Plant rhizosphere is a hotspot for greenhouse gas emissions

MINAMISAWA, Kiwamu

Consortium for Rhizosphere Biogeochemistry, Graduate School of Life Sciences, Tohoku University

Nitrous oxide (N\textsubscript{2}O) is a greenhouse gas that also degrades stratosphere ozone. Marked N\textsubscript{2}O emission were detected from soybean root systems with degraded nodules during late growth stage in field-grown soybeans. A model system developed to produce N\textsubscript{2}O emissions from soybean fields. Soybean plants inoculated with nosZ mutant of Bradyrhizobium japonicum USDA110 (lacking N\textsubscript{2}O reductase) were grown in aseptic jars. After 30 days, shoot decapitation (D, to promote nodule degradation), soil addition (S, to supply soil microbes), or both (DS) were applied. N\textsubscript{2}O was emitted only in the DS treatment. Thus, both soil microbes and nodule degradation are required for the emission of N\textsubscript{2}O from the soybean rhizosphere. The N\textsubscript{2}O flux peaked at 15 days after DS treatment. A \textsuperscript{15}N tracer experiment indicated that the N\textsubscript{2}O was derived from N fixed in the nodules.

As for nitrification, the addition of nitrification inhibitors significantly reduced N\textsubscript{2}O flux. Both AOA and AOB were detected by PCR analysis with N\textsubscript{2}O emission profile in soybean rhizosphere. The N\textsubscript{2}O flux from the nirKnosZ mutant rhizosphere was significantly lower than that from nosZ mutant, but was still 30% to 60% of that of nosZ mutant, suggesting that N\textsubscript{2}O emission is due to both B. japonicum and other soil microorganisms. Only B. japonicum nosZ+ strains could take up N\textsubscript{2}O. In particular, Fusarium spp., a soil fungus may contributed to N\textsubscript{2}O emission in soybean rhizosphere. From these results, the organic-N inside of the nodules was mineralized to NH\textsubscript{4}\textsuperscript{+}, and N\textsubscript{2}O producing processes (nitrification and denitrification) simultaneously occur in the soybean rhizosphere. We continue to examine which microbes really mediated N\textsubscript{2}O methabolism using isotopic techniques including \textsuperscript{15}N site preference of N\textsubscript{2}O molecules. N\textsubscript{2}O emissions from soybeans ecosystems can be mitigated by inoculating B. japonicum mutants with increased N\textsubscript{2}O reductase activity (Nos++ strains). The mutation of nasS gene is responsible for the Nos++ phenotype. We propose that nasS mutation might be an effective strategy to induce higher Nos activities in N\textsubscript{2}O-reducing rhizobia, such as indigenous isolates from local soybean fields or even from other important leguminous crops such as alfalfa, and thus to mitigate N\textsubscript{2}O emission.

Plants have mutualistic symbiotic relationships with rhizobia and fungi by the common symbiosis pathway, in which Ca\textsuperscript{2+}/calmodulin-dependent protein kinase (encoded by CCaMK) is a central component. Although OsCCaMK is required for fungal accommodation in rice roots, little is known about the role of OsCCaMK in rice symbiosis with bacteria. Here, we report the effect of a tos17-induced OsCCaMK mutant (NE1115) on CH\textsubscript{4} flux in low-nitrogen (LN) and standard-nitrogen (SN) paddy fields as compared with wild-type (WT) Nipponbare. Growth of NE1115 was significantly decreased compared with that of WT, especially in the LN field. The CH\textsubscript{4} flux of NE1115 in the LN field was significantly higher (156±407% in 2011 and 170±816% in 2012) than that of WT, although no difference was observed in the SN field. The copy number of pmoA was significantly higher in the roots and rhizosphere soil of WT than those of NE1115. However, mcrA copy number did not differ between WT and NE1115. These results were supported by a \textsuperscript{13}C-labeled CH\textsubscript{4}-feeding experiment. In addition, the natural abundance of \textsuperscript{15}N in WT shoots (3.05 permile) was significantly lower than in NE1115 shoots (3.45 permile), suggesting higher N\textsubscript{2} fixation in WT due to dilution with atmospheric N\textsubscript{2} (0.00 permile). Thus, CH\textsubscript{4} oxidation and N\textsubscript{2} fixation were simultaneously activated in the root zone of WT rice in the LN field, and both processes are likely controlled by OsCCaMK.

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