Dissimilatory nitrate reduction to ammonium, denitrification and anaerobic ammonium oxidation in paddy soil

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Introduction

Rice paddies are flooded for an extended period of time which creates anoxic conditions in the paddy soils. The anoxic conditions in the soil can favour a simultaneous occurrence of several microbial N transformation processes, such as dissimilatory nitrate (NO_3^-) reduction to ammonium (NH_4^+) (DNRA), denitrification and anaerobic NH_4^+ oxidation (anammox) (Fig. 1). DNRA can be an important internal N conservation mechanism, whereas denitrification and anammox can contribute to a loss of N from the paddy soil. Little is known about the role of DNRA and anammox in N cycling in paddy soils, and of the simultaneous occurrence of these N transformations.

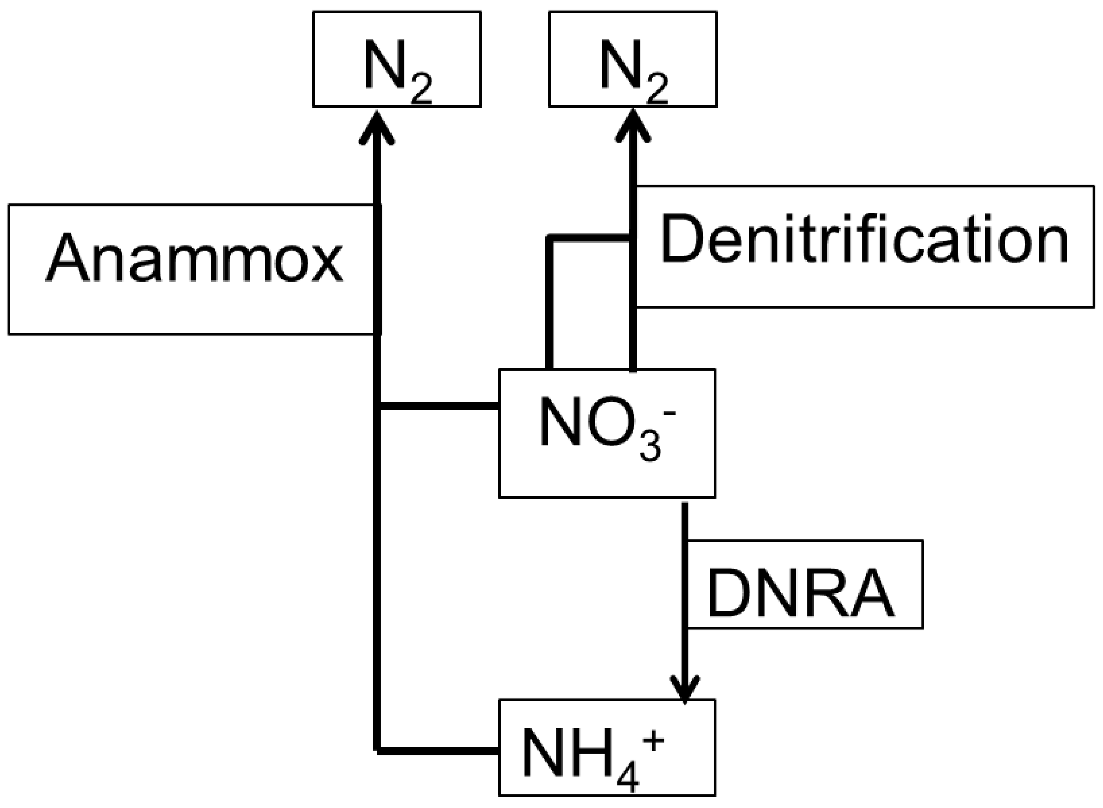

Fig.1 Illustration of DNRA, denitrification and anammox processes in soil.

