**CH₄ 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 (CH₄) sources during irrigated growth periods. CH₄ produced in anaerobic flooded soil is released into the atmosphere through plant- and water-mediated pathways, and the CH₄ emission dynamics are mainly regulated by CH₄ production, oxidation and transportation. In the past, most CH₄ emission studies have neglected to discriminate between plant- and water-mediated pathways. However, understanding and quantifying the different pathways is elemental for comprehending CH₄ emission dynamics and constraining uncertainties CH₄ budget estimates in global rice paddy fields.

We investigated CH₄ 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 (δ¹³C-CH₄ and δ¹³C-CO₂). The CH₄ flux and δ¹³C-C-CH₄ through each pathway were measured using two automated closed chambers. The CH₄ concentration and δ¹³C-CH₄ in the chamber headspace air were analyzed using a wavelength-scanned cavity ring-down spectroscopy CH₄/CO₂ 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 ¹³CH₄ and ¹²CO₂ relative to those in the non-rhizosphere. Mass-balance equations showed that the fractions of CH₄ oxidation and production by aceticlastic methanogens in the rhizosphere surpassed those in the non-rhizosphere due to oxygen supply and organic materials through rice roots, respectively. The values of δ¹³C-CH₄ emitted via plant in the daytime were higher than those in the nighttime, reflecting higher CH₄ oxidation rates in the rhizosphere during the daytime. In the daytime, even with the rhizospheric CH₄ oxidation, the plant-mediated CH₄ emission rates were higher than in the nighttime. This could be due to the increase in CH₄ transportation conductance through rice plants due to the increase in soil surface temperature and the decrease in atmospheric pressure. Also the water-mediated CH₄ emissions were higher in the daytime than in the nighttime. However, in contrast to the plant-mediated pathway, the daytime δ¹³C values of CH₄ emitted via water were lower than the nighttime values. This indicates that bubble ebullition events in the daytime transported ¹²C-enriched CH₄ without being largely affected by CH₄ oxidation, whereas diffusion processes and soil surface oxidation in the nighttime produced ¹²C-depleted CH₄. Our research shows that diurnal variations of emitted δ¹³C-CH₄ via plant are contrary to those via water due to the differences in CH₄ transportation and oxidation processes, and that rice roots play a key role in affecting CH₄ oxidation and production in paddy soil.