Effects of Dolomite Liming on Soil Chemistry in Acidic Forest Soils

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ABSTRACT : A mixed forest of pines (*Pinus densiflora* and *Pinus rigida*) and an oak forest (*Quercus mongolica*) in Mt. Kwanak in Seoul were limed with 1.5 t/ha and 3 t/ha of dolomite in 1993 and investigated the effects of liming on the chemical changes in the 0~5 cm and 5~10 cm layers of soil from 1994 to 1995. Soil pH values were greater in the limed plots than in the control plot by the unit of 0.1~0.6 in the pine forest and 0.1~0.2 in the oak forest. Ca concentrations in the limed plots were greater than those in the control plots in both the pine and oak forests. A considerable increase in Mg concentrations in soil was observed in the limed plots. K and Na concentrations in the limed plots appeared to decrease in both the pine and oak forests two years after liming. Although Al concentrations were greater in the limed plots than in the control plot in the pine forest in 1994, there was a tendency of a decrease in the concentration of this metal in the limed plots in 1995. Mn concentrations also tended to decrease in the limed plots in both the pine and oak forests.

Key words : Calcium, Dolomite, Liming, Magnesium, Oak, Pine, Soil chemistry

INTRODUCTION

Accelerated soil acidification processes in forest ecosystems appear to be an important factor involved in novel forest decline (Ulrich 1983), which has been observed in Europe (Schulze 1989) and North America (Johnson 1987). A reduction in growth of pitch pine caused by soil acidification has also been observed in Seoul, Korea (Rhyu and Kim 1994b). The deficiency of nutrients and an increase in the availability of toxic metals, such as Al and Mn, have been reported in forest soils as a result of soil acidification (Matzner et al. 1985, Lundström et al. 2003). Rhyu and Kim (1994a) suggested that Ca and Mg deficiencies in needles and roots may contribute to the growth reduction of pitch pine in Seoul. In order to improve health condition in forests suffering from soil acidification, liming of acidic forest soils has been increasing widely (Mayr 1998). In particular, dolomite ($CaMg(CO_3)_2$) has been applied to declining forests in Europe (Ingerslev 1997), Canada (Côté et al. 1995) and the northeastern USA (Burke and Raynal 1998), where severe Mg deficiency has been found.

Compared to a number of studies on liming effects on agricultural soils (Park 1974, Lee et al. 1990, Ko and Choung 1991), very few research has been carried out in the fields into the effects of liming on the chemical properties of acidic forest soils in Korea. Rhyu (1994) studied the effects of dolomite treatment on soil and soil solution chemistry in a pitch pine forest in Mt. Kwanak. Yoo et al. (1998) reported the effects of CaO and MgSO4 treatments on the chemical properties of pitch pine, sawtooth oak and Mongolian oak forest soils in Mt. Namsan, Mt. Surak and Kwangnung. Both studies found increases in Ca and Mg concentrations in mineral layer soils. Laboratory studies have also showed increases in pH and concentrations of Ca and Mg in dolomite-applied acidic soils collected from forests in the vicinity of Yeocheon industrial complex (Mun et al. 1997, Lee et al. 1998).

The aim of the present study was to investigate the changes in the chemical properties of mineral layer soil one and two years after liming with increasing liming rates in pine and oak forests.

MATERIALS AND METHODS

Study sites

The study was conducted in Mt. Kwanak, Seoul, Korea (37° 27' 12" N 126° 57' 32" W) and the sites are located in a mixed forest of pines (*Pinus densiflora* and *Pinus rigida*) and an oak (*Quercus mongolica*) forest at an elevation of 230 m. Average tree ages of *P. densiflora*, *P. rigida* and *Q. mongolica* were 24, 32 and 18, respectively. The understorey vegetation of both forests was dominated by *Rhododendron mucronulatum*. The annual mean temperature was 12.1°C and annual precipitation was 961 mm from 1983 to 1992. Three 10 × 10 m plots were established in each pine and oak forest

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and dolomite was applied manually on the surface of litter layer at rates of 0, 1.5 and 3 t/ha in March 1993.

