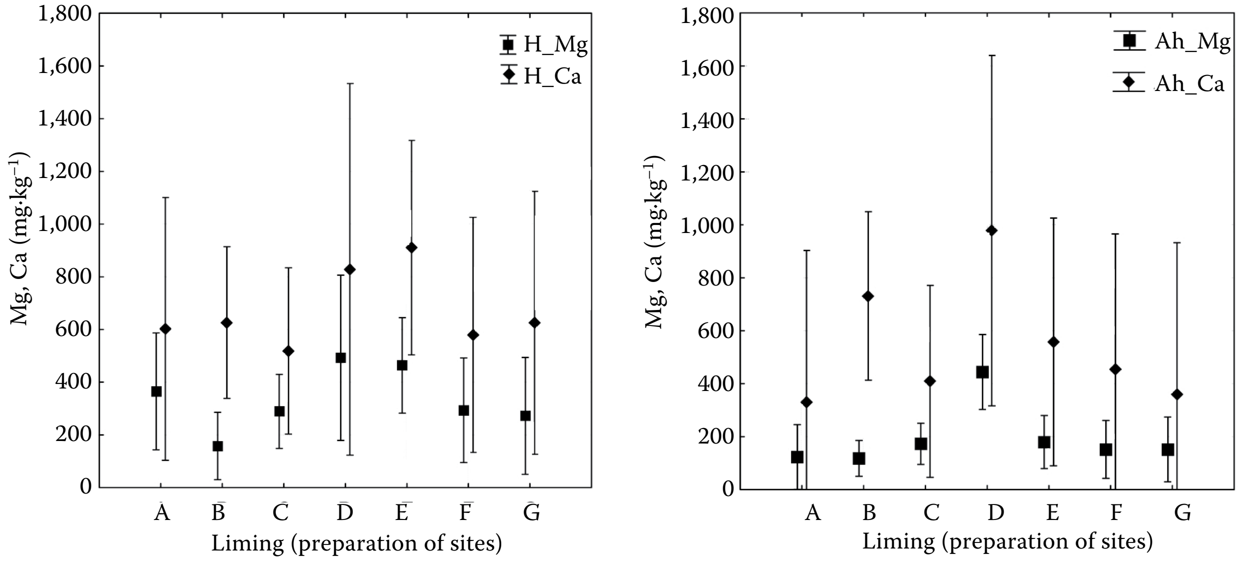

Fig. 4. The content of available magnesium (Mg) and calcium (Ca) in the H horizon of surface humus (left) and in the Ah organomineral horizon (right) of stand variants (Legend see Fig. 1)

able magnesium in the H horizon was in surplus 158–493 mg·kg^{-1} (Fig. 4), in the Ah horizon it was optimum up to in surplus (118.5–444.7 mg·kg^{-1}) (Fig. 4). Our results are confirmed by data of Šrámek et al. (2006b). Existing experience indicates that in heavily acidified areas, the lack of magnesium is negatively reflected as the first in the health condition of trees (Kulhavý et al. 2008). In forest stands of substitute species in Klášterec Forest District the limit of Mg deficiency was not recorded in any of the monitored stands. High contents of magnesium in the forest floor and soil were also noted in the area of Klášterec Forest District by Fiala and Reininger (2000).

The content of calcium in the H horizon was in surplus (519.0–910.8 mg·kg^{-1}) (Fig. 4) and in the Ah horizon it was optimum up to in surplus (330.5–978.3 mg·kg^{-1}) (Fig. 4). Thus, it is evident that liming carried out in the 80s and 90s of the 20th century affected the upper part of the soil profile to the largest extent. Calcium, which markedly influences soil reactions, relatively increases with the rate of dolomitic limestone applied (Kula 2009), which is obvious from the results obtained (Fig. 4). Similar results were also reported from the area of the Krušné hory Mts. by Šrámek et al. (2006b).

