Mitigation of Greenhouse Gas Emissions From Agricultural Lands by Optimizing Nitrogen and Carbon Cycles

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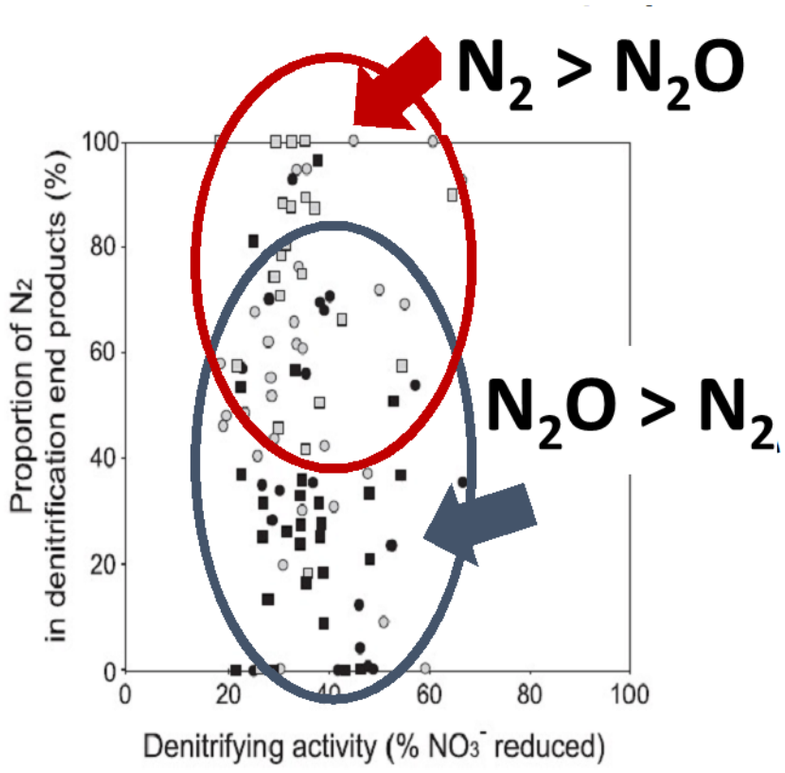
Implementing organizations : Tohoku University, The University of Tokyo
National Agriculture and Food Research Organization (NARO)

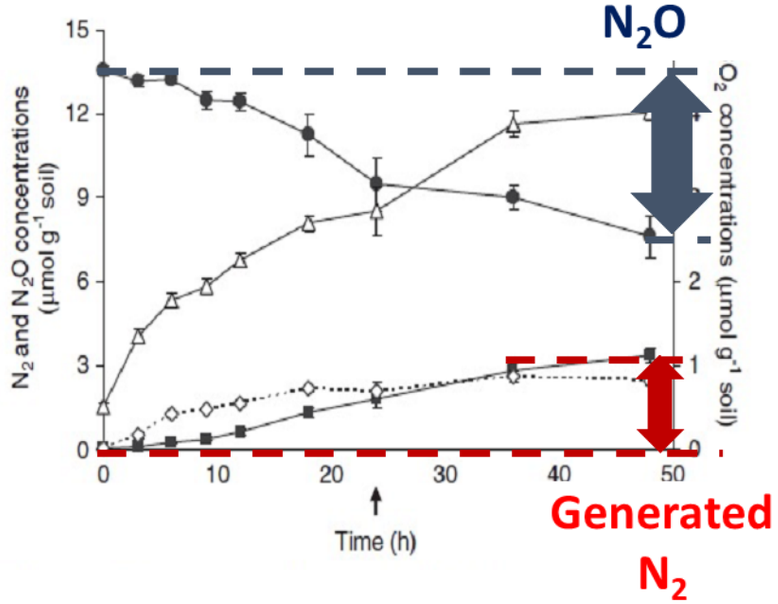
Paddy soils as N_2O sink



(Tago et al., 2011)

