Liming of forest soils: effectiveness of particle-size fractions

I. Musil[1], V. Pavlíček[2]

[1]*Czech Agricultural University, Faculty of Forestry, Prague, Czech Republic*
[2]*Central Supervisory and Experimental Agricultural Institute, OAPVR, Branch Office Opava, Czech Republic*

ABSTRACT: The paper studies the effect of a single use of a textural fraction of dolomitic limestone (5.1 t per ha) on soil reaction (pH/KCl and pH/H_2O) and the content of exchangeable Ca and Mg (in the soil layer of 0–30 cm or in F, H and A horizons) during a 6-year experiment under a mature Norway spruce stand and a 4-year experiment on a clear-felled area. The increase in pH culminated in the 3rd or in the 3rd–6th year of the experiment. Maximum effects were achieved applying the fine fraction of a particle size ≤ 1 mm. The coarse fraction of a particle size > 1 mm showed virtually negligible effects. The increase in Ca and Mg content culminated in the last 6th year of the experiment. Maximum effects were achieved applying fine fractions again. The effect of the coarse fraction was also virtually negligible. After 6 years, maximum increase in all values under study occurred in the upper narrow F horizon while the increase rapidly dropped downwards.

Keywords: forest liming; dolomitic limestone; particle-size fractions; acidity; nutrients

Forest dieback due to air pollution (and other factors) is associated with worsening soil conditions caused among others by soil acidification, leaching of nutrients from the soil profile, release of toxic substances into the soil solutions and decreasing biological activity of soil. All these factors result in damage to forest stands. With the aim to eliminate or at least alleviate these unfavourable effects, liming of forest stands (including clearings) or their soils has been started both abroad and in this country.

Controversial liming of forest stands represents very complicated problems. Their complexity is given particularly by an immense variability of the complex of factors that jointly affect results of the liming itself. It is much less investigated than the problems of liming of agricultural soils that are relatively well worked out and verified with respect to the long-term controlled nutrition of agricultural crops.

A number of authors at many workplaces dealt with liming of forest soils and stands. Summary reports on the effect of liming on forest soil properties and resistance of forest trees to air pollution were published in this country e.g. by Materna and Skoblík (1988), Podrázský and Peřina (1989), Podrázský (1990, 1991), Klimo and Vavříček (1991) etc. Some aspects of using calcium fertilizers, limestone and dolomite in particular, which could be identical with their use for liming of agricultural soils, were mentioned by Pavlíček and Musil (1988), who also reminded the fact that the effectiveness of limestone and dolomite was clearly related to their particle-size distribution. A partial experiment with several-year monitoring was established by the latter authors, the aim of which was to verify or to complete existing knowledge on the effect of main particle-size fractions (i.e. effects of particle size) of ordinarily used dolomitic limestone on selected properties of forest soils in the actual locality of the former Forest Enterprise Vítkov.

A preliminary report on the results of the experiment was presented (in Czech) to the editorial office of the Bulletin of the Central Supervisory and Experimental Agricultural Institute in Brno.

MATERIAL AND METHODS

To verify the effect of main particle-size fractions of dolomitic limestone on changes in the agrochemical properties of forest soils, a precise small-plot long-term trial was established in the area of the former Forest Enterprise Vítkov (Silesia), Forest District Skřipov (at present Municipal Forests of the town of Opava). The experiment was established at an altitude of 410 m in two neighbouring forest operational units (stand parts):
- 108 B7 – mature spruce stand (area 7.16 ha; age 104 years; stocking 0.9; species composition: Norway spruce 100, site class 2; interspersed beech and sycamore maple; management group 571; forest type 5O1);
- 108 A5 – clearing (area l ha; clearcut area reforested by spruce in the course of the experiment; management group 451; forest type 4B1).

Soil conditions of the locality (according to the synthetic soil map of the CR – sheet B5 – Opava): typical Cambisol, acid to very acid variety.

Climatic conditions of the locality (according to the map BPEJ, sheet Bílovec 8–1): moderately warm and humid climatic region; mean annual temperature 6–7°C, mean annual precipitation 650–750 mm.

The trial plots were of circular shape each of 0.785 m^2. In the field, the plots were stabilized by iron pins, a sheet-metal folding template being installed on them during all activities in the plot. The templates accurately defined the trial plots.