Soil texture of the 0~10 cm layer soil, which was determined by the hydrometer method (Bouyoucos 1962) in 1994, was different between the plots (Table 1). Silt and clay contents in soil of the control plot and 1.5 t dolomite/ha treated plot (1.5 t plot) in the pine forest were lower than those of 3 t dolomite/ha treated plot (3 t plot). In the oak forest, silt and clay contents in soil of the 1.5 t plot were greater than those in the control and 3 t plot.

Soil analysis

Five soil samples from the 0~5 cm soil layer and the 5~10 cm layer were collected from each plot in December 1994 and in August 1995. The soil samples were air-dried at room temperature for 2 weeks and sieved through a 2-mm mesh sieve. Soil pH was measured in both water (soil:water = 1:5, w/v) and 0.01 M $CaCl_2$ solution (soil:$CaCl_2$ solution = 1:2.5, w/v). Organic matter content was estimated as loss on ignition. Total N concentration was analysed using the Kjeldahl method. Concentrations of exchangeable Ca, Mg, K, Na, Al, Fe and Mn were measured following extraction with 1 M CH_3COONH_4 using an inductively coupled plasma spectrometer (Shimazu ICPQ-1000).

Because there were no replicate plots, the data presented in the present study cannot provide statistical evidence for the conclusions. Therefore, we attempted to focus on the changes in differences between mean values of five soil samples in each plot from 1994 to 1995, rather than the differences of absolute amounts of elements between the plots each year.

RESULTS AND DISCUSSION

Soil pH

Soil pH (H_2O) and pH ($CaCl_2$) values were greater in the limed plots than in the control plot by the unit of 0.1~0.6 in the pine plots in 1994 and 1995 (Table 2). However, soil pH was not linearly increased with increasing levels of dolomite treatment. Soil pH in the 3 t plot was lower than that in the 1.5 t plot in the pine forest in 1994. This might be explained by the greater contents of clay and soil organic matter in the 3 t plot than those in the 1.5 t plot (Table 1 and 3). Because soils higher in clay and organic matter contents have higher buffering capacity, more lime is required in the clay soil than in the sandy soil in order to increase soil pH (Brady 1990).

Soil pH in the oak plots was not different between the plots in 1994 (Table 2). However, it was greater in the limed plots by the unit of 0.1~0.2 in the 0~5 cm soil layer in 1995. Slower increase in pH in the oak plots than in the pine plots may also be related to the greater contents of clay and organic matter in the oak plots than those in the pine plots. An increase in pH of mineral soil by the unit of 0.4 was observed in a mixed forest of red oak and red maple one year after treatment of 6.6 t dolomite/ha (Demchik and Sharpe 2001). Compared to a laboratory experiment by Mun *et al.* (1997), which reported an increase in pH by the unit of 3.1 in a forest mineral soil mixed with dolomite (50:1, v/v), the increase in pH value in the mineral soil in the present study was not pronounced. In the present study, dolomite was applied on the litter layer without mixing with mineral soil, therefore the changes in the pH of the mineral layer soil might have been slow. This might also be due to the low dissolution rates of dolomitic lime in the field (Matzner *et al.* 1985).

Organic matter content and total N

Organic matter content and total N concentration were greater in the 0~5 cm layer than in the 5~10 cm layer of soil in both the pine and oak plots (Table 3), possibly due to the greater input of decomposed plant residues into the upper soil layer. The organic matter content and total N concentration were greatly different between the plots in both the pine and oak forests. For example, the organic matter content of the 0~5 cm layer in the 3 t plot was almost four times greater than that in the 1.5 t plot in the pine forest in 1994. Total N concentration of the 5~10 cm layer in the 3 t plot

Table 1. Soil texture (%) of control and limed plots in pine and oak forests in Mt. Kwanak. Data are means±standard errors

Soil texture	Pine forest			Oak forest		
	Dolomite (t/ha)			Dolomite (t/ha)		
	0	1.5	3.0	0	1.5	3.0
Gravel (%)	43.4±2.6	47.5±5.2	47.8±3.6	48.0±5.7	43.1±4.5	35.1±2.4
Sand (%)	82.6±1.2	83.4±1.8	73.7±2.1	78.2±1.5	67.9±3.9	76.8±0.8
Silt (%)	6.5±0.8	6.2±1.1	12.2±1.1	8.9±1.5	14.6±2.0	11.0±0.8
Clay (%)	10.9±0.5	10.4±0.7	14.2±1.1	12.9±0.4	17.5±2.1	12.2±0.0