The N_2/N_2O production ratio of denitrifiers in paddy soils is diverse

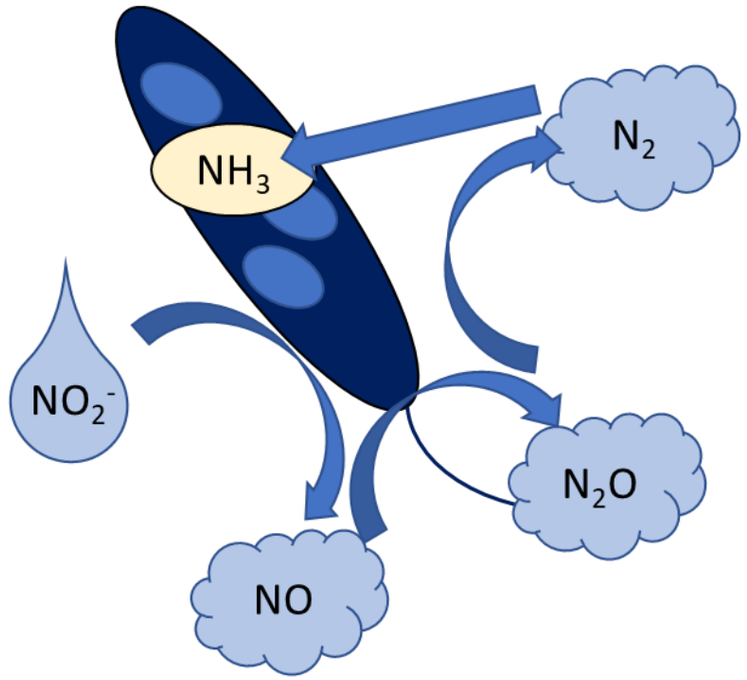
Reduced N_2O > Generated N_2



(Ishii et al., 2011)

60 % of the reduced N_2O is missing

e.g. *Bradyrhizobium* sp.