Objective

This study was conducted to determine the significance of the DNRA, denitrification and anammox processes in N cycling in paddy soils during the first week of flooding

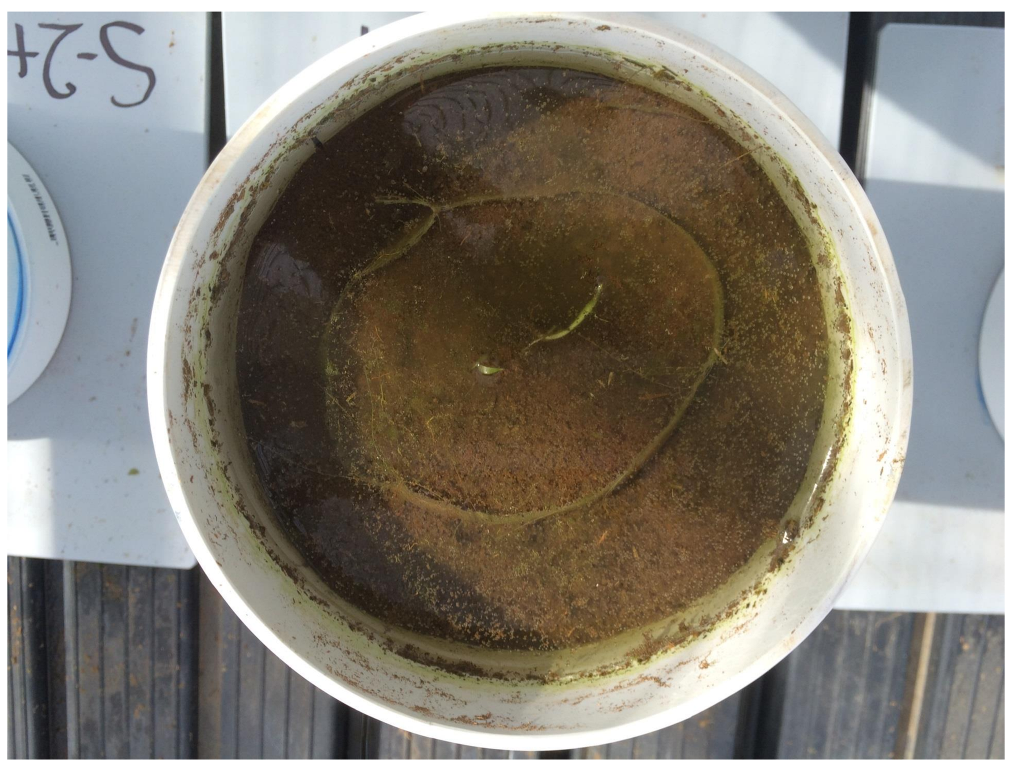

Fig.2 Soil in the pot under flooded condition.

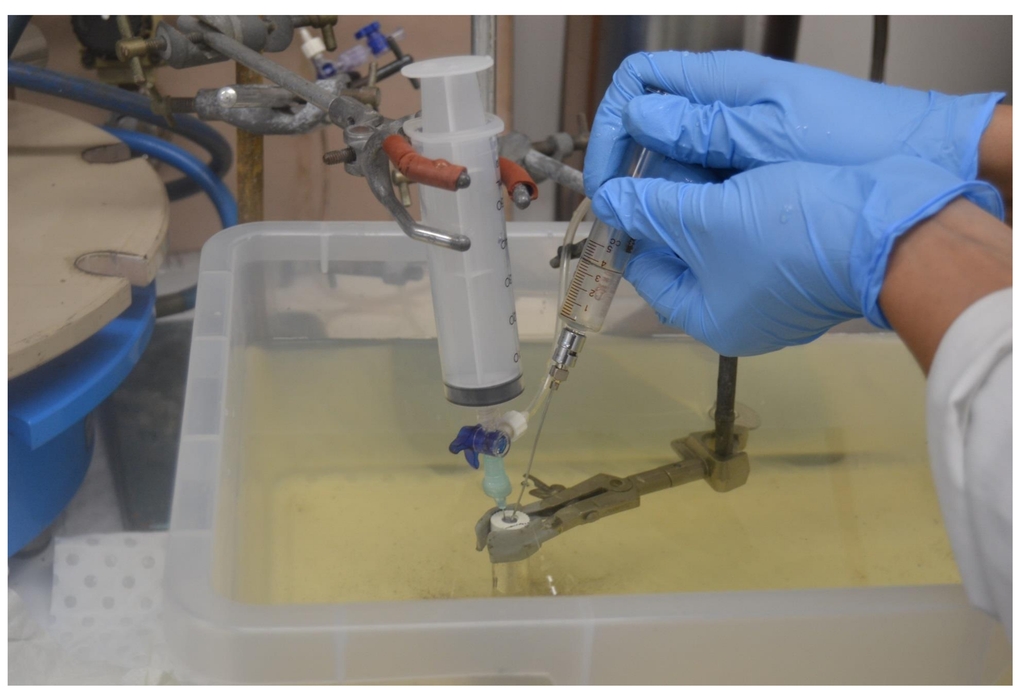

Fig.3 Creating headspace in a vial before $^{15}N_2$ measurement.

