Efficiency of the nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) to mitigate N_2O emissions as affected by environmental variables and soil properties

AARHUS UNIVERSITY
DEPARTMENT OF AGROECOLOGY

Drishya Nair[1] , Diego Abalos [1], Noemi Mateo[2], Laurent Philippot[3], Søren O. Petersen[1]

[1] Dept. Agroecology, Aarhus University, Denmark; [2]Agrifood research & technology centre of Aragon; [3] French National Institute of Agricultural Research, France

INTRODUCTION

- Synthetic N fertilizers and manure applied to soil are the main sources of nitrous oxide (N_2O) emissions in agriculture.
- Nitrification inhibitors (NIs) reduce N_2O emissions from manure by suppressing the activity of ammonia oxidising bacteria and possibly archaea, thereby delaying the conversion of NH_4^+ to NO_3^- .
- Efficiency of NIs depend on environmental and edaphic factors such as soil temperature, moisture content, pH, texture and soil NO_3^- .

OBJECTIVES AND HYPOTHESES

To study how soil texture, temperature, NO_3^- availability and manure-soil contact affect N_2O mitigation by DMPP.

H_1: Potential of DMPP to reduce N_2O emissions would be higher at 10 compared to 20 °C due to slower degradation of DMPP

H_2: Shallow mixing of manure (MM) with soil will lead to higher N_2O emissions than surface application (MS) by enhancing nitrification and hence efficiency of DMPP will be higher in the MM treatments.

H_3: N_2O emissions from soil with low pH ($CS_{4.8}$) will be higher than emissions from neutral-pH soil ($CS_{6.4}$); the effect of DMPP to mitigate N_2O emissions will depend on soil NO_3^- availability.

METHODOLOGY

- Three different incubation experiments were carried out to investigate effects and interactions of selected soil properties with respect to N_2O emissions from cattle manure and mitigation by DMPP.
- Soil was packed into 100 cm^3 stainless steel rings in four portions, each time with addition of water to each layer (in some treatments with NO_3^-) to the predetermined WFPS .
- Manure ±DMPP was either surface-applied to the central 50% of the ring surface or (as part of Experiment 2) mixed into the top 1 cm of the repacked soil sample.
- After manure application, N_2O fluxes were determined at regular intervals after manure application for a period of one month.
- Temporal and spatial dynamics of mineral N, pH, organic matter content etc. in three depth intervals were determined by the end (Experiment 1) or 4-5 times during the experiment by destructive sampling.
- In Exp. 3, on days 7, 14 and 28, soil samples from 1-5 mm depth were analysed for nitrifier and denitrifier gene abundances using real-time quantitative PCR.

	Experiment 1		Experiment 2		Experiment 3	
Experimental conditions						
Soil texture	Sandy loam	Coarse sandy	Sandy loam	Sandy loam	Coarse sandy	Coarse sandy
WFPS (%)	55	55	55	55	25	25
Temperature (°C)	10/20	10/20	20	20	20	20
Soil pH	6	6.4	6.4	6.4	6.4	4.8
Applications						
Manure application	Surface	Surface	Mixed*	Surface	Surface	Surface
Nitrate application (mg g^{-1})	0	0	0	0	0/50	0/50

Table 1: Factorial experimental design and parameters

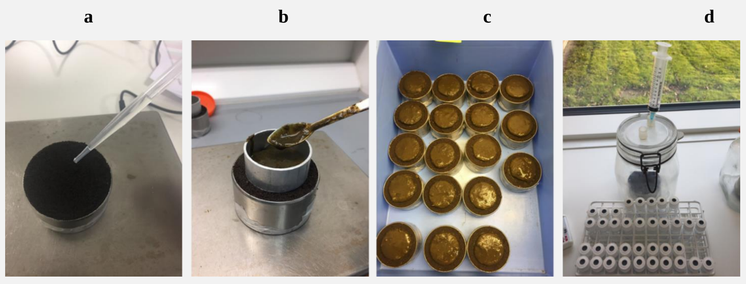

Fig 1: Water and manure addition to packed rings (a,b,c). Rings placed in 1L jar for N_2O sampling