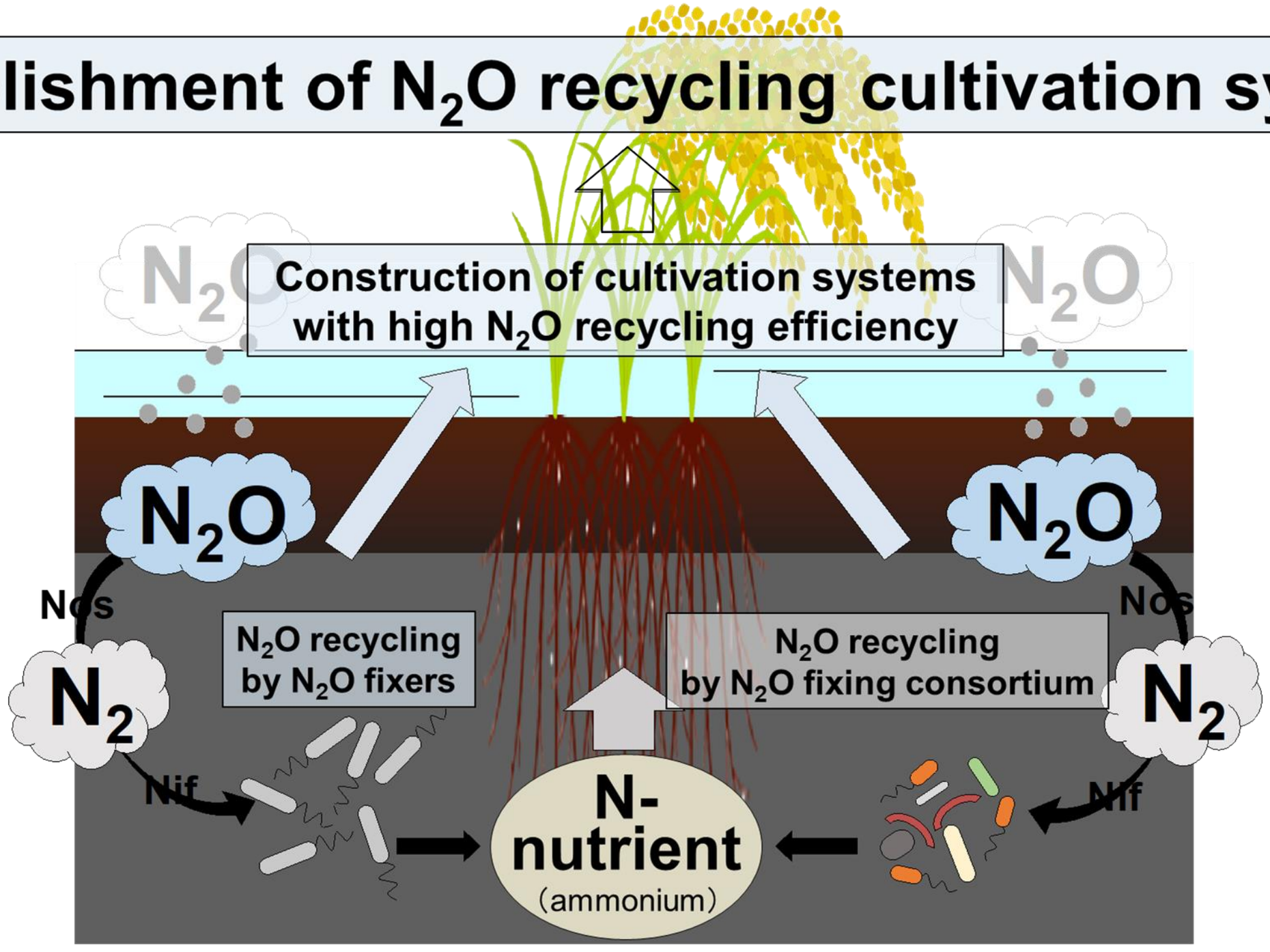


Denitrifiers with nitrogen-fixing ability

<u>N_2O produced in paddy soils might be re-fixed by soil bacteria</u>

Purpose of this study

Establishment of N_2O recycling cultivation system



Conversion of greenhouse gas N_2O to N nutrient

Research Plan

2020

Confirmation of N_2O fixation

2021

Clarification of N_2O fixation pathway

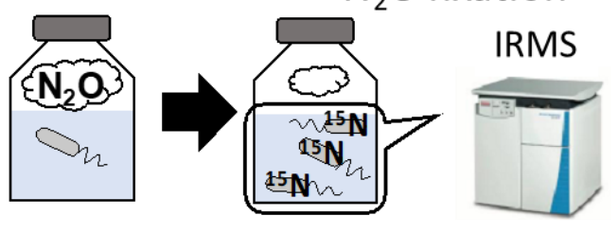
$N_2O \xrightarrow{nos} N_2 \xrightarrow{nif} NH_4^+$

