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.

Keywords: 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.

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