Table 2. Changes in soil pH in control and limed plots in pine and oak forests from 1994 to 1995 in Mt. Kwanak. Data are means ± standard errors

| | | | Pine forest | | | Oak forest | | |
| | Year | Soil depth (cm) | Dolomite (t/ha) | | | Dolomite (t/ha) | | |
			0	1.5	3.0	0	1.5	3.0
pH (H₂O)	1994	0~ 5	4.28±0.08	4.85±0.13	4.54±0.10	4.53±0.03	4.50±0.07	4.55±0.03
		5~10	4.38±0.08	4.94±0.13	4.50±0.05	4.60±0.04	4.58±0.04	4.58±0.08
	1995	0~ 5	4.31±0.06	4.72±0.07	4.77±0.05	4.74±0.05	4.81±0.20	4.93±0.14
		5~10	4.45±0.05	4.85±0.06	4.68±0.04	4.97±0.15	4.73±0.06	4.88±0.10
pH (CaCl₂)	1994	0~ 5	3.78±0.07	4.22±0.17	4.04±0.06	4.04±0.09	4.08±0.06	4.00±0.05
		5~10	3.84±0.07	4.34±0.15	4.06±0.02	4.10±0.13	4.08±0.04	4.14±0.05
	1995	0~ 5	3.45±0.04	3.66±0.02	3.87±0.04	3.78±0.04	3.92±0.12	3.95±0.09
		5~10	3.58±0.04	3.72±0.02	3.85±0.03	3.97±0.05	3.86±0.04	3.98±0.03

Table 3. Changes in soil organic matter content (%) and total N concentrations (mg/g) in control and limed plots in pine and oak forests from 1994 to 1995 in Mt. Kwanak. Data are means ± standard errors

| | | | Pine forest | | | Oak forest | | |
| | Year | Soil depth (cm) | Dolomite (t/ha) | | | Dolomite (t/ha) | | |
			0	1.5	3.0	0	1.5	3.0
O. M. (%)	1994	0~ 5	2.1±0.3	1.1±0.1	4.1±0.5	7.1±0.7	3.7±0.5	4.8±0.6
		5~10	1.8±0.2	0.9±0.1	3.5±0.4	5.1±0.3	3.6±0.5	4.3±0.2
	1995	0~ 5	4.1±0.3	3.0±0.3	5.0±0.4	5.6±0.6	4.7±0.3	5.1±0.4
		5~10	3.0±0.3	2.6±0.1	4.1±0.3	4.9±0.6	4.4±0.2	5.6±0.5
Total N (mg/g)	1994	0~ 5	0.85±0.10	0.66±0.08	1.35±0.06	1.79±0.25	1.00±0.07	1.66±0.14
		5~10	0.62±0.04	0.66±0.05	1.16±0.08	1.50±0.21	0.85±0.10	1.43±0.20
	1995	0~ 5	0.75±0.06	0.56±0.09	0.99±0.07	1.79±0.11	1.04±0.10	1.33±0.13
		5~10	0.62±0.09	0.54±0.07	0.89±0.07	1.04±0.21	0.79±0.08	1.22±0.14

was also 76% greater than that in the 1.5 t plot in the oak forest in 1994. The variation of the values of organic matter content and total N concentration may largely be due to the location effect.