$N_2O \xrightarrow{nos} N_2 \xrightarrow{nif} NH_4^+$

$N_2O \xrightarrow{nos} N_2 \xrightarrow{nif} NH_4^+$

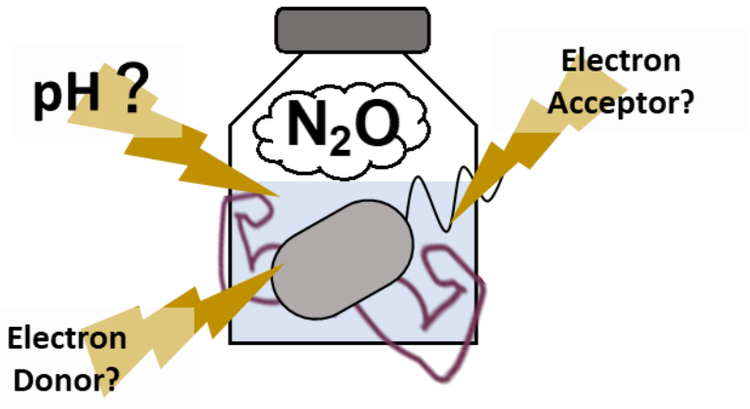
2022

Estimation of the amount of N_2O fixation



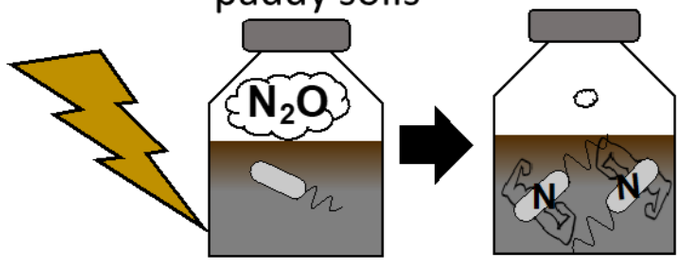
2023

Clarification of factors enhancing N_2O fixation



2024

Development of methods to enhance N_2O sink function of paddy soils



Goal

Establishment of N_2O recycling cultivation system

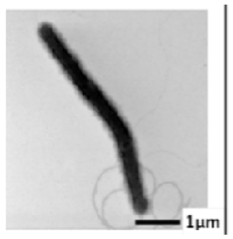
Construction of cultivation systems with high N_2O recycling efficiency

Bacteria harboring N_2O fixation potential

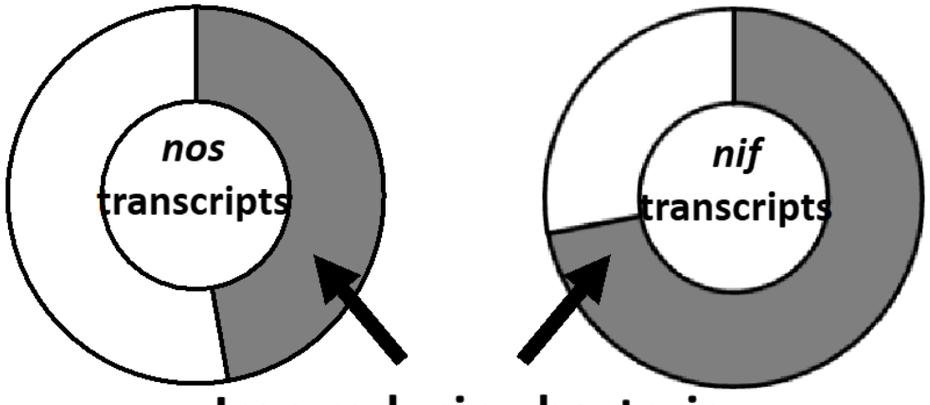
N_2O —*nos*→ N_2 —*nif*→ NH_4^+

① Iron reducing bacteria harboring N_2O reduction enzyme genes (*nos*)

***Anaeromyxobacter* sp.**



- Iron-reducing bacteria predominated in paddy soils
- Large number of *nos* and *nif* transcripts were detected in metatranscriptomics of paddy soils



Iron reducing bacteria

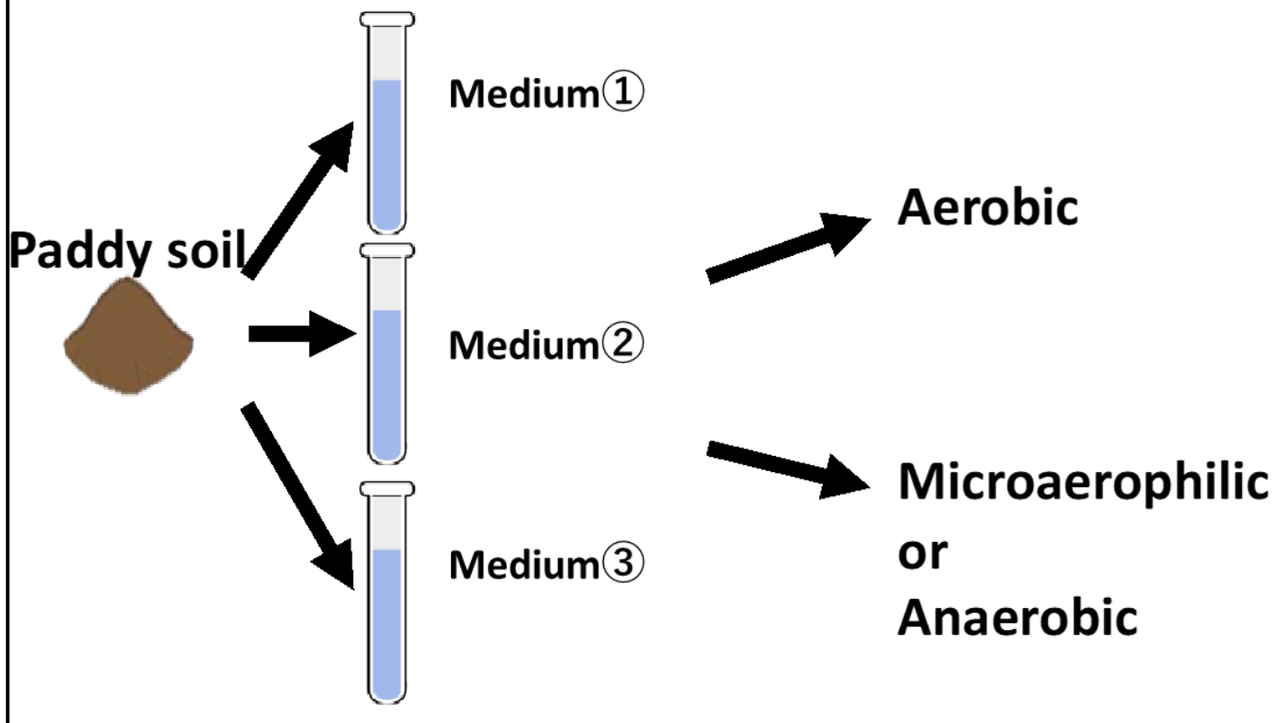
Microbial composition of *nos* and *nif* gene transcripts detected by metatranscriptomics

