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2.29 Positron imaging analysis of assimilation and translocation of carbon and nitrogen sources in rice plant

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Introduction

Leaf photosynthesis is known to be affected by the levels of environmental nitrogen where the plants are grown. It is also known that nitrogen assimilation needs a carbon source to produce amino acid. Thus, interaction between carbon assimilation and nitrogen assimilation is one of the most important factors regulating plant growth, in particular under elevated CO2 conditions. The suppression of photosynthesis by CO2 enrichment is associated with a decrease in total leaf nitrogen content. This suggests that the elevated CO2 condition may affect the assimilation and translocation of carbon and nitrogen sources.

It has been impossible to conduct dynamical studies in translocation and partitioning of fixed carbon as sugars and taken nitrogen as amino acids. Use of Positron Emitting Tracer Imaging System (PETIS) can visualize the real-time movement of these compounds and biosynthetic products. Here we report the results of two experiments for rice plants: effects of nitrogen supply to soil water on 15NO3- and 13NH4+ uptake; translocation of 12CO2, 15NO3- and 13NH4+ under elevated CO2 conditions.

Experiments

Rice (Oryza sativa L. cv. Nipponbare) seeds were germinated in water and cultured hydroponically in a growth chamber with a 14-h light (25°C) / 10-h dark (20°C). The procedure for production of 15NO3-, 13NH4+ and 12CO2 was described elsewhere.

1) Effects of nitrogen supply to soil water on 15NO3- and 13NH4+ uptake

15NH4+ was fed to the roots of rice plants cultivated for a month under distinct conditions: control; 4-day nitrogen deficiency; pretreatment with 0.3 mM NH4+ for 2 h after 4-day nitrogen deficiency. Meanwhile, 15NO3- was fed to the roots pretreated with 0.3 mM NO3- for 2 h after 4-day nitrogen deficiency.

2) Translocation of 12CO2, 15NO3- and 13NH4+ under elevated CO2 conditions

After rice plants were cultured on tap water for 3 weeks, half of the group was transferred to ambient (40 Pa) conditions, and the other
half to elevated CO₂ (140 Pa) conditions for 4 weeks.¹⁴NO₃⁻ and ¹⁴NH₄⁺ were fed to the roots, and CO₂ was supplied at the middle part of the newest and second newest leaves through a

Fig. 1 Schematic of the present positron imaging experiment for a rice plant (left) and a resulting PETIS image (right).

Fig. 2 ¹⁴N translocation from roots to the discrimination center. Curves show the accumulated radioactivity at the DC for different cultivation conditions: control (△); 4-day nitrogen deficiency (○); pretreatment with 0.3 mM NH₄⁺ for 2 h after 4-day nitrogen deficiency (□); pretreatment with 0.3 mM NO₃⁻ for 2 h after 4-day nitrogen deficiency (◇).
Results and discussion

1) Effects of nitrogen supply to soil water on $^{15}$NO$_3^-$ and $^{15}$NH$_4^+$ uptake: Figure 1 shows a PETIS image obtained for $^{15}$NH$_4^+$. From these imaging data, the time-course of $^{15}$N radioactivity at the discrimination center (DC) was obtained for the different pretreatment conditions, as shown in Fig. 2. This revealed that the pretreated rice with 0.3 mM NH$_4^+$ for 2 h after 4-day nitrogen deficiency and the pretreated rice plant with 0.3 mM NO$_3^-$ for 2 h after 4-day nitrogen deficiency absorbed more amounts of $^{15}$N throughout the experiment than the control plant and the plant cultivated in a 4-day nitrogen deficiency condition. This suggests that uptake of nitrogen sources from roots is induced by an increase of the nitrogen content around the roots.

It is possible that this induction of NH$_4^+$ uptake is caused by high affinity NH$_4^+$ transporter (OsAMT1;2) which is induced in NH$_4^+$-treated rice roots after nitrogen deficiency. Analysis of mutant and transgenic rice of OsAMT1;2 gene will verify the hypothesis.

The observed uptake delay between $^{15}$NO$_3^-$ and $^{15}$NH$_4^+$ at the DC may result from the fact that NO$_3^-$ is translocated directly without metabolism, whereas NH$_4^+$ needs to be assimilated into glutamine at the roots.

2) Translocation of $^{15}$CO$_2$, $^{15}$NO$_3^-$ and $^{15}$NH$_4^+$ under elevated CO$_2$ conditions

The results of this PETIS analysis detected no deference in translocation of $^{15}$NO$_3^-$, $^{15}$NH$_4^+$ and $^{15}$CO$_2$ between the rice plants cultivated in the ambient and elevated CO$_2$ conditions (data not shown). Although the elevated CO$_2$ condition may not affect the translocation of these compounds during a period of time as short as one hour, further experiments will be needed to confirm this phenomenon.

References