The content of available potassium was at a level of optimum up to surplus in the H horizon

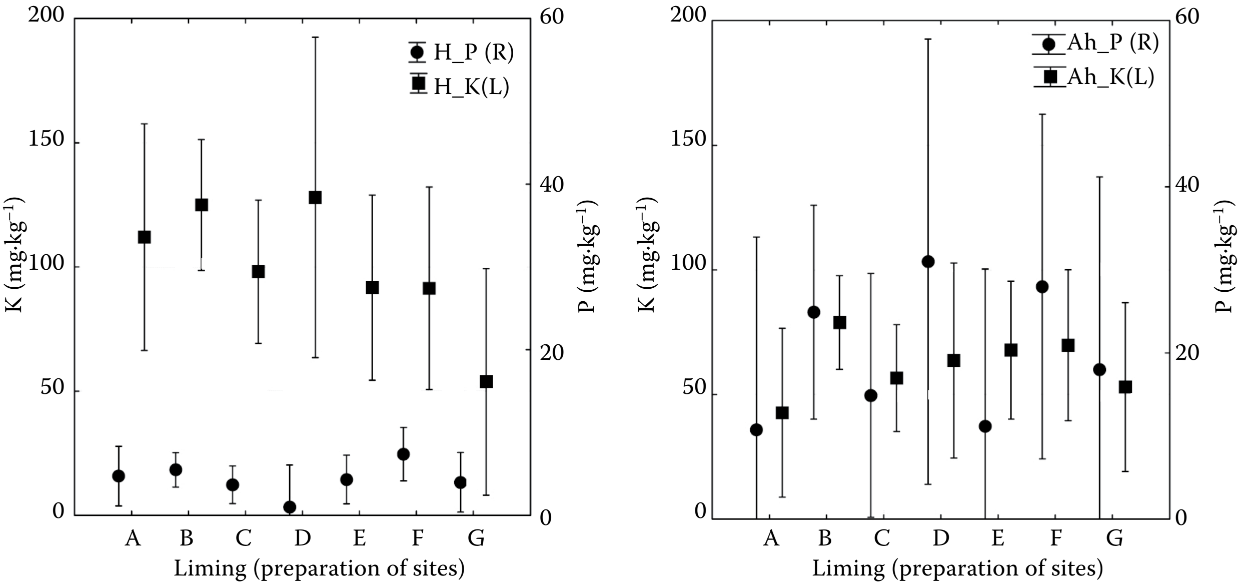

Fig. 5. The content of available phosphorus (P) and potassium (K) in the H horizon of surface humus (left) and in the Ah organomineral horizon (right) of stand variants (Legend see Fig. 1)

