Effects of green manure storage and incorporation methods on greenhouse gas fluxes and N mineralization after soil application

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Organic arable farming faces challenges with low crop yields, partly due to inefficient use of green manure-derived nitrogen (N). Under current farming practices, green manure leys are often cut and mulched during the growing season with the associated risk of environmental N losses, leading to eutrophication and global warming. In this 3-month incubation experiment, we tested a new green manure management strategy as part of the ICROFS project HighCrop. With the new strategy, green manure leys are instead harvested and preserved until the following spring either as compost mixed with straw (grass-clover:straw, 4:1, w:w) or as silage of harvested ley biomass. In spring, these two green manure materials can then be used for targeted fertilization of spring sown crops. The objectives of the study were to:

- Assess how storage methods (compost vs. silage) affect N_2O fluxes and soil respiratory CO_2 emissions after soil application of preserved grass-clover green manure.
- Determine whether the greenhouse gas fluxes are influenced by the 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).
- Compare composted and ensiled green manures concerning their abilities to provide plant-available N during a 3-month period.

During the experiment, gas fluxes were measured at nine occasion followed by eight destructive soil harvests. In total, the study included 192 soil units that were incubated at 15 °C in darkness. Each unit consisted of a packed soil core (26 cm high × 10 cm diameter) with bulk density of 1.07 g cm^{-3} and gravimetric soil moisture of 20 %. The addition of compost and silage corresponded to a fertilization rate of 120 kg total N ha^{-1}. A mineral fertilizer treatment was included as a reference and received 80 kg NH_4-N ha^{-1}.

Compared to the more degraded compost, the silage material had a high content of labile compound. In addition, incorporation of green manure by harrowing was expected to improve soil microbes' access to the materials, and thereby increase the decomposition rate. In line with this, cumulative CO_2 emissions from the green manure treatments was lowest for compost incorporated by ploughing and highest for silage incorporated by harrowing. Between 32 and 54 % of the added green manure carbon was respired as CO_2 during the 3-month experiment. Interestingly, mineral fertilizer suppressed soil respiratory CO_2 emission.

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 0.3 % of applied total N during the 3-month period. This could partly result from denitrification of initial soil nitrate, stimulated by high local oxygen consumption in the labile silage layer. In contrast, compost incorporated by harrowing caused a downwards N_2O flux into the soil, presumably an effect of lacking mineral N availability in this treatment. Overall, our study showed that emissions of N_2O can be reduced by incorporating green manure using harrowing instead of ploughing.

Net mineralization of green manure-derived N was absent until more than three weeks after incorporation of the materials. Over the 3-month experiment, grass-clover silage provided the highest net release of inorganic N with preliminary results corresponding to 38-43 kg N ha^{-1}, 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.