# N2O Formation in Rice Plants

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Rice plants in paddy emit a substantial amount of nitrous oxide ($N_2O$), a potent greenhouse gas to the atmosphere. Field-based studies that report $N_2O$ fluxes from the paddy consider that the $N_2O$ emitted by rice plant is of microbial origin in the soil. Recent studies on other plants suggest that vegetation are also a natural source of $N_2O$. However, the mechanisms of $N_2O$ formation in plants are unknown; consequently, the rice plant is regarded as a channel to transport soil micro-organisms produced $N_2O$. The hypothesis that rice plants are a medium to transport soil produced $N_2O$ is based on flux measurement methods. However, more robust methods like $^{15}N$ isotope analysis methods consider plants are a natural source of $N_2O$. This led us to search for the possible pathway of $N_2O$ formation in rice plants cells. Herein, we have proposed a potential pathway of $N_2O$ formation in rice plants.

rice plants potential pathway nitrous oxide mitochondria

## 1. Introduction

Paddies are a potential site of $N_2O$ emissions to the atmosphere[1]. In paddies, not only the soil but also the rice plants are reported to emit a substantial amount of $N_2O$ and the rice plant is regarded as a medium to channel the soil produced $N_2O$[2][3]. However, the hypothesis that rice plants are a medium to transport soil produced $N_2O$ is based on flux measurement method. Recent studies based on more robust methods like $^{15}N$ isotope analysis[4] and aseptically grown plants[5] suggest that plants cells may also produce the $N_2O$. So, the substantial amount of $N_2O$ emitted by rice plants[2][3] might have been formed in the rice plants cells. So, there is a need to explore the possible pathway of $N_2O$ formation in rice plants cells.

$^{15}N$ isotope labelling studies have shown that nitrate ($NO_3^-$) is a precursor of $N_2O$ formation in plants[4][5]. Similar to $NO_3^-$, the addition of $^{15}N$ labelled nitrite ($NO_2^-$) lead to $N_2O$ formation in plants[5][6]. In addition, eukaryotic cytochrome c oxidase when supplied with $^{15}N$ labelled NO produced $N_2O$[7]. In this scenario, we predicted $NO_3$-$NO_2$-NO pathway might contribute to $N_2O$ formation in rice plant's cells.

## 2. Potential Pathway of N2O Formation in Rice Plants

NO is a signalling molecule at the cellular level and is formed at every eukaryotic cell[8]. There are several pathways and sites of NO formation in the cell[9]. Among the several pathways of NO formation, a reductive pathway is $NO_3$ and $NO_2$ dependent and occurs during oxygen-limited condition in cytosol and mitochondria, respectively[9]. $NO_3$ is further converted to $NO_2$ in the cytosol with the help of nitrate reductase (NR)[10] and the

$NO_2$ can enter the mitochondria with the help of unknown transporter[11]. Then the $NO_2$ can be further reduced to NO by various electron transport chains and the conversion is more favourable in oxygen limitation condition[11]. The NO formed at mitochondria can be further reduced to $N_2O$ by reduced form of eukaryotic cytochrome c oxidase[7][12] and the conversion is more favourable when the oxygen level in the cell is low[12]. As $NO_2$ dependent pathway of NO formation in mitochondria is active during oxygen-limited condition[11] and NO-dependent $N_2O$ formation is also favourable during oxygen-limited condition in mitochondria[12], suggests the $N_2O$ emitted by rice plants might have formed at mitochondria when the cell experience hypoxia and anoxia.

