NITROGEN MINERALIZATION FROM CLOVER LEAVES: EFFECT OF SOIL TYPE AND LOW TEMPERATURE

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Objectives

The period following the incorporation of N-rich leys into soil is crucial both for the N supply to the following crop and for the risk of N leaching. Soil-crop models used for exploring the possibility of improving the nitrogen recovery, generally assume that there is a stoichiometric relationship between carbon and nitrogen mineralization. Our aim was to study how temperature and soil type affect the net N mineralization relative to C mineralization of plant litter incorporated in soil. This knowledge is instrumental for improving the modelling of nitrogen dynamics after ploughing. Our hypotheses were:

1. Rapid N mineralization from N-rich plant material occurs even at 0 °C.
2. The ratio of net mineralized N to mineralized C from N-rich plant material is larger at lower than at higher temperature.
3. The ratio of net mineralized N to mineralized C from N-rich plant material is not affected by soil type

Method

A silty clay loam (27% clay, 3% sand) and a sandy loam (6% clay, 51% sand) from two fields with equivalent weather and cultivation history, were incubated at constant 0, 4, 8.5 and 15 °C for 80 days, alone or with incorporated dried red clover leaves (4.8% N. 4 g leaves dry matter kg^{-1} dry soil). The leaves were labelled with ^{13}C (2.29 atom percent). The soils had been sieved through a 2 mm mesh while moist and pre-incubated in the dark for 4 ½ months at about 15 °C under aerobic and moist conditions. The soils were further moistened to 75% of the pore volume at field bulk density and kept for three days at the final temperature before incorporation of the clover leaves.

The net N mineralization was studied in soil samples equivalent to 50 g dry soil placed in 200 ml jars with the lids left loose, to allow some aeration. At each sampling date, replicates were sampled destructively as the whole sample was extracted with KCl, and analysed for NH_4-N and NO_3-N content. The C mineralization was measured in gas tight 1 l chambers containing soil equivalent to 400 g dry soil. A NaOH solution in a plastic tube placed in the middle of the chamber was used to trap the CO_2. The atmosphere of the chamber was monitored and oxygen was added when needed. Sampling was performed after 24 hours, and on days 3, 8, 15, 30, 52 and 80. Within each temperature, three replicates were used for CO_2 analyses and four replicates for mineral N analyses.

The C mineralization rate k was estimated, assuming first order decay, as $k = -\ln([C]/[C_0])/t$ for the period when the slope of the decay curve was close to a straight line ($R^2 \geq 0.98$), where C_0 is the initial C amount in the substrate, and C is the remaining substrate at sampling time t.

For N a similar analytical approach was not possible.

Results

Carbon and N mineralization occurred even at 0 °C. The rate of C mineralization increased with temperature, as expected. For the soil organic matter and for the initial decomposition of leaves the effect of temperature was well described by Arrhenius-like equations. Soil type affected the rate of soil organic C mineralization, which was twice as fast in the sandy loam as in the clay loam. Contrary to our expectation, soil type affected also the C mineralization of the incorporated leaves, which was faster in the sandy loam.

During the 80 days incubation period the total N mineralization from soil organic matter alone was negligible. We can rule any important loss by denitrification (methods and data not shown). Of the N added with clover leaves, only 13-22% was mineralized, and about half of this was mineralized already during the first few (3 to 8) days. Particularly the mineralization during the first three days was most rapid and it was not affected by temperature. Subsequently, this short but rapid mineralization period was followed by a phase of slow net N mineralization in the sandy loam, and net N immobilization in the silty clay. During this phase, the effect of temperature was weak and irregular in the sandy loam, while immobilization increased with temperature in the silty clay. Only from the sampling on day 52, the net N mineralization from clover leaves increased over all the temperature range of the experiment.

The ratio of inorganic N to mineralized C from clover leaves varied during the experiment: It was remarkably high in the first sampling, then decreased and reached a minimum on day 30. During these 30 days, there was a marked and well-delineated effect of temperature on the N/C ratio. Thus, the N mineralization relative to C mineralization was stronger at 4 °C, and especially at 0 °C, than at higher temperatures. Thereafter, at the last two sampling dates (day 52 and 80) the N/C ratio converged and remained approximately constant (about 0.053), unaffected by temperature and soil type. Thus, only during the last 30 days of incubation there was a clear correlation between net N and C mineralization from the leaves, while in the first 30 days of incubation the ratio of net mineralized N to mineralized C from clover leaves was large at lower temperature, as hypothesized. It was not clear from the data whether soil type modified the N/C ratio in the early period.

These results can be explained by a stronger inhibition of the microbial growth compared to gross mineralization of the plant residue as temperature decreases and approaches 0 °C, leaving a larger share of the gross mineralized N available in the soil solution.

Conclusions

The experiment confirmed that N mineralization of N-rich plant material occurs even at 0 °C, and that the ratio of net mineralized N to mineralized C is larger at lower than at higher temperature.

The results of this study cannot be properly predicted by decomposition models that do not account for the little correspondence between net N and C mineralization the first month after incorporation of N-rich plant residue. The modelling could probably be improved by modifying the response of the microbial growth to temperature. For prediction in a relatively cold environment in transition to warmer temperature, as e.g. after spring incorporation of a ley before sowing a new crop, an erroneous modulation of the temperature effect relative to a parameterization at 15 or even 20 °C is likely to result in an overestimation of N mineralization, particularly on clayey soils. For prediction of ley mineralization after late autumn ploughing, it is likely to underestimate the N mineralization during the first part of the winter. As nitrification was delayed at the lower temperatures, and ammonium is less prone to leaching than nitrate is, it is not sure whether this model inadequacy would result in an underestimation of the risk of leaching shortly after ploughing in late autumn.

More knowledge of how low temperature affects soil biology, and especially microbial growth, is needed for improving prediction of the net N mineralization of newly incorporated plant material.

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