To verify the effectiveness of particular fractions, naturally weathered dolomitic limestone from the west-Slovakian locality Malé Kršteňany was used. The material is commonly used for liming of forests and agricultural soils. Limestone amounts for particular plots were calculated according to the actual content of Ca and Mg in particular tested fractions and corresponded to the average rate of 5.1 t dolomitic limestone per hectare (i.e. 2.6 t CaO + MgO per 1 ha).

Chemical composition of dolomitic limestone and its particle-size fractions

Particle-size fraction		Calcium % CaO	Magnesium % MgO	Converted to %	
				$CaCO_3$	$MgCO_3$
Original sample	(Variant A)	29.6	21.2		
Fraction < 1 mm	(Variant B)	29.3	21.4	52.3	44.8
Fraction > 1 mm	(Variant C)	30.3	20.7	54.1	43.3

Particular variants of dolomitic limestone application

Variant	Applied sample of (5.1 t per 1 ha)
A	original (unscreened) material
B	fraction < 1mm only
C	fraction > 1mm only
D	no application of dolomitic limestone (control)

Particle-size distribution of the original, i.e. unscreened sample of dolomitic limestone (used in Variant A)

Particle size		Proportion (%)	
> 4 mm	coarse fraction (used in Variant C)	11.2	21.9
2.8–4 mm		3.0	
1.0–2.8 mm		7.7	
0.5–1.0 mm	fine fraction (used in Variant B)	3.3	78.1
< 0.5 mm		74.8	

Each of the variants was carried out in three replications under a stand (108 B7) and complementarily in 1 replication in a clearing (clear-felled area 108 A5). In establishing the experiment, soil samples were taken with a boring bar from a depth of 0–30 cm prior to limestone application from each of the experimental plots. The samples were homogenized and analysed. Raw forest litter was removed before sampling. Then respective amounts of dolomitic limestone were applied.

In the course of the experimental period, soil samples were taken from each of the plots in a similar way, always in autumn.

All samples were individually homogenized and analysed to monitor changes in soil reaction (pH/KCl, pH/H_2O) and the exchangeable Ca and Mg content. Values of soil acidity rectified by control (see tables) were obtained by conversion using hydrogen ion concentration (not only by a hydrogen exponent).

After the experiment finished, single soil samples were taken from F horizons separately from particular plots (upper part – humus detritus), H (intermediate part – mull) and A (lower part to a depth of 30 cm – humus horizon). The content of exchangeable Ca and Mg was analysed in these samples and soil reaction was determined according to the methods of ÚKZÚZ (ZBÍRAL 1995). The whole experiment lasted for 6 years (4 years only in the clearing). All chemical analyses (including those mentioned above) were carried out in a laboratory of the ÚKZÚZ Branch Office in Opava.

RESULTS AND DISCUSSION

Data determination and their analyses can be divided into several parts:

1. Changes in soil reaction values (pH/KCl, pH/H_2O) – in the soil layer homogenized sample of a depth to 30 cm

Table 1. Changes in soil reaction (pH) in the 0–30 cm soil horizon under a spruce stand in the course of a 6-year experiment with the application of dolomitic limestone (5.1 t per ha in Variants A, B and C; control Variant D); ① – unrectified values; ② – values rectified by an increase in the control plot (D)

Characteristics	Variant (particle-size fraction)	before application	1 year	2 years	3 years	4 years	6 years
			Samples for analyses taken from experimental plots after application of dolomitic limestone				
pH/KCl ①	A	3.17	3.37	3.77	3.30	3.35	3.58
	B (≤ 1 mm)	3.10	3.33	3.60	3.40	3.40	3.41
	C (> 1 mm)	3.13	3.10	3.43	3.03	2.95	3.21
	D (control)	3.13	3.10	3.30	3.00	3.00	3.07
pH/KCl ②	A	3.17	3.43	3.39	3.62	3.73	**3.81**
	B (≤ 1 mm)	3.10	3.38	3.31	**3.86**	**3.86**	3.55
	C (> 1 mm)	3.13	3.13	3.21	3.17	3.06	**3.30**
	D (control)	3.13	3.13	3.13	3.13	3.13	3.13
pH/H_2O ①	A	3.77	4.17	4.43	4.03	4.07	3.85
	B (≤ 1 mm)	3.60	4.13	4.17	4.20	4.20	4.20
	C (> 1 mm)	3.70	3.77	4.03	3.70	3.67	4.08
	D (control)	3.73	3.80	3.90	3.60	3.67	3.98
pH/H_2O ②	A	3.77	4.02	4.01	**4.55**	4.24	3.65
	B (≤ 1 mm)	3.60	3.99	3.89	**5.72**	4.45	3.84
	C (> 1 mm)	3.70	3.70	3.81	**3.87**	3.73	3.78
	D (control)	3.73	3.73	3.73	3.73	3.73	3.73

Note: No soil samples were taken after the 5th year of the experiment

taken under a mature Norway spruce stand – are given in Table 1 (measured non-rectified values or rectified values by means of respective control values obtained in variant D). Rectified differential values of pH increase or decrease related to the respective initial value, i.e. prior to the application of dolomitic limestone, are given in Table 1a.