Base cations

Ca concentrations in the 0~5 cm layer were greater than those in the 5~10 cm layer of both the pine and oak forests (Fig. 1A and 1B). This may be due to higher concentrations of base cations in the fresh litter of *Q. mongolica* than those of *P. densiflora* or *P. rigida*. Kim (1996) observed higher concentrations of Ca, Mg and K in the leaves of *Q. mongolica* than those in the latter two pine species in the same study sites described in the present study. In

1994, soil Ca concentrations in the 0~5 cm layer were greater in the 1.5 t and 3 t pine plots than in the control plot by 18% and 10%, respectively (Fig. 1A). The Ca concentrations in the 5~10 cm layer were greater in the 1.5 t and 3 t pine plots than in the control plot in 1994 by 5% and 3%, respectively. However, two years after liming, the Ca concentrations in the 5~10 cm layer were greater in the 1.5 t and 3 t pine plots than in the control plot by 30% and 25%, respectively, indicating downward transport of Ca from the upper layer of soil. In 1995, the Ca concentrations in the 0~5 cm layer were greater in the 1.5 t and 3 t plots than in the control plot in the oak forest by 14% and 12%, respectively (Fig. 1B).

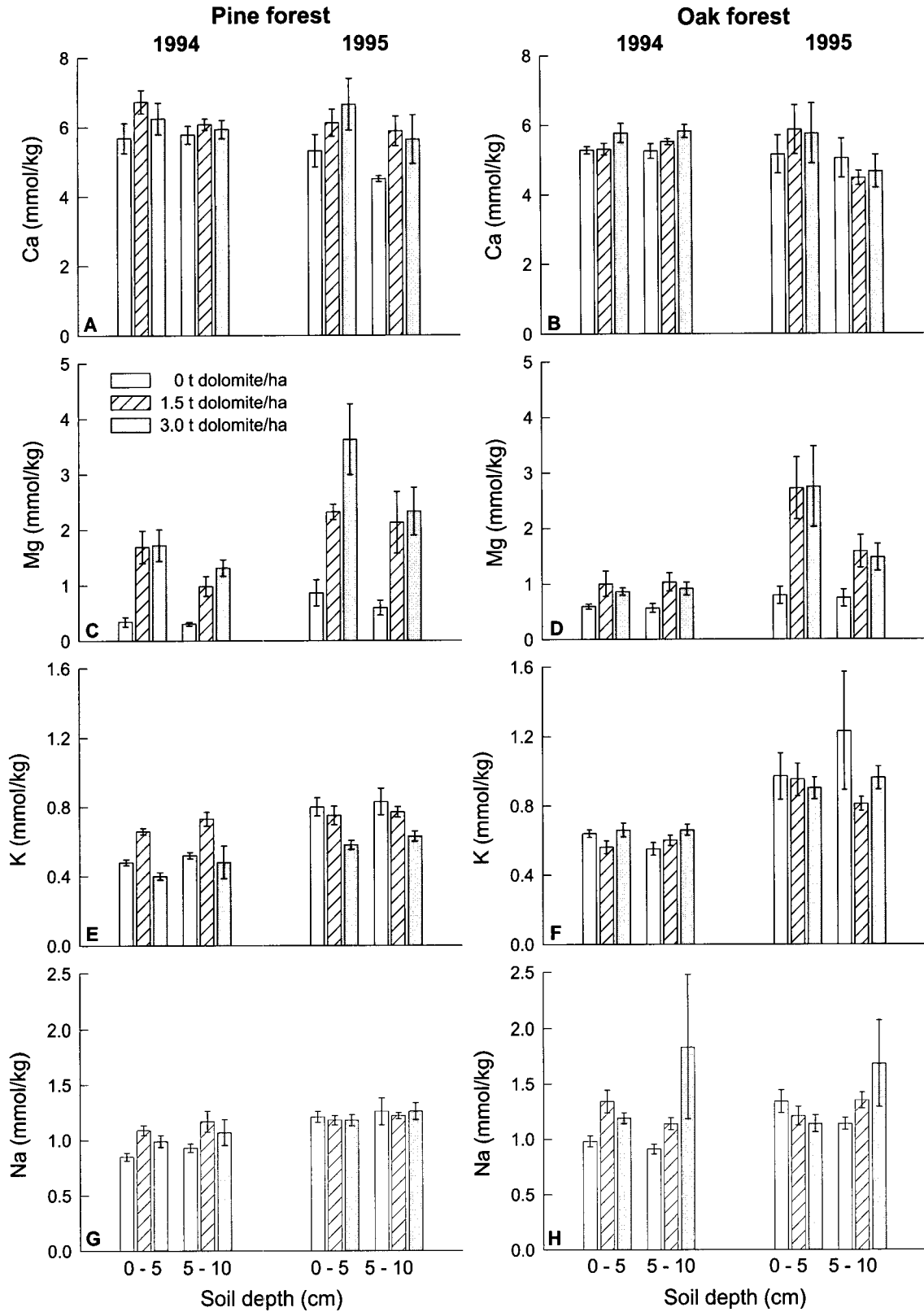Liming considerably increased Mg concentrations in the limed

