IMPROVING NITROGEN RECOVERY FROM GREEN MANURE ON CONTRASTING SOIL TYPES UNDER COLD CLIMATE CONDITIONS

Objectives

To improve the N recovery from grass-clover green manure on contrasting soil types under cold climate conditions. Mineralization shortly after incorporation of the green manure in the soil in early spring is particularly important in this respect. Specific objectives within this scope were to:

- evaluate the effects of various strategies for green manure management, including biogas production and using the herbage-based digestate as fertilizer, on the yield and N recovery of a subsequent spring barley crop.
- estimate the effects that low temperature and soil type have on N and C mineralization of N-rich plant residue.

Materials and methods

In order to evaluate various green manure herbage strategies, a three-year field experiment was run in Norway at four locations with contrasting soil types. The first year, a green manure of 20% red clover and 80% grasses was established as a ley, undersown in spring barley. The second year, the green manure was cut three times, and the herbage was either removed or chopped and left on the stubble (mulched). In the following spring, green manure was ploughed and barley was sown, either unfertilized or fertilized with digestate (11 g N m^{-2}). The amount of N in the applied digestate represented about 45% of the N in the harvested herbage. A control treatment with repeated cereal cropping was also included; unfertilized spring barley the first year, unfertilized spring oats the second year, and spring barley fertilized with either digestate (11 g N m^{-2}) or inorganic fertilizer (8 g N m^{-2}) the third year.

Soil from two of the field trial locations with equivalent weather and cultivation history, a silty clay loam and a sandy loam, were also used in an incubation experiment to study the effect of low temperature and soil type on C and N mineralization from soil organic matter and added clover leaves. Soil with or without dried red clover leaves (4 g dry matter kg^{-1} dry soil) were incubated at constant 0, 4, 8.5 and 15°C for 80 days. Sampling was performed after 24 hours, and on days 3, 8, 15, 30, 52 and 80.

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. The four replicates were sampled destructively as the whole sample was extracted with KCl, and the amounts of NH_4-N and NO_3-N were analysed. Simultaneously, the C mineralization was measured in gas tight 1 l chambers containing soil equivalent to 400 g dry soil. There were three replicates within each temperature. A NaOH solution in a plastic tube placed in the middle of the chamber was used to trap CO_2.

Results and discussion

The field experiment showed in general that the grain yields of spring barley (dry matter and N) sown after the green manure were in the following order: herbage removal ≤ herbage digestate without green manure ≤ herbage mulched ≤ herbage removal and digestate application ≤ inorganic fertilizer without green manure [1]. Depending on the site, removal of green manure herbage reduced the barley grain yield by nil to 33%, compared to leaving it on-site. Herbage removal reduced the yields mostly on the two sites with sandy loam.

Applying digestate as fertilizer for barley gave the same yields as those when all herbage had been mulched the preceding season. The removal of the herbage and application of digestate increased the recovery in the barley crop of the N present in the herbage at the time of the three cuttings. Overall, the apparent N recovery was enhanced from 7% when all herbage was mulched, to 16% when approximately 50% of it was returned as digestate.

Relatively little of the total plant N was mineralized either in the field or in the laboratory experiment, yet noticable amounts of net mineralized N were observed below 5°C in both investigations. At the end of the incubation, net mineralization was only 13–22% of the N added with clover leaves, and about half of this was mineralized already the first few days. This rapid initial mineralization was unaffected by temperature.

Subsequently the short 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. The immobilization was greater at higher than at lower temperatures, and also the ratio between mineralized N and C was higher at low temperatures than at high temperatures during the first weeks of decomposition. A net immobilization in the silty clay loam in late spring after ploughing the green manure may also contribute to the low barley yields on clay loam compared to those on the sandy loam, which we found under field conditions.

The incubation of clover leaves in the two soil types showed delayed nitrification at the lower temperatures, which may reduce the risk of N leaching, as ammonium is less prone to leaching than nitrate.

Conclusion

Of the various green manure herbage measures tested, the digestate strategy was be the most promising option with regard to reduced risk of N losses and improved N recovery by a subsequent spring barley crop. Removal of the herbage reduces the risk of N losses from the crop rotation, since such losses are highly dependent upon the N input and weather conditions. Nevertheless, removal of the herbage without any fertilizer application to the subsequent crop is not recommended, unless the soil is very fertile. Cost-efficient and practical solutions are needed for running small herbage-based biogas plants under cold climate conditions.

Our results show that at low temperatures N mineralization is not simply a function of C mineralization. If soil-crop models fail to simulate the short-term dynamics of N mineralization from easily decomposable plant material under low temperatures, this can lead to erroneous estimates of N leaching and early N supply to the succeeding crop. This study suggests that fundamental model changes are needed for simulating the effects of low temperatures on N mineralization from fresh plant material.

References

[1] Frøseth, R. B., Bakken, A. K., Bleken, M. A., Riley, H., Pommeresche, R., Thorup-Kristensen, K., Hansen, S. 2014. European Journal of Agronomy 56, 90-102