1.1 Table 1 shows that regardless of an experimental variant the non-rectified values of exchangeable soil acidity – pH/KCl culminated already at the end of the 2nd year of the experiment including the control, i.e. non-limed, variant. This fact indicates that for the purpose of comparisons it will be more suitable to use values (obtained from Variants A, B, C) in a form rectified by control values (D). Respective data are in Tables 1 or 1a. They show that the maximum increase in pH/KCl values occurred in the 3rd–6th experimental year. Absolute ma-ximum was reached in plots limed with the fine fraction (< 1 mm, Variant B) already in the 3rd and the 4th year. However, a decrease already occurred in the 6th year of the experiment.

The values calculated for plots limed with the original unscreened sample (Variant A) considerably approached Variant B (fine fraction); they culminated in the last 6th year of the experiment. On the contrary, the effects of the coarse fraction sample (> 1 mm, Variant C) were virtually negligible (pH increase ranged between 0.00 and 0.17 only, i.e. below the level of accuracy of the

Table 1a. Increase in soil reaction (pH) in the 0–30 cm soil horizon under a spruce stand in comparison with the values before the application of dolomitic limestone (see Table 1) rectified by control (D)

Characteristics	Variant (particle-size fraction)	before application	1 year	2 years	3 years	4 years	6 years
			Samples for analyses taken from experimental plots after application of dolomitic limestone (rectified pH increase)				
pH/KCl	A	3.17	+0.26	+0.22	+0.45	+0.56	+**0.64**
	B (≤ 1 mm)	3.10	+0.28	+0.21	**+0.76**	**+0.76**	+0.45
	C (> 1 mm)	3.13	0.00	+0.08	+0.04	–0.07	+**0.17**
	D (control)	3.13	0	0	0	0	0
pH/H_2O	A	3.77	+0.25	+0.24	+**0.78**	+0.47	–0.12
	B (≤ 1 mm)	3.60	+0.39	+0.29	+**2.12**?	+0.85	+0.24
	C (> 1 mm)	3.70	0.00	+0.11	+**0.17**	+0.03	+0.08
	D (control)	3.73	0	0	0	0	0

used methods, minimum value being even negative [–0.07]).

1.2 A different situation is in active soil acidity – pH/H_2O. Table 1 shows that non-rectified values culminated at the end of the 2nd year of the experiment in Variant A only whereas in other variants (B, C, D) culmination occurred at the end of the 6th year of the experiment (in Variant B, maximum value was the same from the end of the 3rd year). After rectification of the values (obtained from limed plots) by control values (Tables 1 or 1a) it is evident that according to our supposition the highest increase in pH/H_2O (by 2.12[!?]) occurred in Variant B with the fine fraction at the end of the 3rd year.

At the same time, culmination and somewhat lower increase occurred in plots limed with the unscreened sample (Variant A).

Virtually negligible, under the resolution level of the used methods, are increases in values from plots where only the coarse fraction was applied (Variant C – pH increase by 0.00–0.17 only).

1.3 For the purpose of orientation, changes in soil reaction values (pH/KCl, pH/H_2O) were also determined in a clearing covered with herb vegetation in the soil layer homogenized sample of a depth 30 cm – see Table 4 (unrectified and rectified values) – and Table 4a (increase in unrectified and rectified values related to initial values).

1.3.1 Table 4 shows that irrespective of the experimental variant unrectified pH/KCl values also culminated in the clear-felled area at the end of the 2nd year of the experiment including the control (non-limed) variant. (A similar hardly explainable situation occurred also in plots situated under the stand.) Therefore, rectification of measured values by control values was carried out in this case.

The highest increase in pH/KCl values (by 0.3, i.e. from 3.2 to 3.5) was achieved in plots treated with the screened fine fraction sample (Variant B) – but also in plots limed with the original unscreened sample (Variant A – from 3.3 to 3.6).

The lowest pH/KCl increase (only from –0.04 to +0.10) occurred in plots treated with the coarse fraction (Variant C).

