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Release of carbon and nitrogen from decomposing roots of red clover as affected by liming of soil

MICHAEL M. MÜLLER[1] and BJÖRN BERG[2]
[1]*Department of General Microbiology, University of Helsinki, Mannerheimintie 172, SF-00280 Helsinki 28, Finland and* [2]*Section of Forest Ecology, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, S-750 07 Uppsala, Sweden*

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Abstract

Red clover root material confined in mesh bags was buried in three different limed and unlimed soils and incubated for 196 days at room temperature. Remaining amounts of organic matter, as well as concentrations of C and N of the decomposing material were determined three times during the incubation and finally the concentration of soil mineral N and pH of remaining roots was also assessed.

Liming only temporarily affected the decomposition rate of organic matter and N release, and at the end of the incubation no effects could be observed due to liming. A possible explanation is that the decomposing root residues provide a well buffered micro-environment for the decomposing microflora. Liming did not change the pH of the root residues even when 97–98% of dry mass had disappeared from the mesh bags.

Concentrations of mineral N were higher in limed than in unlimed soils.

Introduction

The net mineralization rates of carbon (CO_2 emission) often increase for at least short time periods of some weeks or months after liming of acid agricultural soils (Frercks and Kosegarten, 1956; Jackman, 1969; Kappen *et al.*, 1949), and it is a general belief that organic matter decomposes more rapidly in neutral soils than in acid soils (Foy, 1984). In experiments lasting for several years the effect of liming on decomposition rates may level off, as can be seen from the results of Turk and Millar (1936) and Frercks and Kosegarten (1956).

Rates of net mineralization of N (accumulation of $NH_4^+ + NO_3^-$) can also be increased by liming of agricultural soils (Cornfield, 1952; 1959; Edmeades *et al.*, 1981; Nyborg and Hoyt, 1978), although the opposite has also been found (Nnadi and Balasubramanian, 1978). In their review on organic N mineralization Harmsen and van Schreven (1955) conclude:'. . . generally liming of acid soils was found to have a stimulating effect on the mineralization of humus nitrogen.'

Liming may, however, affect several soil processes, which makes it difficult to interpret results correctly from measurements of organic matter mass loss or net mineralization of C and N. The rates of organic matter mass loss and net mineralization of C and N are affected by the efficiency of biological assimilation going on within and outside the decomposing material concomitantly with the decomposition processes. Thus, a change in the organic matter mass loss rate or net mineralization rates of C and N may be caused by changes either in rates of assimilation or actual mineralization, or both. Regarding N the possiblility of denitrification, leaching and chemical immobilization has also to be considered. Consequently, our knowledge about effects of liming on different turnover processes of C and N in soil will be poor if only net mineralization studies are emphasized.

In order to gain more information about the effects of liming on turnover of C and N in soil a laboratory experiment was conducted with red clover root material in three different soils using mesh bags. This enabled the release of C and N (= net disappearance of C and N from decomposing plant material within mesh bags) to be followed. In contrast to net mineralization of C and N, the rate of release of C and N from plant material is not affected by their fate outside the decomposing material. Hence, the mesh bag method differs essentially from those methods used earlier in studies on the effects of liming on decomposition processes.

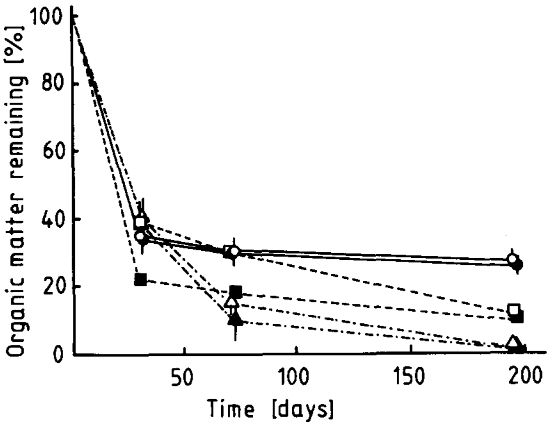

Fig. 1. Remaining amount of organic matter (expressed as percent of input) of decomposing red clover root material in three different limed or unlimed soils at 22°C and a moisture of pF 2–3.
(□) sandy loam, (■) sandy loam limed
(○) silt loam, (●) silt loam limed
(△) clay loam, (▲) clay loam limed
Vertical bars show standard deviation, n = 20–37.

