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CH_4 dynamics via plant- and water- pathways in tropical rice paddy fields evaluated by stable carbon isotopes

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Rice paddy fields are one of the major anthropogenic methane (CH_4) sources during irrigated growth periods. CH_4 produced in anaerobic flooded soil is released into the atmosphere through plant- and water-mediated pathways, and the CH_4 emission dynamics are mainly regulated by CH_4 production, oxidation and transportation. In the past, most CH_4 emission studies have neglected to discriminate between plant- and water-mediated pathways. However, understanding and quantifying the different pathways is elemental for comprehending CH_4 emission dynamics and constraining uncertainties CH_4 budget estimates in global rice paddy fields.

We investigated CH_4 emission dynamics via plant- and water-mediated pathways during the reproduction stage in tropical Thailand rice paddy fields in 2014 using natural abundance carbon stable isotope ratios (δ^{13}C-$CH_4$and δ^{13}C-CO_2). The CH_4 flux and δ^{13}C-CH_4 through each pathway were measured using two automated closed chambers. The CH_4 concentration and δ^{13}C-CH_4 in the chamber headspace air were analyzed using a wavelength-scanned cavity ring-down spectroscopy CH_4/CO_2 analyzer (G2201-i, Picarro Inc., USA). The gases in planted and unplanted soil (rhizosphere and non-rhizosphere, respectively) were collected using diffusive equilibration samplers and analyzed by G2201-i.

The soil gases in the rhizosphere were enriched with $^{13}CH_4$ and $^{12}CO_2$ relative to those in the non-rhizosphere. Mass-balance equations showed that the fractions of CH_4 oxidation and production by acetoclastic methanogens in the rhizosphere surpassed those in the non-rhizosphere due to oxygen supply and organic materials through rice roots, respectively. The values of δ^{13}C-CH_4 emitted via plant in the daytime were higher than those in the nighttime, reflecting higher CH_4 oxidation rates in the rhizosphere during the daytime. In the daytime, even with the rhizospheric CH_4 oxidation, the plant-mediated CH_4 emission rates were higher than in the nighttime. This could be due to the increase in CH_4 transportation conductance through rice plants due to the increase in soil surface temperature and the decrease in atmospheric pressure. Also the water-mediated CH_4 emissions were higher in the daytime than in the nighttime. However, in contrast to the plant-mediated pathway, the daytime δ^{13}C values of CH_4 emitted via water were lower than the nighttime values. This indicates that bubble ebullition events in the daytime transported ^{12}C-enriched CH_4 without being largely affected by CH_4 oxidation, whereas diffusion processes and soil surface oxidation in the nighttime produced ^{12}C-depleted CH_4. Our research shows that diurnal variations of emitted δ^{13}C-CH_4 via plant are contrary to those via water due to the differences in CH_4 transportation and oxidation processes, and that rice roots play a key role in affecting CH_4 oxidation and production in paddy soil.