Methods

- Soil samples were collected from rice paddies in the Riverina region of New South Wales in Australia and transferred to pots and flooded in the glasshouse (Fig.2).
- After one week of flooding of the pots, soil samples were transferred to 24 vials (12.5 mL, 3-4 g in each).
- The collected soil was incubated anaerobically with irrigation water for 48 hours to deplete soil indigenous NO_3^-.
- Thereafter, $^{15}NO_3^-$ (>99 atom%) was injected in the vials and the soil was incubated in the dark for 0, 6, 12 and 24 hours (Fig. 4 and 5).
- Reduction of $^{15}NO_3^-$ to $^{15}NH_4^+$ in soil during DNRA was determined using the hypobromite (NaOBr) method[1] (Fig.4a).
- Denitrificationa and anammox was determined by measuring $^{29}N_2$ and $^{30}N_2$ in the vials after headspacing[2] (Fig. 4b and 5).

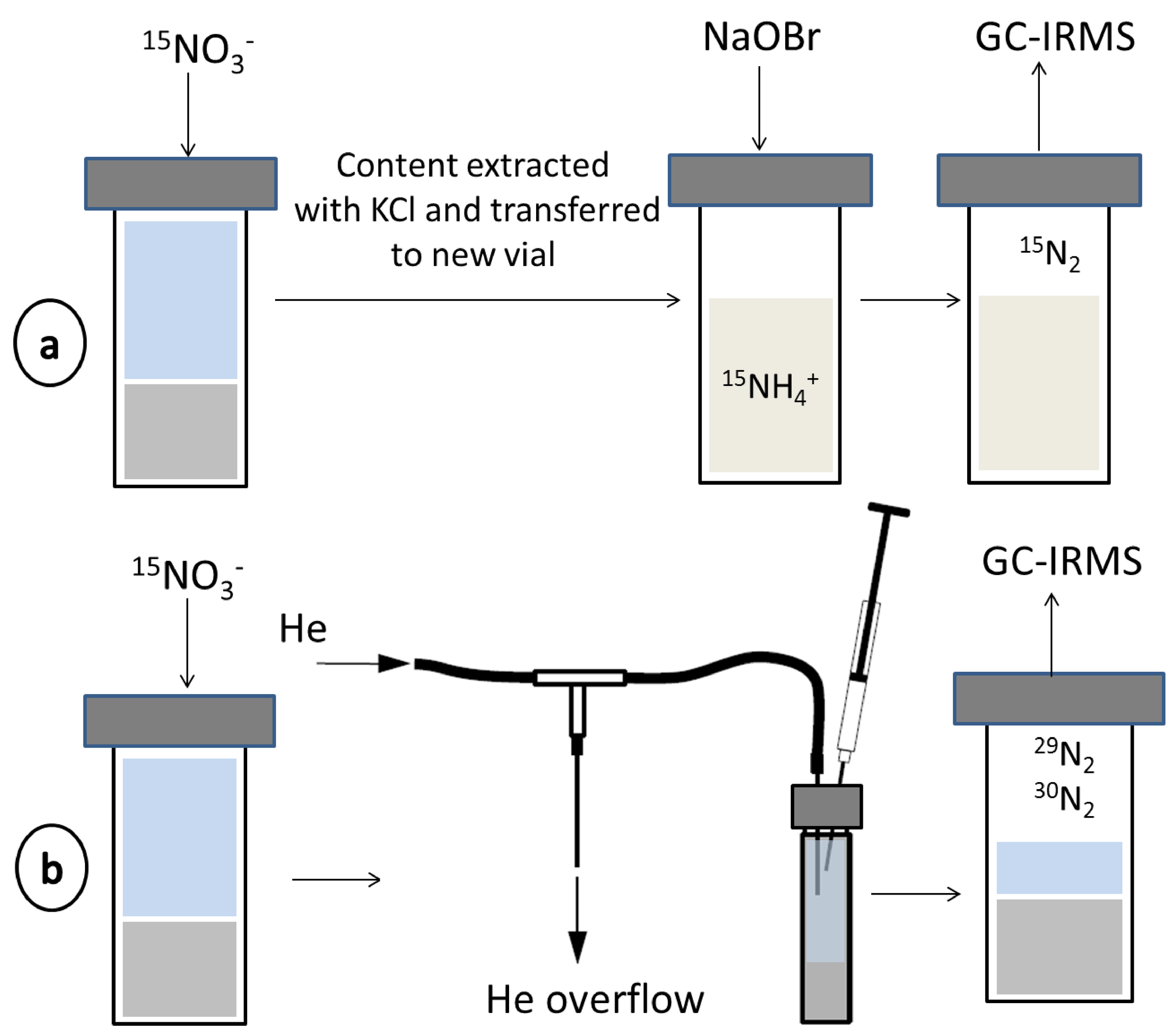

Fig.4 Methods for measuring DNRA (a), denitrification and anammox (b).