② Denitrifier harboring N fixation enzyme genes (*nif*)

***Bradyrhizobium* sp.**

- Isolated as denitrifiers with high N_2O reducing activity
- harboring *nif* (nitrogen fixation gene)

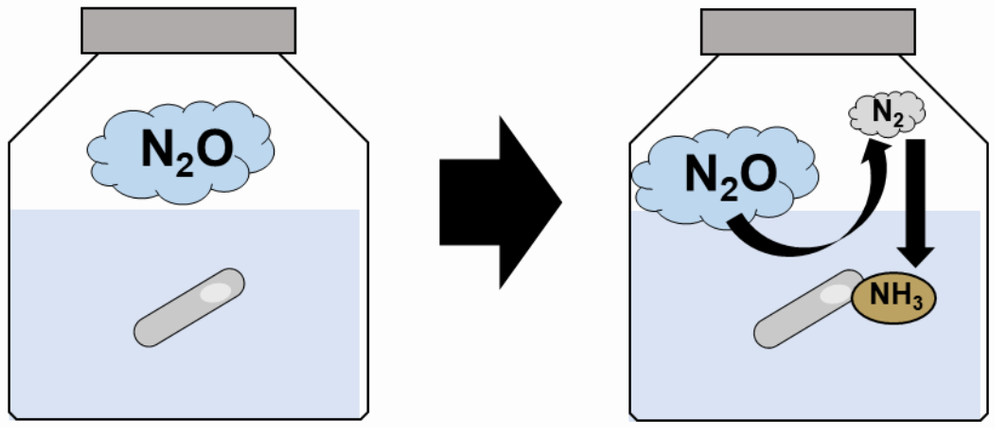
③ Microbial consortium growing with N_2O as a sole N source