In the course of the 4th year of the experiment, a decrease in pH/KCl values occurred in the majority of limed variants on the clear-felled area.

1.3.2 Similarly, pH/H_2O values in the clearing culminated at the end of the 2nd year (or simultaneously in the following years – see Table 4). Therefore, the values were rectified by control values also in this case; thus, culmination occurred in the 3rd year after liming.

The highest increase in pH/H_2O (by 0.60, i.e. from 3.9 to 4.5) was achieved in a plot limed with the fine fraction (Variant B) – see Table 4a.

On average, the lowest pH/H_2O increase (only by –0.04 to +0.20) was recorded in the coarse fraction (Variant C). Variant A treated with unscreened limestone provided virtually the same low values.

2. Changes in the content of exchangeable calcium (Ca) and magnesium (Mg) in the homogenized soil layer sample of a depth ≤ 30 cm under a spruce stand are given in Table 2; in the majority of cases, the measured values are highest in the last (i.e. in the 6th) year of the experiment with the exception of magnesium in the control variant where culmination occurred one year after limestone application. Therefore the actual 'increase' was also assessed according to differential values (i.e. from the values measured in particular limed plots [A to C] rectified by respective values obtained from control, i.e. non-limed, plots [D]) – see Table 2a.

2.1 Increase in exchangeable calcium culminated as late as in the 6th year of the experiment; the highest values were achieved in Variant B (or in Variants B and A); after the 1st year, maximum occurred in Variant A only. Values obtained in Variant C were markedly lower or even negligible.

2.2 Increase in exchangeable magnesium also culminated in the 6th year of the experiment; the highest values were achieved exclusively in Variant B. However, the values obtained in Variant A differed much less than those in Variant C that were by an order lower (in one case even negative) – and could also be evaluated as negligible.

3. At the end of the experiment, after 6 years of the effect of dolomitic limestone in soil under the forest stand, selected soil characteristics (Table 3) were studied in relation to

Table 2. Changes in the content of exchangeable calcium (Ca) and magnesium (Mg) in the 0–30 cm soil horizon under a spruce stand in the course of a 6-year experiment with the application of dolomitic limestone (5.1 t per ha in Variants A, B and C; control Variant D)

Characteristics	Variant (particle-size fraction)	before application	1 year	3 years	4 years	6 years
			after application of dolomitic limestone			
Exchangeable Ca	A	260	455	385	515	**980**
(mg/kg)	**B** (≤ 1 mm)	240	375	385	515	**1,055**
(Mehlich II)	C (> 1 mm)	240	340	255	345	**460**
	D (control)	220	320	215	**325**	**325**
Exchangeable Mg	A	35	91	119	165	**387**
(mg/kg)	**B** (≤ 1 mm)	35	97	154	168	**394**
(Mehlich II)	C (> 1 mm)	35	71	39	53	**81**
	D (control)	33	**63**	49	52	44

Table 2a. Increase in the content of exchangeable calcium (Ca) and magnesium (Mg) from Table 2 related to values before the application of dolomitic limestone (①) and rectified by an increase in the control plot (②)

Characteristics	Variant (particle-size fraction)	before application	1 year	3 years	4 years	6 years
			after application of dolomitic limestone (increase)			
Exchangeable Ca	A	260	+195	+125	+255	**+720**
(mg/kg) ①	**B** (≤ 1 mm)	240	+135	+145	+275	+**815**
(MEHLICH II)	C (> 1 mm)	240	+100	+15	+105	+**220**
	D (control)	220	+100	–5	**+105**	**+105**
Exchangeable Ca	A	260	+95	+130	+150	+**615**
(mg/kg) ②	**B** (≤ 1 mm)	240	+35	+150	+170	+**710**
(MEHLICH II)	C (> 1 mm)	240	0	+20	0	+**115**
	D (control)	220	0	0	0	0
Exchangeable Mg	A	35	+56	+84	+130	+**352**
(mg/kg) ①	**B** (≤ 1 mm)	35	+62	+119	+133	+**359**
(MEHLICH II)	C (> 1 mm)	35	+36	+4	+18	+**46**
	D (control)	33	+**30**	+16	+19	+11
Exchangeable Mg	A	35	+26	+68	+111	+**341**
(mg/kg) ②	**B** (≤ 1 mm)	35	+32	+103	+114	+**348**
(MEHLICH II)	C (> 1 mm)	35	+6	–12	–1	+**35**
	D (control)	33	0	0	0	0

Samples for analyses taken from experimental plots: before application; 1 year, 3 years, 4 years, 6 years after application of dolomitic limestone (increase).