Fig. 1. Changes in exchangeable base cations (mmol/kg) in soil in control and limed plots in a pine forest (A, C, E and G) and an oak forest (B, D, F and H) from 1994 to 1995 in Mt. Kwanak. Data are means±standard errors.

plots in both the pine and oak forests (Fig. 1C and 1D). An increase in soil Mg concentration was greater in the pine plots than in the oak plots. In 1994, the Mg concentrations in the 0~5 cm layer were greater in the 1.5 t and 3 t plots than in the control plot in the pine forest by 397% and 406%, respectively (Fig. 1C). Although the effect of increasing rates of dolomite treatment was not found in the pine forest in 1994, two years after liming, the Mg concentration in the 0~5 cm layer of the 3 t plot was 34% greater than that of the 1.5 t plot. Two years after liming, the Mg concentrations in the 0~5 cm layer were greater in the 1.5 t and 3 t plots than in the control plot in the oak forest by 244% and 248%, respectively (Fig. 1D).

Liming appeared to decrease soil K concentrations in both the pine and oak forests (Fig. 1E and 1F). The K concentration in the 0~5 cm layer in the control plot was 27% lower than that in the 1.5 t plot but 17% greater in the 3 t plot in the pine forest in 1994 (Fig. 1E). However, K concentration in the same layer was greater in the control plot than in the 1.5 t and 3 t plots in 1995 by 6 % and 28%, respectively. The K concentrations in the 5~10 cm layer were greater in the 1.5 t and 3 t plots than in the control plot in the oak forest in 1994 by 9% and 20%, respectively. However, K concentrations in the same layer were lower in the 1.5 t and 3 t plots than in the control plot in 1995 by 34% and 22%, respectively (Fig. 2F). Sikström (2001) reported a reduction in K concentration in the 0~10 cm layer of Norway spruce forest soil following the application of 6 t/ha of CaCO$_3$. The decreases in K availability as a result of liming in laboratory experiments have also been reported by Magdoff and Bartlett (1980) and Curtin and Smillie (1986).

A decrease in Na concentrations in both the pine and oak plots as a result of liming was similar to that in the K concentrations (Fig. 1G and 1H). Soil Na concentrations in the 0~5 cm layer were greater in the 1.5 t and 3 t plots than in the control plot in the pine forest in 1994 by 28% and 16%, respectively (Fig. 1G). However, the Na concentration in the same layer was greater in the control plot than in the 1.5 t and 3 t plots in 1995 by 2%. The Na concentrations in the 0~5 cm layer were also greater in the 1.5 t and 3 t plots than in the control plot in the oak forest in 1994 by 37% and 21%, respectively. However, the Na concentrations in the same layer were lower in the 1.5 t and 3 t plots than in the control plot in 1995 by 10% and 15%, respectively (Fig. 1H). The decreases in K and Na concentrations in the limed plots might be resulted from decreasing selectivity for the monovalent ion (K and Na) relative to the divalent (Ca and Mg) caused by increased CEC by liming (Magdoff and Bartlett 1980).

Al, Fe and Mn

The concentrations of Al, Fe and Mn were greater in the oak

plots than in the pine plots (Fig. 2). Liming effect on Al concentration in the oak plots was not clear (Fig. 2B). However, Al concentration in the pine plots tended to decrease as a result of liming. Soil Al concentrations in the 0~5 cm layer was greater in the 1.5 t and 3 t plots than in the control plot in the pine forest in 1994 (Fig. 2A). The greater Al concentration in the limed plots in the pine forest in 1994 may be related to the variations between the plots and/or the result from the increase in Al concentration at the initial stages of liming (Rhyu 1994, Lee et al. 1998). Lee et al. (1998) observed an increase in Al levels during the first three weeks of dolomite treatment on a forest mineral soil.