Materials and methods

Collection, preparation and apportioning of red clover roots into mesh bags, incubation procedure, sampling and analysis were carried out as described earlier (Berg *et al.*, 1987). In the present study only thin roots (diameter below 1 mm) were used. The root layer within the mesh bags was at maximum 3 mm thick. The soils were collected from agricultural fields in Southern Finland, and their characteristics are given in Table 1. The clay loam was collected from two adjacent field plots one of which had been limed two years before with 6.3 metric tons/ha of $Ca(OH)_2$. both these plots had been cultivated with red clover. Part of the sandy loam was limed with 3 g and part of the silt loam with 4 g $Ca(OH)_2$ per kg of dry soil prior to the preincubation of three weeks. At the end of the experiment concentrations of $NH_4^+ + NO_3^- + NO_2^-$ in the soil were determined by steam distillation of KCl-extracts as described by Keeney and Nelson (1982).

Results and discussion

Liming increased the rate of organic matter mass loss of red clover roots only transiently in sandy loam, and at the end of the incubation no differences could be observed between any limed and corresponding unlimed control (Figure 1). Liming had finally no effect on residual amounts of C within litter bags (Table 2). Despite methodological differences, our results support those of Jenkinson (1977).

The pattern of N release from the root remains (Figure 2) was similar to that of organic matter mass loss. The release of N was, however, slower and the C/N decreased considerably during the incubation (Table 2). Only in clay loam the C/N of the material incubated appeared to differ depending on liming; those values, however, were uncertain, since the amount of organic material within the mesh bags had decreased to about 1.6–2.3% of the intial amount, and at such low remaining amounts a large proportion of the material may have been fungal mycelium (Berg *et al.*, 1987; Wess-

Table 1. Some characteristics of the experimental soils

Soil	Particle-size fractions (%)			C	N	pH (H_2O)	
	Diameter (mm)			(%)	(%)	unlimed	limed
	> 0.02	0.02–0.002	< 0.002				
Sandy loam	81	13	6	1.8	0.11	5.1	6.4
Silt loam	49	35	16	2.4	0.13	4.3	6.2
Clay loam	48	20	32	4.6	0.30	5.0	6.2

Table 2. Amount of C (given as percent of input), C/N and pH of red clover roots initially and remaining after decomposition in three limed and unlimed soils

Variable	Soil liming	Initial	At the end of incubation		
			Sandy loam	Silt loam	Clay loam
C (%)	–	100	15	32	3
	+	100	16	33	2
C/N	–	26	11	11	18
	+	26	9	11	13
$pH(H_2O)$	–	5.2	5.5	5.7	5.7
	+	5.2	5.4	5.8	5.8

en and Berg, 1986) and additionally contaminated by soil organic material. the corresponding C/N values of samples taken after 71 days of incubation were 19 for the material both in limed and unlimed soil (values not given in Tables), suggesting that liming of clay loam caused no variation in the C/N of the decomposing material.