Amplicon sequencing of community composition

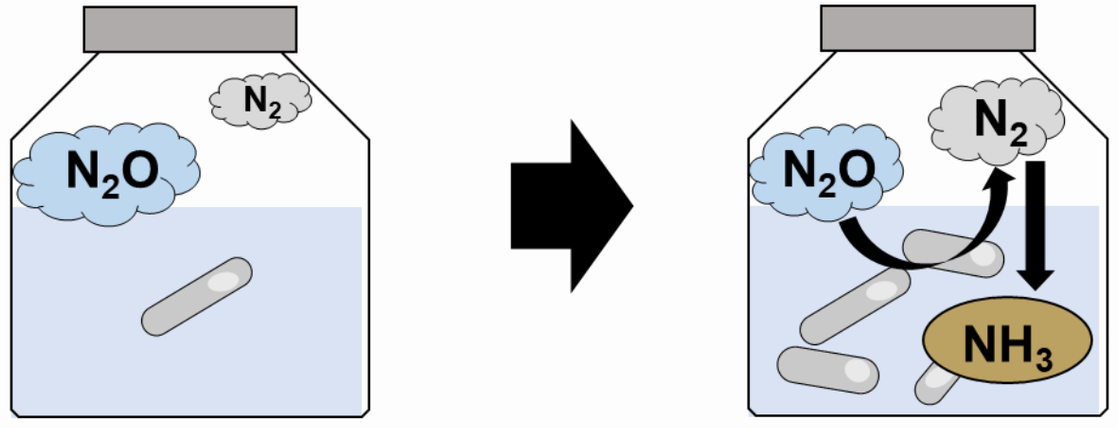
Verification of N_2O fixing ability

① Verification of N_2O fixation ability of *Anaeromyxobacter* sp.
–optimal culture conditions for N_2O fixation–



Survive but no growth in the medium with N_2O as sole N source and e-acceptor.

Growth was observed after transferred to N_2 containing medium.



Growth was observed in the presence of N_2O and small amount of N_2. The amount of N_2O decreased.

Anaeromyxobacter sp. fix N_2O in the presence of small amount of N_2

② Verification of N_2O fixation ability of *Bradyrhizobium* sp.
–optimal culture conditions for N_2O fixation–

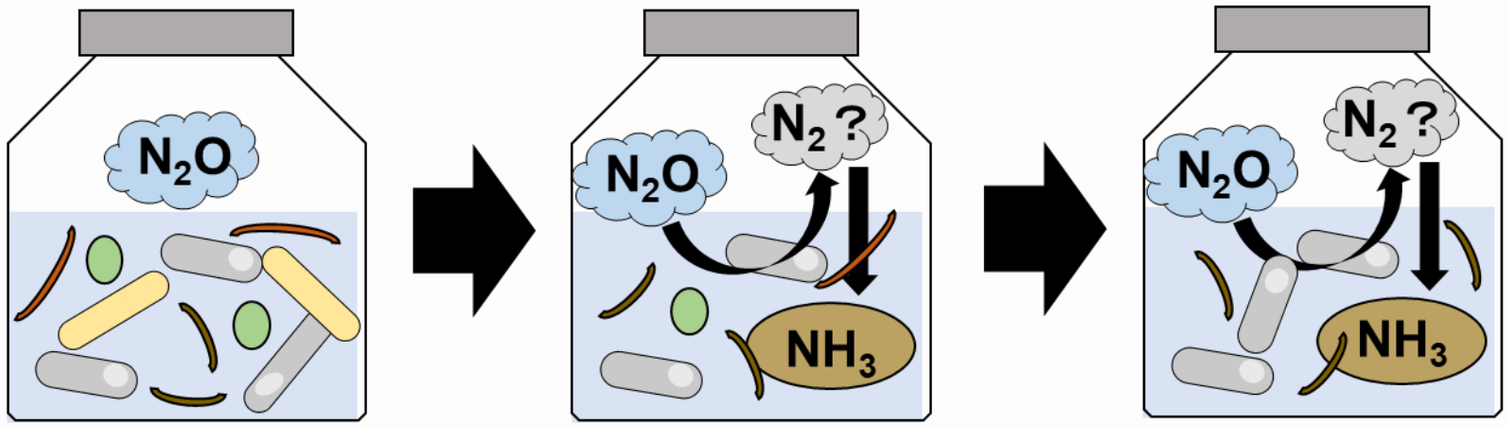
* No growth was observed in the absence of N_2 → N_2 is essential for growth.
* Growth was observed in the presence of N_2O and small amount of N_2.