3 soil horizons: F, H and A (approximately 0–1, 1–10, 10–30 cm). Differential values expressing the increase (or decrease) in the given quantity were used again (Table 3a).

3.1 Increase in the pH/KCl value was always highest in the upper soil horizon F (pH increase by 1.5–2.9) with maximum values in plots limed with the fine fraction (Variant B). The lowest increase occurred in the lowest A horizon (pH increase by 0.05–0.10 only). Relatively small pH/KCl increase (pH increase by 0.25–1.5) was also found in the intermediate soil horizon H.

3.2 Increase in the pH/H_2O value was highest also in this case in the upper soil horizon F (pH increase by 1.10–1.95) with maximum values in plots limed with the fine fraction (Variant B). Similarly, the smallest increase occurred in the lower A horizon (pH increase by 0.0–0.15 only). Relatively smaller pH/H_2O increase was found in this case in the intermediate soil horizon H (pH increase by 0.45–1.15).

3.3 Increase in exchangeable calcium was also highest in the upper soil horizon F (increase by 750–4,090 mg/kg) with maximum values in plots limed with the fine fraction

Table 3. Some characteristics of three soil horizons in plots under a spruce stand in Variants A–D after the termination of 6-year experiment with the application of dolomitic limestone

Characteristics	Soil horizon	Variant of liming (particle-size of limestone) A	B (≤ 1 mm)	C (> 1 mm)	Control D
pH/KCl	**F**	5.40	**5.80**	4.40	2.90
	H	**4.30**	4.15	3.05	2.80
	A	**3.30**	3.25	3.25	3.20
pH/H_2O	**F**	5.10	**5.95**	5.20	4.00
	H	4.10	**4.65**	3.95	3.50
	A	4.20	**4.25**	4.10	4.10
Exchangeable	**F**	4,620	**5,400**	2,060	1,310
Ca (MEHLICH II)	H	1,950	**2,120**	700	385
(mg/kg)	A	**360**	**360**	270	250
Exchangeable	**F**	**1,460**	1,340	317	164
Mg (MEHLICH II)	H	880	**935**	140	52
(mg/kg)	A	112	103	43	35

Table 3a. Increase in some soil characteristics under a spruce stand from Table 3, situation 6 years after the application of dolomitic limestone in three soil horizons – expressed by the difference between limed variants (A, B, C) and the respective control variant (D)

Characteristics	Soil horizon (control value)	Difference between limed variant and control variant A – D (A – unscreened fertilizer)	B – D (B – fraction ≤ 1 mm)	C – D (C – fraction > 1 mm)
pH/KCl increase	**F** (2.90)	+2.50	+**2.90**	+1.50
	H (2.80)	+**1.50**	+1.35	+0.25
	A (3.20)	**+0.10**	+0.05	+0.05
pH/H_2O increase	**F** (4.00)	+1.10	+**1.95**	+1.20
	H (3.50)	+0.60	+**1.15**	+0.45
	A (4.10)	+0.10	+**0.15**	0.0
Increase of exchangeable Ca (mg/kg) (Mehlich II)	**F** (1,310)	+3,310	+**4,090**	+750
	H (385)	+1,565	+**1,735**	+315
	A (250)	+**110**	+**110**	+20
Increase of exchangeable Mg (mg/kg) (Mehlich II)	**F** (164)	+**1,269**	+1,176	+153
	H (52)	+828	+**883**	+88
	A (35)	+**77**	+68	+8

(Variant B). Similarly, the lowest increase occurred in the lower A horizon (increase by 20–110 mg/kg only).

Medium increase in exchangeable Ca values was also found in the intermediate H horizon (increase by 315–1,735 mg/kg) with maximum values in Variant B (fine fraction).

3.4 Increase in exchangeable magnesium was highest in the upper soil horizon F (increase by 153–1,269 mg/kg) with maximum values in plots limed with the unscreened sample (Variant A), however, it was immediately followed by plots treated with the fine fraction (Variant B). Similarly, the lowest increase occurred in the lower A horizon (increase by 8–77 mg/kg only). Medium increase in exchangeable Mg was also found in the intermediate H horizon (increase by 88–883 mg/kg) with maximum values in Variant B (fine fraction).