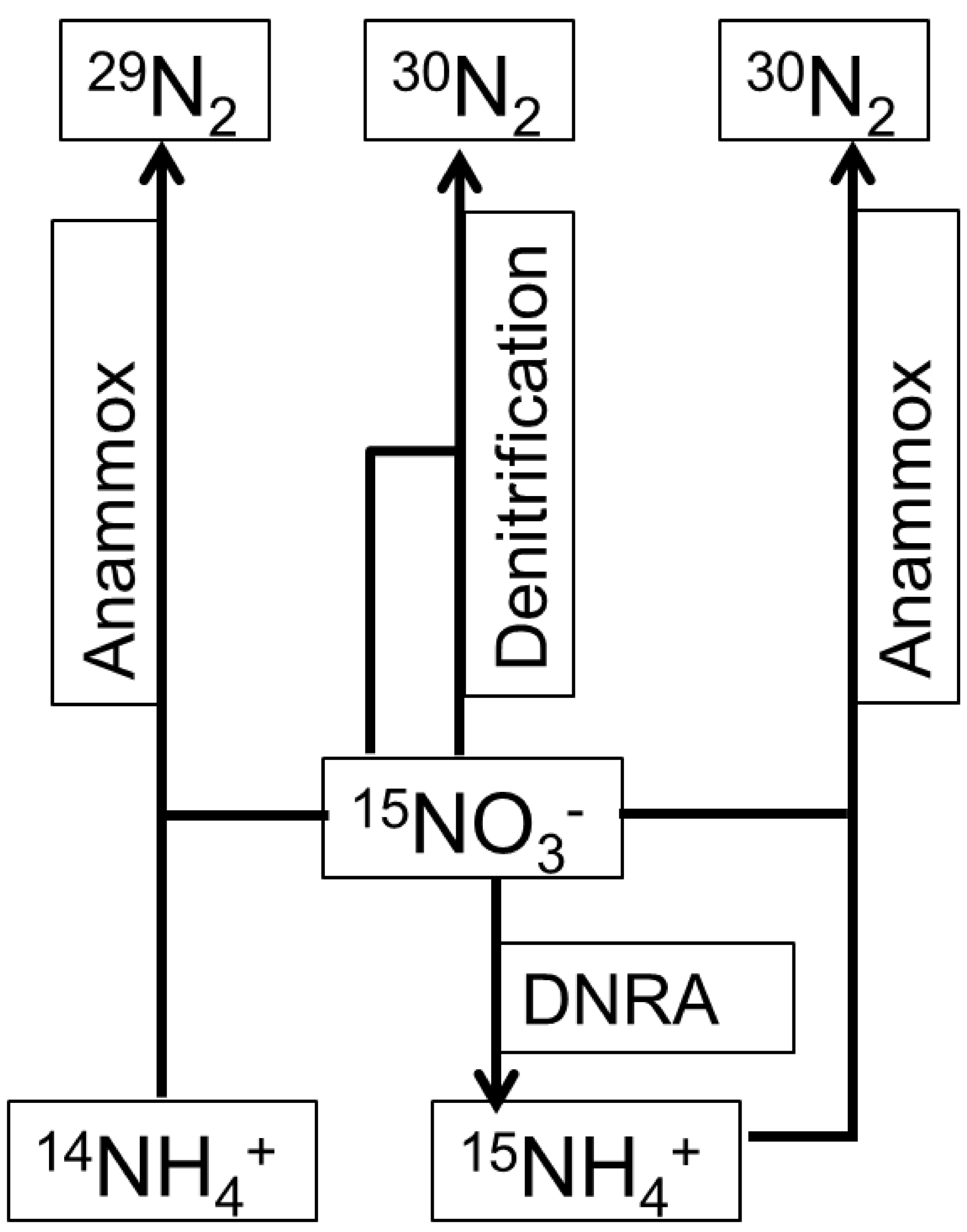

Fig.5 Illustration of DNRA, denitrification and anammox after $^{15}NO_3^-$ injection.

Results

- The rate of the N transformation processes were determined by using the rate of accumulation of $^{15}N_2$ in the headspace of vials over time (Fig. 6).
- DNRA showed the potential for reduction of 0.34 µmole NO_3^- to NH_4^+-N hr^{-1} kg^{-1} paddy soil (Fig.7).