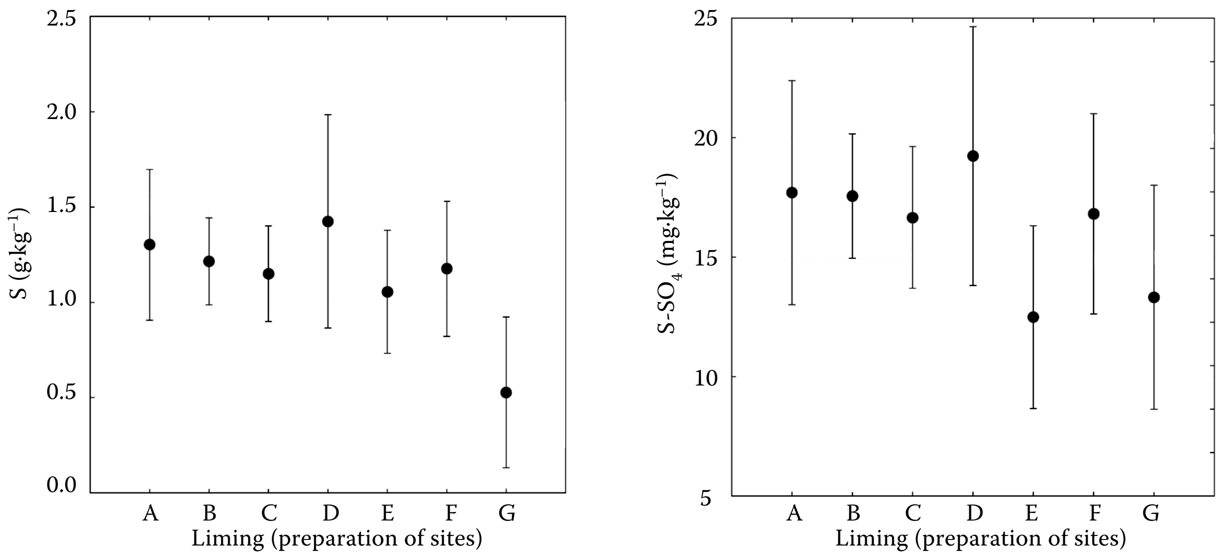

Fig. 6. Sulphur content (S; S-SO_4) in the H horizon of surface humus (left) and in the Ah organomineral horizon (right) of stand variants (Legend see Fig. 1)

53.7–128.0 mg·kg^{-1} and at a level of optimum in the Ah horizon 42.8–78.9 mg·kg^{-1} (Fig. 5).

Statistically significant differences were not found out in any of the stand variants in available nutrients (P, Mg, Ca and K) in monitored horizons. The content of available potassium in both horizons can be evaluated the most positively of all main basic nutrients. We acknowledge results obtained by Kulhavý et al. (2008) that the medium to good content of potassium occurred on more than 90% of the area of the Krušné hory Mts.

The content of sulphur

TThe content of sulphur in the H horizon (S g·kg^{-1}) and in the Ah horizon (S-SO_4 mg·kg^{-1}) ranged differentially between horizons H (0.5–1.4 g·kg^{-1}) and (12.4–19.2 mg·kg^{-1}) (Fig. 6).

Significant differences (α = 0.05) in the content of sulphur in the H horizon occurred between variants A and G (P = 0.0202). The content of sulphur in the H horizon was reported to be similar (0.02–2.0 g·kg^{-1}) in the majority of soils in humid and semi-humid regions (Stevenson 1994; Kopec, Gondek 2002; Šimek 2003). Similar data were also mentioned in forest floor in the H horizon on limed forest soils in Germany (Schaaf, Hüttl 2006). On the contrary, our results showed that the content of sulphur exceeded this limit several times in the Ah horizon. It is due to the fact that stands and soils in the Krušné hory Mts. were damaged by sulphur dioxide (sulphur depositions) to the greatest extent in Europe (Šrámek et al. 2008). Sulphur depositions ranged about 30–40 kg·ha^{-1}·year^{-1} in the open area in 1978–1990 and now it is about 6–10 kg·ha^{-1}·year^{-1}. High depositions of sulphur were the reason for soil acidification in the past because in the transformation of sulphur in soil by the mineralization of one mole it corresponds to two equivalents of H^+ and the plant uptake of this mole of sulphur corresponds to equivalents of OH^-, which conditions the neutralization of H^+ released in the process of mineralization. In contrast to nitrogen, sulphur is not so required by plants and thus mineralized soil and accompanying hydrogen ions are accumulated in soil (Klimo et al. 1999).

CONCLUSION

In an area with the long-term ameliorative liming of different intensity and time horizon, we determined actual characteristics of forest floor (H horizon) and upper soil layer (Ah horizon) from the aspect of soil reaction, carbon content, nitrogen content, C/N ratio, sorption complex (base-exchange complex) and available nutrients.

Liming contributed to the partial reduction of acidity by 0.3–0.5 in the H horizon, particularly in variants with the repeated application of dolomitic limestone independently of the type of site/soil preparation before reforestation.

The soils remained sorption-unsaturated (< 50%). An increase in the values of the sorption complex saturation was noted in stands with repeated liming, which was related to the more favourable value of pH in H and Ah horizons. The C/N ratio in the H (Ah) horizon occurs below a critical limit (< 24).

Contents of available nutrients in the H (Ah) horizon are insufficient (optimum) in phosphorus, optimum or even in surplus in magnesium, in surplus (optimum or even in surplus) in calcium and in optimum (surplus) in potassium.

In the Krušné hory Mts., forest management will be dependent on the effectiveness of biological and chemical revitalization of soils also in the future.

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