Table 4. Changes in soil reaction (pH) in the 0–30 cm soil horizon in a clearing covered with herbs during a 4-year experiment with the application of dolomitic limestone (5.1 t per ha in Variants A, B and C; control Variant D); ① – unrectified values; ② – values rectified by an increase in the control plot (D)

Characteristics	Variant	Samples for analyses taken from experimental plots: before application	after 1 year	after 2 years	after 3 years	after 4 years
pH/KCl ①	A	3.3	3.6	3.9	3.5	3.4
	B (≤ 1 mm)	3.2	3.4	3.7	3.5	3.3
	C (> 1 mm)	3.3	3.4	3.5	3.4	3.4
	D (control)	3.2	3.2	3.4	3.2	3.2
pH/KCl ②	**A**	3.3	**3.60**	3.45	3.50	3.40
	B (≤ 1 mm)	3.2	3.40	3.36	**3.50**	3.30
	C (> 1 mm)	3.3	**3.40**	3.26	**3.40**	**3.40**
	D (control)	3.2	3.20	3.20	3.20	3.20
pH/H_2O ①	A	4.0	4.3	4.4	4.2	4.1
	B (≤ 1 mm)	3.9	4.4	4.5	4.5	4.2
	C (> 1 mm)	4.0	4.2	4.3	4.2	4.2
	D (control)	3.9	4.0	4.1	3.9	4.1
pH/H_2O ②	A	4.0	4.12	4.06	**4.20**	3.90
	B (≤ 1 mm)	3.9	4.18	4.11	**4.50**	3.96
	C (> 1 mm)	4.0	4.05	4.02	**4.20**	3.96
	D (control)	3.9	3.90	3.90	3.90	3.90

Note: The experiment in a clearing was established in one replication only. After 4 years, the experiment had to be finished because the plot was damaged to such an extent that it was not possible to identify the trial plots

Table 4a. Increase in soil reaction (pH) in the 0–30 cm soil horizon in a clearing covered with herbs during a 4-year experiment (see Table 4) related to values obtained before the application of dolomitic limestone; ① – unrectified values; ② – values rectified by control D

Characteristics	Variant	Samples for analyses taken from experimental plots				
		before application	after 1 year	after 2 years	after 3 years	after 4 years
pH/KCl	**A**	3.3	+0.3	+**0.6**	+0.2	+0.1
①	B (≤ 1 mm)	3.2	+0.2	+**0.5**	+0.3	+0.1
	C (> 1 mm)	3.3	+0.1	+**0.2**	+0.1	+0.1
	D (control)	3.2	0	+**0.2**	0	0
pH/KCl	A	3.3	+**0.30**	+0.15	+0.20	+0.10
②	**B** (≤ 1 mm)	3.2	+0.20	+0.16	+**0.30**	+0.10
	C (> 1 mm)	3.3	+**0.10**	–0.04	**+0.10**	**+0.10**
	D (control)	3.2	0	0	0	0
pH/H_2O	A	4.0	+0.3	+**0.4**	+0.2	+0.1
①	**B** (≤ 1 mm)	3.9	+0.5	+**0.6**	+**0.6**	+0.3
	C (> 1 mm)	4.0	+0.2	+**0.3**	+0.2	+0.2
	D (control)	3.9	+0.1	+**0.2**	0	+**0.2**
pH/H_2O	A	4.0	+0.12	+0.06	+**0.20**	–0.10
②	**B** (≤ 1 mm)	3.9	+0.28	+0.21	+**0.60**	+0.06
	C (> 1 mm)	4.0	+0.05	+0.02	+**0.20**	–0.04
	D (control)	3.9	0	0	0	0

Note: If compared to the increase in the upper F horizon, an increase in values in the intermediate H horizon (about 2–10 cm) reached only 17–60, 38–59, 42–47 and 58–75% in pH/KCl, pH/H_2O, Ca and Mg, respectively.

4. The following problems remain more or less open:

4.1 What caused an increase in 'absolute' pH/KCl and pH/H_2O values – in limed as well as control plots – in the period of the 2nd or 3rd year of the experiment (calendar years 1989 or 1990). It is possible to suppose that external influences were involved mediated by the atmosphere or determined by the different course of weather in the given years (?). Laboratory and field procedures were identical and carried out by the same persons.

4.2 Another question could be evoked by the fact that in several cases when the most intensive effect of liming with the finest fractions was expected (Variant B), a somewhat more marked effect was found when an unscreened sample was used for liming (Variant A) although the 'superiority' was generally small and often rather symbolic. A logical explanation is, however, evident: the original sample of dolomitic limestone used in Variant A contained primarily the fine fraction (more than 78%) and only a lower proportion of the coarse fraction (less than 22% – see a table in Material and Methods). Therefore its effectiveness approaches the sample used in Variant B and this relatively small difference was (in some cases) obviously below the resolution level of the used methods.