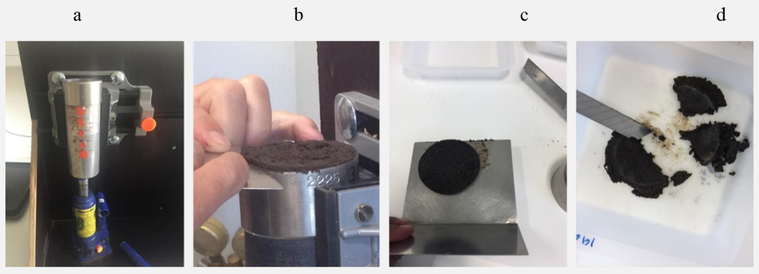

Fig 2: Soil slicing procedure: a) customized instrument for holding and slicing of soil columns b) slicing of top layer c)sliced layer d) top layer with manure separated for analysis of pH and moisture

RESULTS

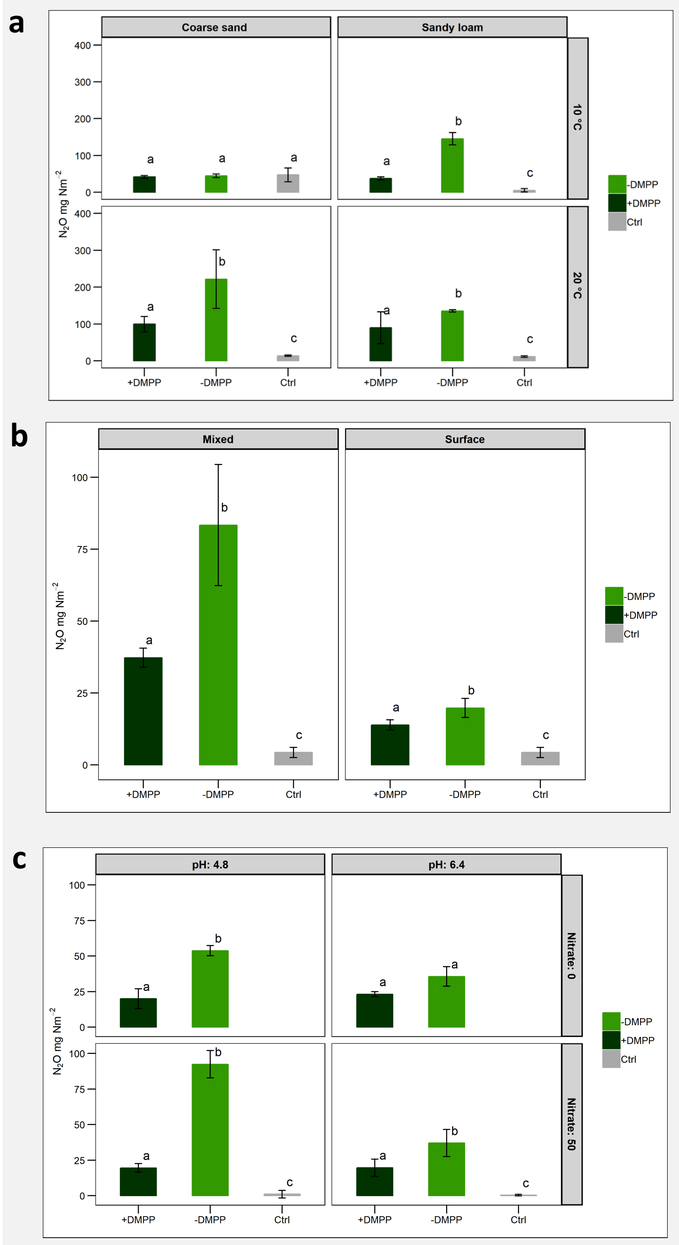

Fig 3: Cumulative N_2O emissions from Experiment 1 (a), 2 (b) and 3 (c)

