Production of N_2O in grass-clover pastures

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ABSTRACT: The aim of this project is to increase the knowledge of the biological and physical-chemical mechanisms, which control the production of N_2O in grazed grass-clover pastures.

1 INTRODUCTION

Nitrous oxide (N_2O) accounts for 6 % of the present greenhouse forcing rate ascribed to anthropogenic derived gases, and agriculture contribute with about half of the anthropogenic N_2O emission (Houghton et al. 2001). The major part of whole farm emissions originates from the soils. Bacterial processes of nitrification and denitrification appear to be the dominant sources of N_2O (Firestone & Davidson 1989) (Fig. 1). The level of soil inorganic nitrogen influences the rate of emission. Therefore organic farming has been suggested as a means to reduce agricultural N_2O emissions, since no artificial fertilizer is used in this farming system.

In organic as well as conventional dairy farming, grass-clover pastures is an important component of the cropping system. This is because grass-clover is an excellent cattle fodder, and because clover has the ability of fixing atmospheric N_2. When budgets for N_2O emissions are made according to the IPCC guidelines it is assumed that 1.25 % of added nitrogen is emitted as N_2O. This emission factor is used for all nitrogen inputs although the factor relies on experiments with fertilizer and manure, only. The emission factor for biological fixed nitrogen may be lower than 1.25 %, because nitrogen is released only slowly into the soil. However knowledge is very sparse.

On the other hand, when the effect of grazing cattle is added the situation might be different. In Denmark organic cattle are supposed to be on grazing fields for at least 150 days a year. Nitrogen returned to the system in urine and dung is likely to locally exceed the needs of the plants and is therefore at risk of being lost as N_2O. Thus far, however, there have only been a few detailed estimates of total N_2O emissions from grassland livestock productions, and understanding of the factors controlling N_2O emissions remains unsatisfactory. The aim of the Ph.D.-project is to increase the knowledge of the biological and physical-chemical mechanisms, which control the production of N_2O in grazed grass-clover pastures. The project is part of a Danish Research Centre for Organic Farming project dealing with N_2 fixation, N_2O emissions and modeling in organic grass-clover pastures. Below, three planned experiments are briefly described.

2 FROM N_2 FIXATION TO N_2O PRODUCTION

The objective of this pot experiment is to:
– develop a method to measure N_2 fixation and N_2O production
– assess contribution of recently fixed N_2 as a source of N_2O

Pots with grass and clover are placed in a closed-system flow-through apparatus with nitrogen-15 (^{15}N) labeled atmosphere. Clover N_2 fixation is calculated from the ^{15}N-enrichment of the clover material. Furthermore, the turnover of recently fixed N_2 is assessed by ^{15}N-analysis of companion grass and emitted N_2O.

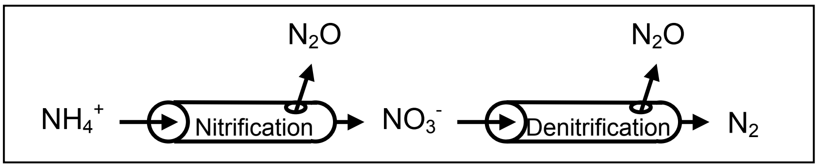

Figure 1. Loss of N_2O from nitrification and denitrification. Modified after Firestone & Davidson (1989).

3 NITRIFICATION, DENITRIFICATION AND URINE

The objective of this field experiment is to:

– identify which of the two microbial processes, nitrification or denitrification, is the main responsible for the production of N_2O
– examine how nitrification and denitrification are influenced by urine deposition

The loss of N_2O from nitrification and denitrification are determined using a ^{15}N-tracing technique. In sets of plots, either soil ammonium or soil nitrate is labeled with ^{15}N and after a short incubation atom% ^{15}N is analyzed in emitted N_2O.

The rate of total N_2O emission from nitrification and denitrification (E) is determined by four parameters forming the following equation:

$$E = N \bullet F_N + D \bullet F_D ,$$

where N and D are the rate of nitrification and denitrification, respectively, F_N is N_2O-N produced per NH_4^+ oxidized in nitrification and F_D is N_2O-N produced per NO_3^- reduced in denitrification. In Figure 1, N and D are illustrated as the flux of nitrogen through the pipes, whereas F_N and F_D are indicated as the holes in the pipes. It is well-known that grazing cattle's urine deposition locally gives rise to a high N_2O emission. Using various nitrogen isotope techniques it is examined how urine deposition affects each of the four parameters N, D, F_N and F_D.

4 CARBON MINERALIZATION AND URINE

The objective of this field experiment is to study the connection between N_2O production and carbon mineralization in the root zone. One reason for the elevated N_2O emissions from urine spots may be that the applied nitrogen increases the rate of nitrification and denitrification. Furthermore, plants may be scorched by urine deposition due to high levels of ammonia following urea hydrolysis. This may imply leaching of labile carbon compounds into the soil. In contrast to the nitrificating microorganisms, the denitrificating microorganisms are heterotrophs and need carbon compounds for their metabolism. Thus, an additional reason for high N_2O emissions from urine spots may be enhanced denitrification caused by increased availability of labile carbon compounds.

This experiment examines the effect of urine on the mineralization of carbon compounds originating from grass and clover. Grass and clover are labeled with carbon-13, urine is added and emission of carbon-13 dioxide ($^{13}CO_2$) is measured. The effect of urine on the $^{13}CO_2$ emission is compared to the urine-induced loss of N_2O from denitrification to evaluate if carbon compounds leaching from the plants is increasing the denitrification.

References

Firestone, M.K. & Davidson, E.A. 1989. Microbiological Basis of NO and N_2O Production and Consumption in Soil. In M.O. Andreae & D.S. Schimel (eds), Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere: 7-21. John Wiley & Sons Ltd.

Houghton, L.T. et al. 2001. Climate Change 2001: The Scientific Basis. Intergovernmental Panel on Climate Change. Available: http://www.ipcc.ch/ [21.12.01].