Two years after liming, there was a change in the differences in Al concentrations between the plots in the present study. Although the Al concentration in the 0~5 cm layer was greater in the 1.5 t plot than in the control plot in the pine forest in 1994 by 31%, it was greater in the control plot than in the 1.5 t plot in 1995 by 8%. Al concentration in the 0~5 cm layer was also greater in the 3 t plot than in the control plot by 103% in 1994, however, the difference between the control and 3 t plot was reduced in 1995. Al concentration was greater in the 3 t plot than in the control plot by 29% in 1995. This result indicates a tendency of a decrease in Al concentrations in the pine plots. Curtin and Smillie (1986) found a significant reduction in Al concentrations in the top 15 cm of soil 16 years after lime application at doses of 4.2~12.5 t/ha. They suggested that liming can affect Al concentrations in soil by precipitating free Al and by increasing organically complexed Al.

Fe concentrations in the 0~5 cm and 5~10 cm layer in the limed plots were lower than those in the control plots in both the pine and oak forests in 1994 (Fig. 2C and 2D). However, the effect of liming on soil Fe concentration was not clear because the differences of Fe concentrations in the 0~5 cm layer between the control and the 1.5 t plots decreased but those between the control and the 3 t plots increased in the oak forest from 1994 to 1995.

Mn concentration in soil appeared to decrease as a result of liming. Soil Mn concentration in the 0~5 cm layer was greater in the 1.5 t and 3 t plots than in the control plot in the pine forest in 1994 by 22% and 178%, respectively (Fig. 2E). Two years after liming, the Mn concentration in the 0~5 cm layer in the control plot was 109% greater than that in the 1.5 t plot and it was 70% lower than that in the 3 t plot in 1995, indicating a reduction in the Mn concentrations in the limed plots in the pine forest. Kreutzer (1995) reported that the Mn concentration in the 0~5 cm layer of soil in the limed plot was 88% lower than that in the control plot. The tendency of a decrease in Mn concentration was also found in the 3 t plot in the oak plot, although the degree of a reduction was not profound. In the oak plots, the Mn concentration in the 3 t plot was 17% greater than that in the control plot in 1994, however, no
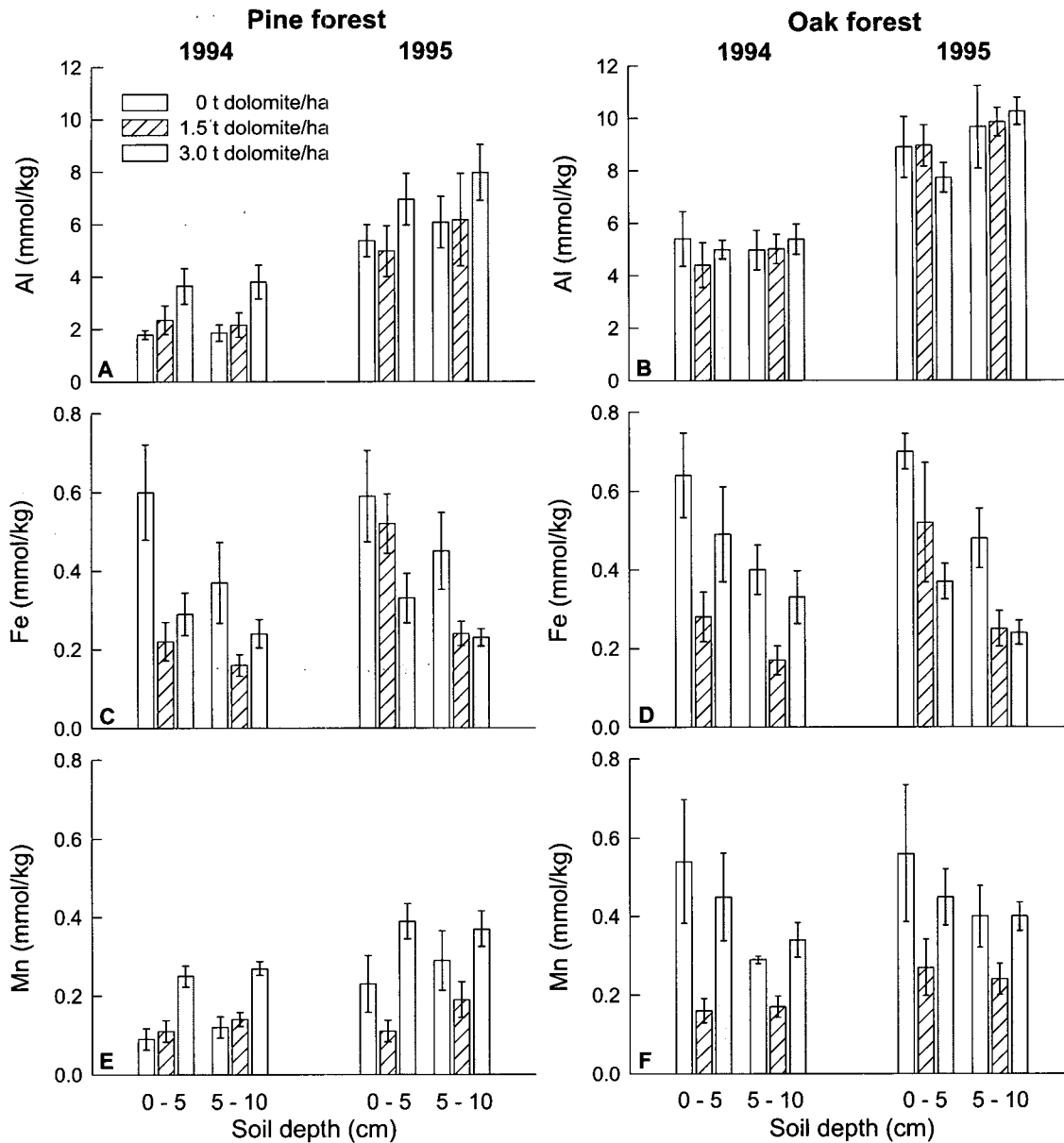
Fig. 2. Changes in exchangeable Al, Fe and Mn (mmol/kg) in soil in control and limed plots in a pine forest (A, C and E) and an oak forest (B, D and F) from 1994 to 1995 in Mt. Kwanak. Data are means±standard errors.