RESULTS (CONTINUED)

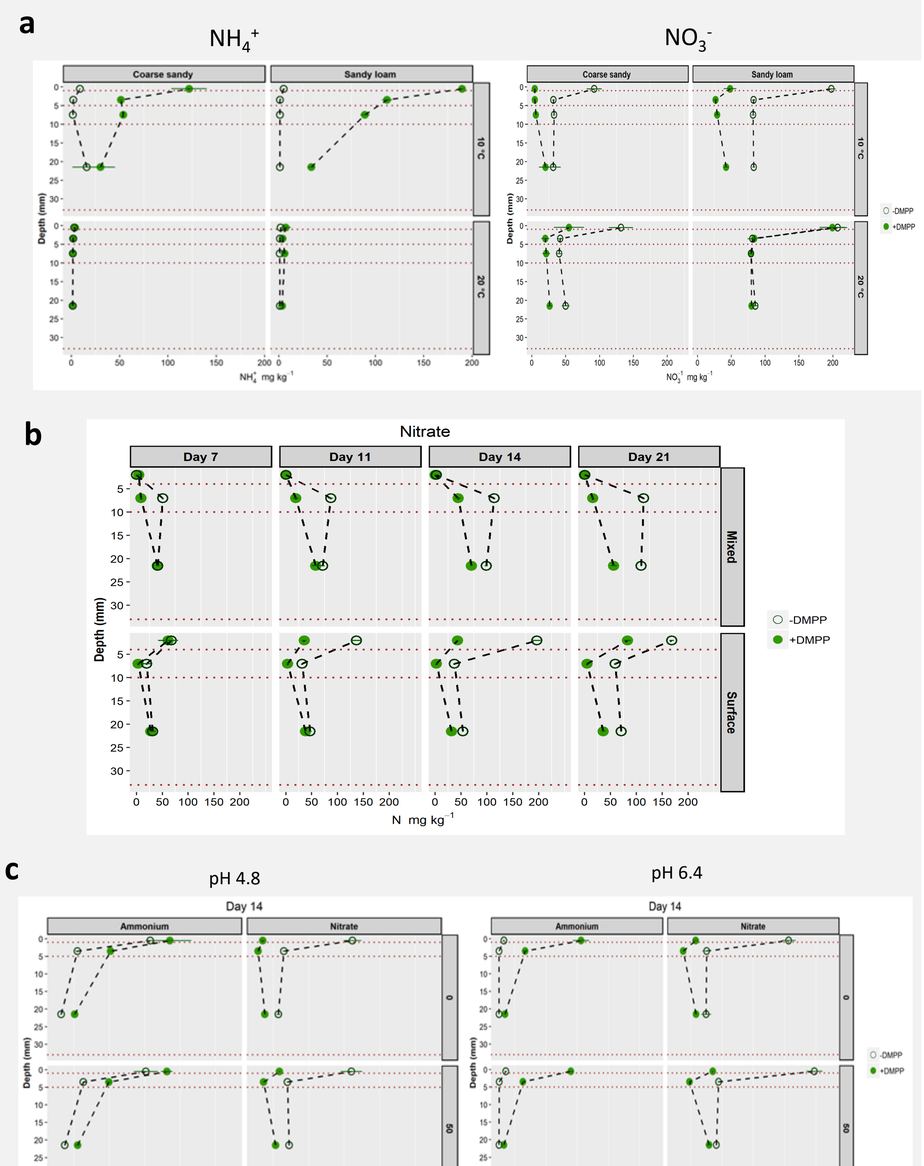

Fig 4: Temporal and spatial mineral N dynamics from Experiment 1 (a), 2 (b) and 3 (c)

RESULTS (CONTINUED)