SUMMARY AND CONCLUSION

Effects of the application of several fractions of dolomitic limestone (5.1 t per ha at the beginning of a 6-year experiment conducted under a mature Norway spruce stand or in a clearing covered with herb vegetation) on selected soil properties can be summarized as follows:

a) Increase in the values of exchangeable soil acidity – pH/KCl – culminated in the 3rd–6th year of the experiment. Maximum effects (pH [3.10] increase by as much as 0.76) were achieved using a fine fraction for liming (particle size ≤ 1 mm). Effects of the coarse fraction (particle size > 1 mm) were negligible (pH increase [3.13] ranged between –0.07 and +0.17, i.e. virtually below the limit of accuracy of the used methods).
b) Increase in the value of active soil acidity – pH/H_2O – culminated in the 3rd year of the experiment. Maximum effects (pH increase [3.60] by 0.24 to 2.12[?]) were achieved using the fine fraction. Effects of the coarse fraction were negligible (pH increase [3.70] ranged between 0.00 and 0.17).
c) Changes in soil acidity in plots situated on a clearing covered with herb vegetation were generally somewhat smaller.
d) Increase in the content of exchangeable Ca and Mg culminated in the last 6th year of the experiment. Maximum effects were achieved by liming with the fine fraction; the results obtained applying unscreened fertilizer were only a little lower. Minimum increases in the content of exchangeable Ca and Mg were found in plots limed with the coarse fraction.
e) Increase in the value of soil pH/KCl and pH/H_2O as well as in the values of the content of exchangeable Ca and Mg six years after the application of dolomitic limestone was always highest in the upper horizon F

(≤ 1–2 cm) and smallest in the lowest horizon A (approximately between 10 and 30 cm).

In conclusion, it is necessary to emphasize that the application of coarse fractions of dolomitic limestone (particle size > 1 mm, application rate 5.1 t per ha) during the 6-year experimental period did not virtually affect the studied characteristics (pH, Ca, Mg). Application of finer fractions (< 1 mm) was relatively more effective, however, their effects also decreased rapidly towards the lower-located soil horizons. While the values of exchangeable Ca and Mg were highest in the last 6th year of measurement, pH values culminated earlier, most often about the 3rd year.

References

KLIMO E., VAVŘÍČEK J., 1991. Acidifikace a vápnění lesních půd v Beskydech. Lesnictví, *37*: 61–72.

MATERNA J., SKOBLÍK J., 1988. Vápnění – nutné opatření pro omezení vlivu imisí na les. Lesn. Práce, *67*: 387–391.

NĚMEC A., 1938. Vliv vápnění na vzrůst sazenic smrku v lesních školkách. Lesn. Práce, *17*: 209–234.

PAVLÍČEK V., MUSIL I., 1988. Některé chemické a fyzikální aspekty ovlivňující účinnost vápnění v imisních oblastech. Lesn. Práce, *67*: 397–399.

PAVLÍČEK V., MUSIL I., 2001. Vápnění lesů – vliv zrnitostních frakcí na některé agrochemické vlastnosti půdy. Praha, Odbor agrochemie, půdy a výživy rostlin ÚKZÚZ 9 (in print).

PODRÁZSKÝ V., 1990. Dosavadní výsledky výzkumu vápnění v imisních oblastech Jizerských hor, Krkonoš a Orlických hor. Lesn. Práce, *69*: 399–404.

PODRÁZSKÝ V., 1991. Vliv vápnění na vlastnosti lesních půd a na odolnost lesních dřevin vůči působení imisí. Lesnictví, *37*: 161–182.

PODRÁZSKÝ V., PEŘINA V., 1989. Zahraniční zkušenosti s vápněním lesních půd. Lesn. Práce, *68*: 117–120.

ZBÍRAL J., 1995. Analýza půd I. Jednotné postupy. Brno, SKZÚZ.