Since the concentration of N of the decomposing material was comparatively high during the whole incubation period, it is unlikely that significant amounts of N have been transferred from the soil into the mesh bags or that atmospheric N_2 has been fixed by decomposing bacteria (Müller *et al.*, 1988). The application of mesh bags has probably not affected the minerlization of the root material, since in previous investigations with ^{15}N-labelled clover materials no differences could be found between the fate of N from material confined within or

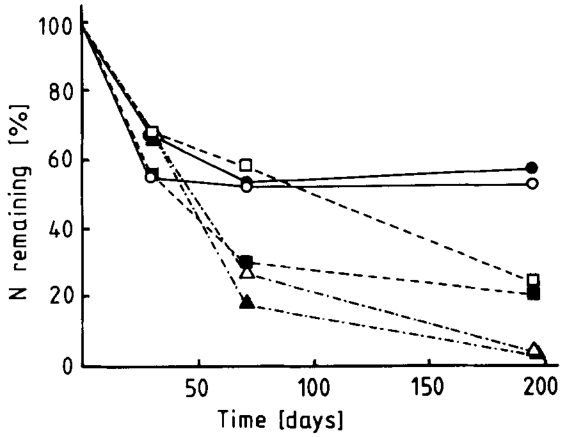

Fig. 2. Remaining amount of nitrogen (expressed as percent of input) of decomposing red clover roots in three different limed or unlimed soils at 22°C and a moisture of pF 2–3. *Symbols* as in Fig. 1.

placed without mesh bags in soil (Müller, 1987; Müller and Sundman, 1988).

In this investigation the pattern of organic matter mass loss and N release from the root material showed variation dependant on the type of soil studied, and it appears as if soil type is a more important factor than liming regarding decomposition processes of recently introduced organic matter. The patterns in the sandy loam and the clay loam (Figures 1 and 2) differed from that in the silt loam, which showed extremely low rates of organic matter mass loss and N release after an early phase of high rate of decomposition. This kind of decomposition pattern had been observed earlier in certain environments. Howard and Howard (1974) and Uvarov (1982) observed such an asymptotic decomposition pattern with leaf litter when fauna was excluded, and Wieder and Lang (1982) with decomposing tall fescue (*Festuca elatior*) litter in a nonvegetated surface mine soil. The frequent wetting under our experimental conditions caused some dispersion of the soil and consequently decreased aeration especially in the silt loam soil, which may have caused anaerobic conditions and which in turn may have affected the decomposition rate of the lignin-rich remains. This soil contains high amounts of fine silt (0.02–0.002 mm), this fraction is known to increase susceptibility of the soil.

Liming, although raising soil pH by 1.2–1.9 units, had no effect on the pH of the decaying root material, even when only 2–3% of the material remained (Table 2). The observation that rates of organic matter mass loss and N release were independent of liming and consequently of the increased pH may be due to the decomposing material being a well-buffered micro-environment. In practical agriculture plant roots remain separated in the soil even after plowing, and are in a better contact with the surrounding soil than the material within our mesh bags. The diameter of a red clover main root, however, often exceeds the root layer thickness of the mesh bags (the latter being $\leqslant$ 3 mm).

Despite the fact that liming had no effect on the net release of N from the decaying root material it did affect the amounts of mineral N in soil KCl-extracts at the end of the experiment. These differences were attributable to differences in absolute amounts of NO_3^- + NO_2^-. The amounts were distincly higher in limed soils than in the unlimed soils

Table 3. Concentrations of mineral N ($\mu g\, g^{-1}$) in soil (KCl-extract) after incubation of red clover root residues for 196 days at 22°C and a moisture of pF 2–3

		Soil		
N compound	Soil liming	Sandy loam	Silt loam	Clay loam
NH_4^+	–	5	6	11
	+	1	6	11
$NO_3^- + NO_2^-$	–	23	53	101
	+	45	73	174
Sum	–	28	59	112
	+	46	79	185

(Table 3), the results being consistent with those of Cornfield (1952; 1959), Nyborg and Hoyt (1978) and Edmeades *et al.* (1981). It is possible that liming accelerated the mineralization of indigenous soil nitrogen, but also a change in the rate of assimilation by microbes and the rate of chemical immobilization may have taken place. The latter process has been suggested to proceed at a higher rate at higher pH (Nömmik and Vahtras, 1982). The results emphasize the difference between net mineralization of N as compared to N release from newly added organic matter.

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