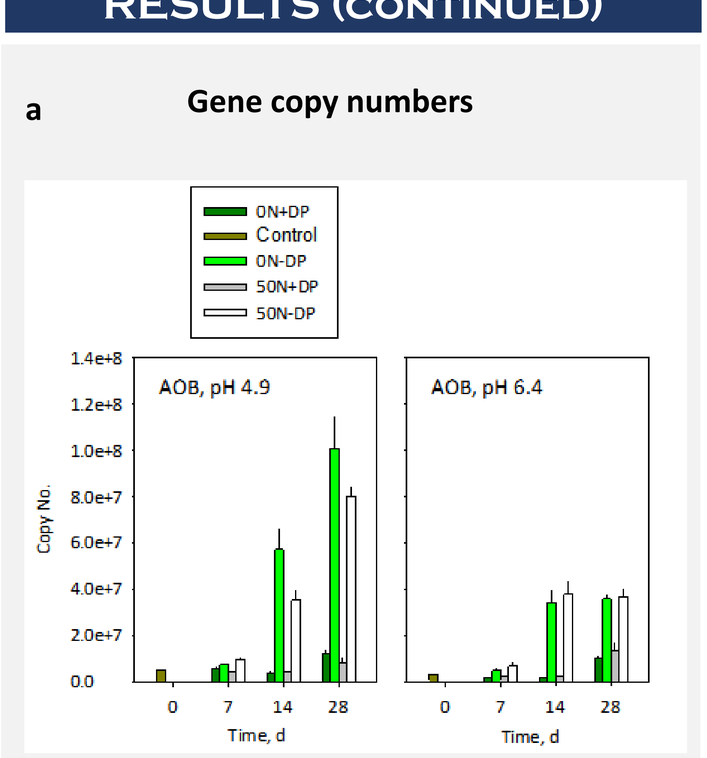

Fig 5: Nitrifier and denitrifier microbial gene abundance as affected by soil pH, NO_3^- and DMPP

CONCLUSIONS

- Exp 1: Efficiency of DMPP was influenced by both temperature and soil texture. In sandy loam soil, DMPP reduced N_2O emissions more at 10°C than at 20°C, while no reductions were observed at 10°C in coarse sandy soil (Fig 3a)
- Exp 1:NO_3^- accumulation was lower in coarse sandy soil at 10 °C indicating delayed nitrification (Fig 4a)
- Exp 2: In general, N_2O emissions were higher in treatments with manure mixed to 1-10 mm of soil and efficiency of DMPP was independent of application depth.
- Exp 2: The depletion of soil NO_3^- at 0-5 mm when manure was mixed into the top soil, but accumulation of NO_3^- when surface applied, indicates that better soil-manure contact enhanced denitrification. At 5-10mm, opposite trends were observed
- Soil pH was an important factor that controlled N_2O emissions and higher emissions were observed in acidic soil ($CS_{4.8}$) attributed to lower abundance of nosZ genes resulting in higher N_2O:N_2+N_2O (Fig 5b).
- DMPP reduced N_2O emissions in all treatments irrespective of nitrate availability in $CS_{4.8}$ and only in treatments with NO_3^- amendment in $CS_{6.4.}$ (Fig 3c) . In contrast to the hypothesis, N_2O mitigation potential of DMPP was found to be higher when NO_3^- availability was not a limiting factor across both soil pH (Fig 3c).
- In comparison to $CS_{4.8}$, NO_3^- accumulation was higher in $CS_{6.4}$ on day 14 indicating increased nitrification rates (Fig 4c)
- DMPP reduced AOB abundance significantly in all treatments (Fig 5a), but had no effect on the abundance of AOA (data not shown).
- In $CS_{4.8}$ DMPP reduced the abundance of ComaA (clade A), ComaA ntsp, as well as nosz-I

ACKNOWLEDGEMENT

We would like to thank all the technicians involved and BASF for financially supporting the project.