At the cellular level there exists the pathway of $N_2O$ formation through $NO_3$-$NO_2$-NO pathway as reported in various studies[7][10][11][12]. So, considering rice plants only as a medium to transport the soil-microorganism produced $N_2O$ will be misleading. To mitigate the effects of global warming and ozone depletion effectively, a good understanding of all of the sources of $N_2O$ and the regulating factors is crucial. So understanding the role of rice plants (i.e., source or medium to channel or both) in paddies is crucial. Further research at the cellular level would insight to the proposed pathway of $N_2O$ formation in the rice plants. Furthermore, field-based studies should evaluate the $N_2O$ fluxes from the rice plants only (excluding soil) that could insight the rice plants role to the total emissions of $N_2O$ from paddies. Moreover, as various other plants species are also reported to emit a substantial amount of $N_2O$, there is a current need to search for the possible pathways of $N_2O$ formation in plants cells.

## References


1. Bruce Linquist; Kees Jan Van Groenigen; Maria Arlene Adviento-Borbe; Cameron Pittelkow; Chris Van Kessel; An agronomic assessment of greenhouse gas emissions from major cereal crops. *Global Change Biology* **2011**, *18*, 194-209, 10.1111/j.1365-2486.2011.02502.x.
2. K. W. Yu; Z. P. Wang; G. X. Chen; Nitrous oxide and methane transport through rice plants. *Biology and Fertility of Soils* **1997**, *24*, 341-343, 10.1007/s003740050254.
3. X Yan; Pathways of N2O emission from rice paddy soil. *Soil Biology and Biochemistry* **2000**, *32*, 437-440, 10.1016/s0038-0717(99)00175-3.
4. Katharina Lenhart; Thomas Behrendt; Steffen Greiner; Jörg Steinkamp; Reinhard Well; Anette Giesemann; F. Keppler; Nitrous oxide effluxes from plants as a potentially important source to the atmosphere. *New Phytologist* **2018**, *221*, 1398-1408, 10.1111/nph.15455.
5. Naoki Goshima; Toshihiro Mukai; Mamiko Suemori; Misa Takahashi; Michel Caboche; Hiromichi Morikawa; Emission of nitrous oxide (N2O) from transgenic tobacco expressing antisense NiR mRNA. *The Plant Journal* **1999**, *19*, 75-80, 10.1046/j.1365-313x.1999.00494.x.

6. Makoto Hakata; M. Takahashi; W. Zumft; Atsushi Sakamoto; H. Morikawa; Conversion of the Nitrate Nitrogen and Nitrogen Dioxide to Nitrous Oxides in Plants. *Acta Biotechnologica* **2003**, *23*, 249-257, 10.1002/abio.200390032.
7. G W Brudvig; T H Stevens; S I Chan; Reactions of nitric oxide with cytochrome c oxidase.. *Biochemistry* **1980**, *19*, 5275–5285, 10.1021/bi00564a020.
8. Rőszer, T. The Biology of Subcellular Nitric Oxide; Springer: Dordrecht: The Netherlands, 2012; pp. 3.
9. Kapuganti J. Gupta; Alisdair R. Fernie; Werner M. Kaiser; Joost Van Dongen; On the origins of nitric oxide. *Trends in Plant Science* **2011**, *16*, 160-168, 10.1016/j.tplants.2010.11.007.
10. Alejandro Chamizo-Ampudia; Emanuel Sanz-Luque; Angel Llamas; Aurora Galvan; Emilio Fernandez; Eduardo Perez-Albela Fernandez; Nitrate Reductase Regulates Plant Nitric Oxide Homeostasis. *Trends in Plant Science* **2017**, *22*, 163-174, 10.1016/j.tplants.2016.12.001.
11. Kapuganti J. Gupta; Abir U. Igamberdiev; The anoxic plant mitochondrion as a nitrite: NO reductase. *Mitochondrion* **2011**, *11*, 537-543, 10.1016/j.mito.2011.03.005.
12. X.J. Zhao; V. Sampath; W.S. Caughey; Cytochrome c Oxidase Catalysis of the Reduction of Nitric Oxide to Nitrous Oxide. *Biochemical and Biophysical Research Communications* **1995**, *212*, 1054-1060, 10.1006/bbrc.1995.2076.