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Inoculants of leguminous crops for mitigating soil emissions of the greenhouse gas nitrous oxide

Catherine Hénault and Cécile Revellin

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CHANGES IN ATMOSPHERIC CONCENTRATIONS OF TRACE GASES

Atmospheric concentrations of greenhouse gases

a) Concentrations atmosphériques globales de trois gaz à effet de serre bien mélangés

GAS	GWP (100 years)
CO_2	1
CH_4	23
N_2O	296

SOURCES OF N₂O (Tg N-N₂O y⁻¹), from IPCC 2007

AR4 (2007)		
SOURCE	value	range
Anthropogenic sources		
Fossil fuel combustion and Industrial processes	0.7	0.2-1.8
Agriculture	2.8	1.7-4.8
Rivers, estuaries, coastal zones	1.7	0.5-2.9
Biomass and biofuel burning	0.7	0.2-1.0
Human excreta	0.2	0.1-0.3
Atmospheric deposition	0.6	0.3-0.9
Anthropogenic total	6.7	
Natural sources		
Soils under natural vegetation	6.6	3.3-9.0
Oceans	3.8	1.8-5.8
Atmospheric chemistry	0.6	0.3-1.2
Natural sources total	11	
Total sources	17.7	8.5-27.7
Atmospheric sink	12.3	
Atmospheric increase	3.9	
Unbalanced	1.5 ???	large range

MECHANISMS INVOLVED IN N₂O BUDGET IN SOILS

denitrification (anaerobic) – nitrification (aerobic)

REGULATION OF THE LEVEL OF N_2O EMISSION BY THE REDUCTION OF N_2O

- Study of N_2O production by the first steps of denitrification and by nitrification
- **Study of N_2O Consumption**

(From Hénault et al., 2001)

OBJECTIVES OF THE STUDY

- To mitigate N_2O emission by managing the N_2O to N_2 reduction, specially in soils where this function is inefficient
- By managing soil microbial communities : use of microorganisms that grow in symbiosis with crop plants
- Some *rhizobia*, symbionts of leguminous crops possess the *nosZ* genes coding for the enzyme involved in the N_2O reduction (Sameshima-Saito et al., 2006)

⇒ To crop some leguminous

- Inoculated with strains carrying the *nosZ* genes
- On soil emitting high levels of N_2O due to an inefficient N_2O reduction

$$[\text{SOIL}]_{\text{PhN}_2\text{ORed-}} + [\text{Plant} + \text{Inoculant}]_{\text{PhN}_2\text{Ored+}} \Rightarrow [\text{SOIL} + \text{Plant} + \text{Inoculant}]_{\text{PhN}_2\text{Ored+}}$$

STEPS OF THE STUDY

- A **greenhouse experiment** for testing the previous equation

$$[\text{SOIL}]_{\text{PhN}_2\text{Ored-}} + [\text{Plant} + \text{Inoculant}]_{\text{PhN}_2\text{Ored+}} \Rightarrow [\text{SOIL} + \text{Plant} + \text{Inoculant}]_{\text{PhN}_2\text{Ored+}}$$

- Some **laboratory experiments** to develop knowledges on the process
- A **modelling approach** to assess quantitative benefits of this process at the field scale

MAIN USED MATERIALS

- Soybean plants inoculated with different strains of *Bradyrhizobium japonicum*
- Gas chromatography

GREENHOUSE EXPERIMENT

Soil inefficient to reduce N_2O

$\Delta nosZ$

USDA 110

G 49

---●--- Kr —●— N_2O

LABORATORY EXPERIMENT

QUANTIFICATION BY A MODELING APPROACH

THE MODEL

A new version of the NOE model (Hénault et al., 2005) that includes the reduction of N_2O by rhizobia

Parametrisation of the model using results obtained during both the laboratory and greenhouse experiments

N_2O emission by soil ———
by nodules inoculated into soybean ———
in a hypothetical system including active nodules ———

CONCLUSIONS

- Switch from an N_2O emitting system to a consuming one by means of the inoculation of strains containing the *nosZ* gene
 - Observations
 - that the process is insensitive to the O_2 concentration
 - that rates increase with the ambient N_2O concentration
 - that the efficiency of the process is strain dependant
 - Assessment of a significant benefit of the process at the field scale
- ⇒ To **measure** the environmental benefit of the process on the field scale

Thank you