***Anaeromyxobacter* sp. and *Bradyrhizobium* sp. fix N_2O in the presence of small amount of N_2**

Verification of N_2O fixing ability

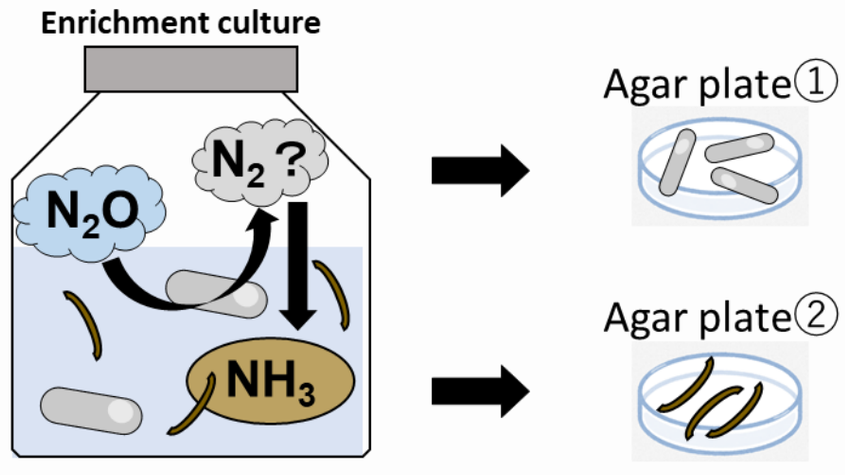
③ Enrichment culture and isolation of microbial consortia growing with N_2O as sole nitrogen source

Enrichment culture in Medium① (aerobic)

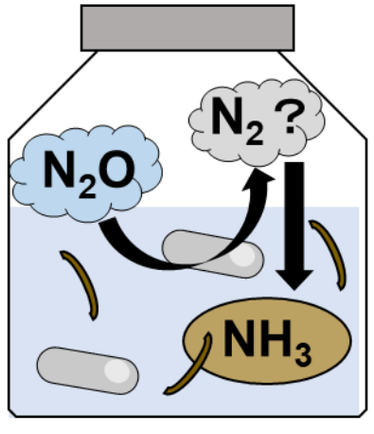


Microbial community composition became simplified

Isolation



※ Two strains dominated in the culture were successfully isolated



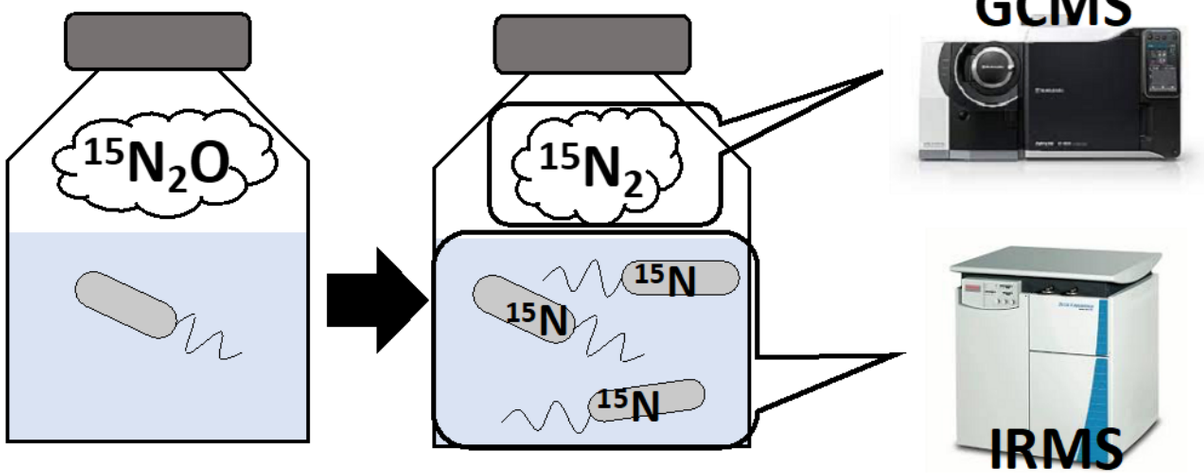
A microbial consortium has been obtained growing with N_2O as sole nitrogen source