- Denitrification was the dominant N transformation pathway in the paddy soil which produced 3.35 µmole N_2 hr^{-1} kg^{-1} soil.
- Anammox produced 0.65 µmole N_2 hr^{-1} kg^{-1} paddy soil.
- Internal N conservation activity (DNRA) in paddy soil was significantly lower than the N loss activities (denitrification and anammox).

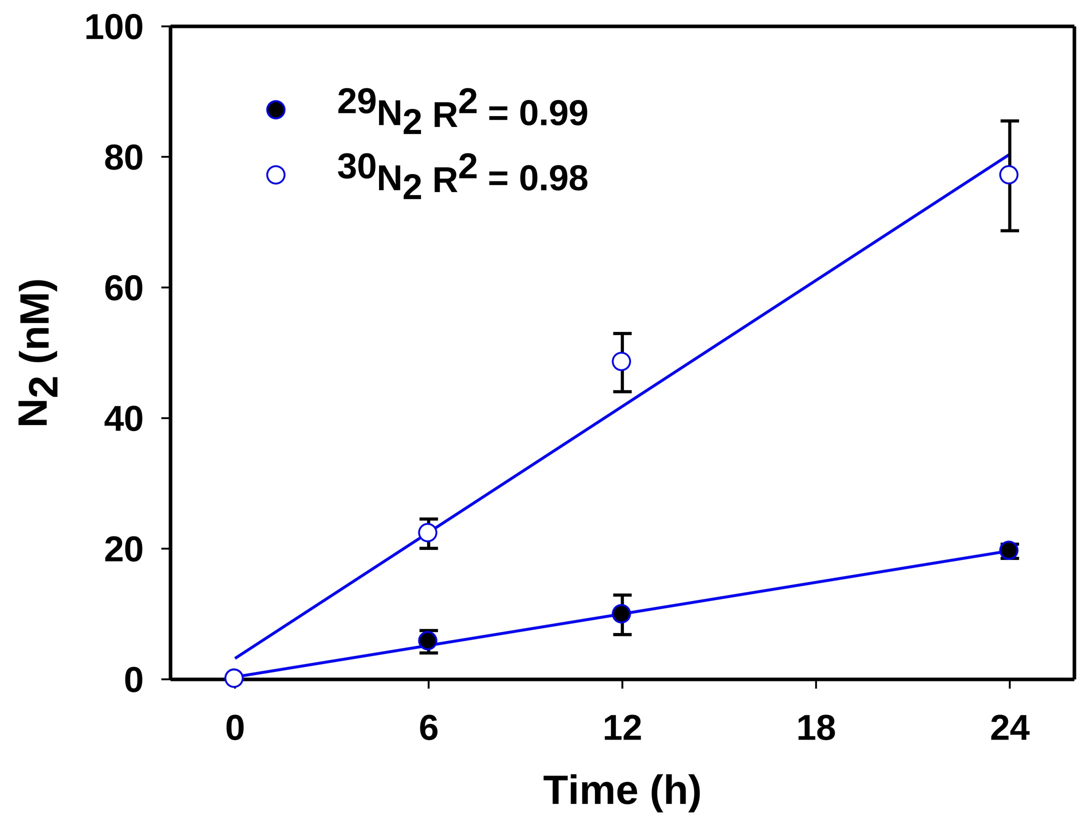

Fig.6 Accumulation of $^{29}N_2$ and $^{30}N_2$ in vials.

