Nitrogen mineralization and greenhouse gas emissions after soil incorporation of ensiled and composted grass-clover as green manure

M.S. Carter[1], P. Sørensen[2], S.O. Petersen[2] and P. Ambus[1]

[1] *Centre for Ecosystems and Environmental Sustainability, Department of Chemical and Biochemical Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark (mthy@kt.dtu.dk),* [2]*Department of Agroecology, Aarhus University, Blichers Alle 20, 8830 Tjele.*

Implications

Main conclusions and recommendations: This 3-month incubation study showed that ensiled grass-clover was a better nitrogen (N) source than a composted grass-clover and straw mix (grass-clover:straw, 4:1, w:w), owing to the high content of labile compounds compared to the more degraded compost. Our study also indicated that emissions of the strong greenhouse gas nitrous oxide (N_2O) can be reduced by incorporating green manure using harrowing instead of ploughing. The silage-derived N release by the end of the incubation was equivalent to 38-42 kg N ha^{-1}, which corresponded to one third of the N applied in silage, with no difference between ploughing and harrowing. In contrast, no net release of mineral N was detected from the composted grass-clover.

Expected importance and impact: These results are important for organic arable crop producers, who depend on nitrogen input to their farming systems via biological N_2 fixation in leguminous green manure crops. Organic arable farming faces challenges with low crop yields, partly due to inefficient use of green manure-derived N, which also leads to significant environmental N losses with negative implications for aquatic ecosystems and the global climate. Our results suggest a way to improve green manure nutrient management in order to 1) increase yields of cash crops in organic rotations, and 2) reduce the environmental impact of arable organic farming.

How we contribute to solve the problem: In this experiment, we test a new green manure management strategy as part of the ICROFS project HighCrop. Under current farming practices, green manure leys are often cut and mulched during the growing season with the associated risk of N losses to aquifers and atmosphere. With the new strategy evaluated here, green manure leys are instead harvested and preserved until the following spring either as compost mixed with straw or silage of harvested ley biomass. In spring, these two green manure materials can then be used for targeted fertilization of spring sown crops.

Background and objectives

In this study, the objectives were to:

- Compare composted and ensiled grass-clover green manures concerning their abilities to provide nitrogen for a growing crop during a 3-month period. We expected faster N mineralization from silage because of its high content of labile compounds and lower C/N ratio compared to the more degraded grass-clover and straw compost.
- Determine whether N mineralization from the two materials is influenced by soil incorporation method, more specifically harrowing (simulated by mixing the material into the top 5 cm soil layer) and ploughing (the material placed at 15 cm depth). We expected that harrowing would result in the largest N release, because decomposing microorganisms had better access to the plant material when mixed into the top soil rather than being placed in a layer in the simulated ploughing treatment.
- Assess the N loss via soil emissions of the strong greenhouse gas, N_2O. We expected that ploughing would lead to higher N_2O emissions due to the development of oxygen-limited conditions around the decomposing materials, which could stimulate N_2O production via denitrification.

Key results and discussion

Mineralization of green manure-derived N started more than three weeks after incorporation of the materials (Fig. 1). As expected, grass-clover silage provided the highest N mineralization with a total N release corresponding to 38-42 kg N ha^{-1} over the 3-month period, irrespective of the incorporation method used. In contrast, no increase in soil mineral N was observed for the composted grass-clover and straw mixture compared to the unfertilized control soil. In fact, soil incorporation of compost by harrowing caused immobilization of soil mineral nitrogen 1-2 months after experimental set-up (Fig. 1). Thus, overall we had to reject the hypothesis that harrowing would stimulate N mineralization more than ploughing.

Generally, N_2O emissions were higher from the silage-amended soils than from soils fertilized with compost. Especially, silage incorporated by ploughing gave rise to increased N_2O effluxes, corresponding to 0.4 % of applied total N during the 3-month period. In contrast, compost incorporated by harrowing stimulated a downwards N_2O flux into the soil, presumably an effect of lacking mineral N availability in this treatment. Thus, we were right in the hypothesis that ploughing would stimulate highest N_2O effluxes.

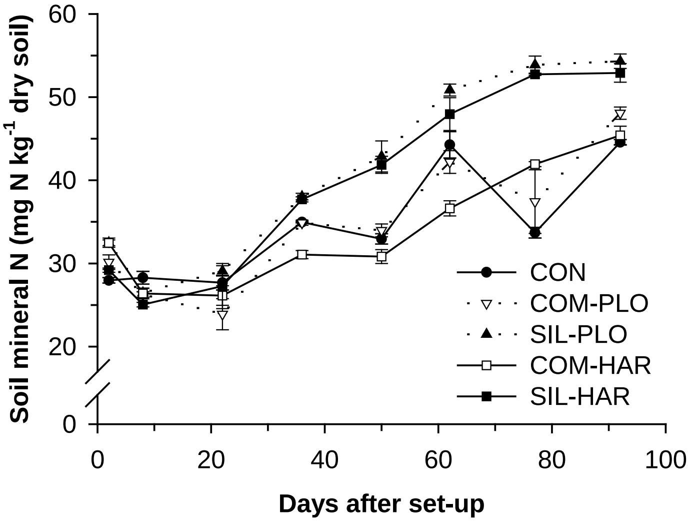

Fig. 1 Soil mineral N after incorporation of grass-clover compost (COM) and silage (SIL) by either simulated ploughing (PLO) or harrowing (HAR) compared to an unfertilized control soil (CON) in a 92-day incubation experiment at 15 °C (means ± SE; n = 4)

How work was carried out?

The experimental design included eight sets of 20 soil units, each consisting of a 28 cm long × 10 cm diameter PVC pipe. Each unit was sealed at the bottom by a ventilated plastic cap, and was gradually filled with 25 cm of soil to obtain a consistent bulk density. For the ploughing simulation, a portion of green manure was placed in the unit before the upper 15 cm soil layer was established. For the harrowing simulation, a green manure portion was homogeneously mixed into the upper 5 cm soil layer. The addition of compost and silage corresponded to a fertilization rate of 12 g total N m^{-2}. All 160 soil units were incubated at 15 °C in darkness.

On eight occasions, N_2O emissions were measured from a set of soil units using a photoacoustic gas analyzer coupled sequentially to 20 static gas-flux chambers each containing a soil unit (Johansen et al., 2013). Destructive soil sampling occured the day after gas-flux measurement and a representative subsample of the 0-25 cm soil profile was analysed for ammonium and nitrate contents.

References

Johansen A, Carter MS, Jensen ES, Hauggaard-Nielsen H and Ambus P 2013. Effects of digestate from anaerobically digested cattle slurry and plant materials on soil microbial community and emission of CO_2 and N_2O. Appl. Soil Ecol., 63: 36-44.