Future plan

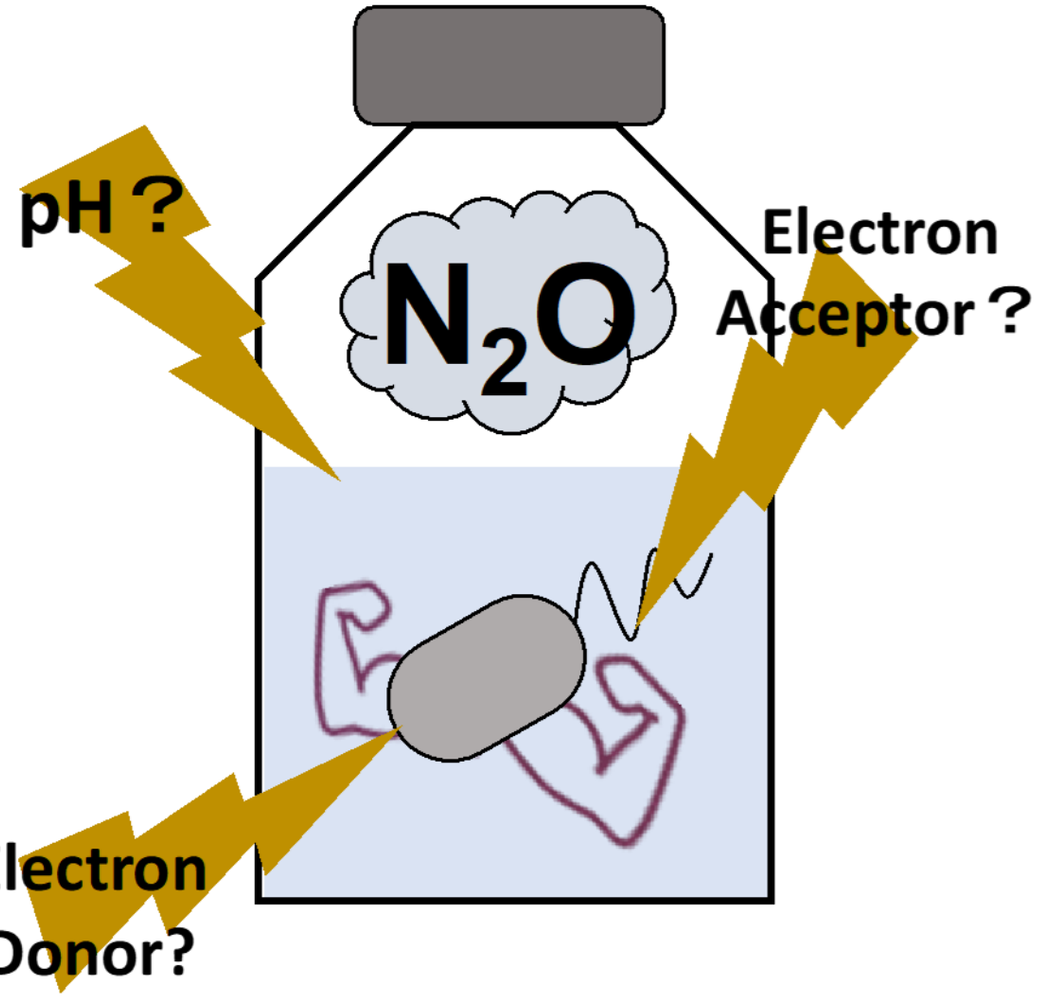
Clarification of N_2O fixation pathway

$$N_2O \xrightarrow{nos} N_2 \xrightarrow{nif} NH_4^+$$

Quantification of fixed N_2O



Exploration of factors enhancing N_2O fixing-activity of the bacteria/consortium



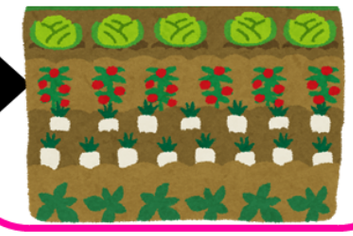
2029: Pilot scale experiments

N_2O

Boosting N_2O sink function

Establishment of N_2O recycling cultivation system

Application to field crops



N_2O Construction of cultivation systems with high N_2O recycling efficiency N_2O

N_2O N_2O

Nos Nos

N_2 N_2

N_2O recycling by N_2O fixers

N_2O recycling by N_2O fixing consortium

Nif Nif

N-nutrient (ammonium)

Possible application to N_2O recycling industry

Application of N_2O recycling technology to agriculture and industry

MOONSHOT
RESEARCH & DEVELOPMENT PROGRAM