difference was found between the plots in 1995 (Fig. 2F). A decrease in Mn concentration as a result of liming has been suggested to be caused by precipitation of Mn^{2+} as one of the Mn(IV) oxides (Curtin and Smillie 1986).

ACKNOWLEDGEMENT

LITERATURE CITED

Bouyoucos, G.J. 1962. Hydrometer method improved for making particle size analysis of soils. Agron. J. 54: 464-465.

Brady, N.C. 1990. The Nature and Properties of Soils. Macmillan Publishing Company, New York.

Burke, M.K. and D.J. Raynal. 1998. Liming influences growth and nutrient balances in sugar maple (*Acer saccharum*) seedlings on an acidic forest soil. Env. Exp. Bot. 39: 105-116.

Côté, B., I. O'Halloran, W.H. Hendershot and H. Spankie. 1995.

Possible interference of fertilization in the natural recovery of a declining sugar maple stand in southern Quebec. Plant Soil 168-169: 471-480.

Curtin, D. and G.W. Smillie. 1986. Effects of liming on soil chemical characteristics and grass growth in laboratory and long-term field-amended soils. I. Soil chemistry. Plant Soil 95: 15-22.

Demchik, M.C. and W.E. Sharpe. 2001. Forest floor plant response to lime and fertilizer before and after partial cutting of a northern red oak stand on an extremely acidic soil in Pennsylvania, USA. For. Ecol. Manage. 144: 239-244.

Ingerslev, M. 1997. Effects of liming and fertilization on growth, soil chemistry and soil water chemistry in a Norway spruce plantation on a nutrient poor soil in Denmark. For. Ecol. Manage. 92: 55-66.

Johnson, D.W. 1987. A discussion of the changes in soil acidity due to natural processes and acid deposition. In T.C. Hutchinson and K.M. Meema (eds.), Effects of Atmospheric Pollutants of Forests, Wetlands and Agricultural Ecosystems. Springer Verlag, Berlin. pp. 333-345.