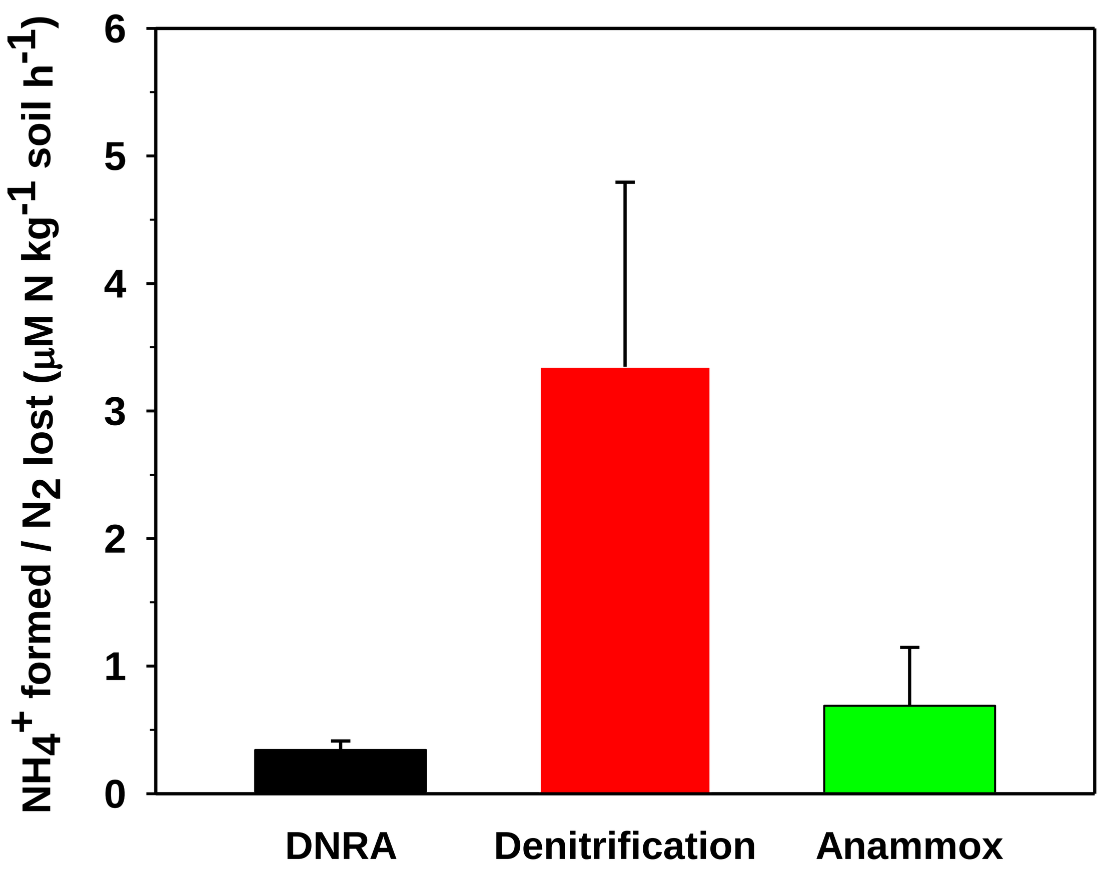

Fig.7 Rates for each of the processes.

Conclusions

- DNRA, denitrification and anammox can start within a week of flooding of paddy soils.
- Denitrification is the dominant N transformation pathway followed by anammox and DNRA.
- As the paddy soils environment changes with the growth of rice plants and extended period of flooding, there is a need to study these processes throughout the rice growing period.

Acknowledgements

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References

1. Trimmer, M.; Nicholls, J. C. *Limnol Oceanogr* **2009**, *54*, 577-589.
2. Thamdrup, B.; Dalsgaard, T. *Applied and environmental microbiology* **2002**, *68*, 1312-1318.

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