Received 9 November 2001

Vápnění lesních půd – účinnost použitých zrnitostních frakcí

I. MUSIL[1], V. PAVLÍČEK[2]

[1]*Česká zemědělská univerzita, Lesnická fakulta, Praha, Česká republika*

[2]*Ústřední kontrolní a zkušební ústav zemědělský, OAPVR, pobočka Opava, Česká republika*

ABSTRAKT: Příspěvek zkoumá vliv jednorázově použité zrnitostní frakce dolomitického vápence (v dávce 5,1 t/ha) na půdní reakci (pH/KCl a pH/H_2O) a na obsah výměnného Ca a Mg (v půdní vrstvě 0–30 cm, resp. v půdních horizontech F, H, A) během šestiletého pokusu pod dospělým smrkovým porostem a čtyřletého pokusu na holině. Nárůst pH kulminoval ve třetím, resp. ve třetím až šestém roce pokusu. Maximálního účinku bylo dosaženo při aplikaci jemné frakce o velikosti zrn do 1 mm. Frakce hrubá – o velikosti zrn nad 1 mm – měla účinek prakticky zanedbatelný. Nárůst obsahu Ca a Mg kulminoval až v posledním, šestém roce pokusu. Maxima bylo dosaženo opět při aplikaci jemné frakce. Vliv hrubé frakce byl rovněž prakticky zanedbatelný. Po šesti letech se u všech sledovaných hodnot projevil maximální nárůst ve svrchním, úzkém horizontu F, zatímco směrem dolů se nárůst velmi rychle snižoval.

Klíčová slova: vápnění lesů; dolomitický vápenec; zrnitostní frakce; acidita; živiny

Vliv pozemní aplikace několika frakcí dolomitického vápence (dávka 5,1 t/ha, na počátku šestiletého pokusu pod mýtným smrkovým porostem, resp. na pasece porostlé bylinnou vegetací) na vybrané vlastnosti půdní je možné shrnout takto:

a) Nárůst hodnot výměnné půdní acidity – pH/KCl – kulminoval ve třetím až šestém roce pokusu. Maximálního účinku (zvýšení pH [ze 3,10] až o 0,76) bylo dosaženo při vápnění jemnou frakcí (velikost zrn do 1 mm). Vliv hrubé frakce (velikost zrn nad 1 mm) byl zanedbatelný (zvýšení pH [ze 3,13] se pohybovalo mezi –0,07 a +0,17 – prakticky zřejmě již pod hranicí přesnosti použitých metod).

b) Nárůst hodnot aktivní půdní acidity – pH/H_2O – kulminoval již ve třetím roce pokusu. Maximálního účinku (zvýšení pH [ze 3,60] o 0,24 až 2,12[?]) bylo dosaženo i zde při vápnění jemnou frakcí. Vliv hrubé frakce byl více než zanedbatelný (zvýšení pH [ze 3,70] se pohybovalo v rozmezí 0,00 až 0,17).

c) Orientační výsledky změn půdní acidity z ploch umístěných na pasece porostlé bylinnou vegetací byly celkově poněkud nižší.
d) Nárůst obsahu výměnného Ca i výměnného Mg kulminoval až v posledním, šestém roce pokusu. Maxima bylo dosaženo při vápnění jemnou frakcí; jen o málo nižší byly výsledky dosažené aplikací netříděného hnojiva. Minimální přírůsty obsahu výměnného Ca a Mg byly u parcel vápněných hrubou frakcí.
e) Zvýšení hodnot půdního pH/KCl i pH/H_2O, jakož i hodnot půdního obsahu výměnného Ca i Mg – po šesti letech od aplikace dolomitického vápence – bylo vždy největší v nejvýše položeném horizontu F (do 1–2 cm) a nejmenší v nejníže položeném horizontu A (přibližně již mezi 10–30 cm).

Závěrem je nutné zdůraznit, že aplikace hrubších frakcí dolomitického vápence (se zrny o velikosti nad 1 mm v dávce 5,1 t/ha) během šestileté pokusné doby zkoumané charakteristiky (pH, Ca, Mg) prakticky neovlivnila. – Aplikace jemnějších frakcí (< 1 mm) byla relativně účinnější, avšak i její působení velmi rychle klesalo směrem do níže položených půdních horizontů. – Zatímco hodnoty výměnného Ca a Mg dosahovaly nejvyšších hodnot v posledním, tj. v šestém roce měření, hodnoty pH kulminovaly dříve, nejčastěji kolem třetího roku.

Corresponding author:

Doc. Ing. IVAN MUSIL, CSc., Česká zemědělská univerzita, Lesnická fakulta, 165 21 Praha 6-Suchdol, Česká republika
tel.: + 420 2 24 38 34 04, fax: + 420 2 20 92 31 32, e-mail: musil@lf.czu.cz