Kim, C.-G. 1996. Changes of Chemical Properties of Soil and Soil Solution and Responses of Ectomycorrhizal and Saprophytic Basidiomycetes by Dolomitic Liming on Acid Soil. M. Sc. thesis, Seoul National Univ., Seoul (in Korean with English abstract).

Ko, S.B. and C.C. Choung. 1991. Effects of lime and phosphate applications on physical and chemical properties of soil, and forage productivity in volcanic ash soil of Cheju Island. I. Effects of lime and phosphate applications on physical and chemical properties of soil. Korean J. Anim. Sci. 33: 322-331 (in Korean with English abstract).

Kreutzer, K. 1995. Effects of forest liming on soil processes. Plant Soil 168-169: 447-470.

Lee, C.-S., J.-Y. Kim and Y.-H. You. 1998. Amelioration of soil acidified by air pollutant around the industrial complexes. Korean J. Ecol. 21: 313-320.

Lee, J.K., S.S. Lee, W.L. Youn and K.J. Park. 1990. Effect of nitrogen and lime application at the seeding time on the soil properties, weeds development, dry matter yield and nutritive value in alfalfa meadow. Korean J. Anim. Sci. 32: 635-641 (in Korean with English abstract).

Lundström, U.S., D.C. Bain, A.F.S. Taylor and P.A.W. Van Hees. 2003. Effects of acidification and its mitigation with lime and

wood ash on forest soil processes: a review. Water, Air, and Soil Pollut. Focus 3: 5-28.

Magdoff, F.R. and R.J. Bartlett. 1980. Effect of liming acid soils on potassium availability. Soil Sci. 129: 12-14.

Matzner, E., P.K. Khanna, K.J. Meiwes and B. Ulrich. 1985. Effects of fertilization and liming on the chemical soil conditions and element distribution in forest soils. Plant Soil 87: 405-415.

Mayr, R. 1998. Soil acidification and cycling of metal elements: cause effect relationships with regard to forestry practices and climatic changes. Agr. Ecosys. Environ. 67: 145-152.

Mun, H.-T., B.-K. Park and J.-H. Kim. 1997. Response of plants and changes of soil properties to added acid soil ameliorants. Korean J. Ecol. 20: 43-49 (in Korean with English abstract).

Park, Y.S. 1974. Studies of liming effect on the improvement of an acid sulphate paddy soil. J. Kor. Agric. Chem. Soc. 17: 193-218 (in Korean with English abstract).

Rhyu, T.-C. 1994. Mechanism and recovery of Pinus rigida forest decline by acidic deposition in the metropolitan area of Seoul, Korea. Ph. D. thesis, Seoul National Univ., Seoul (in Korean with English abstract).

Rhyu, T.-C. and J.-H. Kim. 1994a. Cation deficiencies in needles and fine roots of pitch pine in Seoul metropolitan area. Korean J. Ecol. 17: 277-286.

Rhyu, T.-C. and J.-H. Kim. 1994b. Growth decline of pitch pine caused by soil acidification in Seoul metropolitan area. Korean J. Ecol. 17: 287-297.

Schulze, E.-D. 1989. Air pollution and forest decline in a spruce (Picea abies) forest. Science 244: 776-783.

Sikström, U. 2001. Effects of pre-harvest soil acidification, liming and N fertilization on the survival, growth and needle element concentrations of Picea abies L. Karst. seedlings. Plant Soil 231: 255-266.

Ulrich, B. 1983. Soil acidity and its relations to acid deposition. In B. Ulrich and J. Pankrath (eds.), Effects of Accumulation of Air Pollutants in Forest Ecosystems: Proceedings of a Workshop held at Göttingen, West Germany, May 16-18, 1982. D. Reidel Publishing Company, Dordrecht. pp. 127-146.

Yoo, J.-H., J.-K. Byun, C. Kim, C.H. Lee, Y.-K. Kim and W.-K. Lee. 1998. Effects of lime, magnesium sulfate, and compound fertilizers on soil chemical properties of acidified forest soils. J. Kor. For. Soc. 87: 341-346 (in Korean with English abstract).