LETTER

What is the relationship between soil methane oxidation and other C compounds?

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We measured potential rates of methane (CH4) oxidation in semiarid soil and observed greater rates of CH4 oxidation in the wet season than the dry season (Sullivan et al., 2013). Importantly, we demonstrated that common mechanisms (soil water, soil texture), thought to control methane (CH4) oxidation in upland soil did not explain seasonal patterns in potential CH4 oxidation in semiarid soil. Instead, dissolved organic carbon (DOC) was the chemical characteristic that best predicted CH4 oxidation. We then used a series of laboratory studies to attribute this trend to the ability of CH4 oxidizers in dry ecosystems to metabolize both DOC and CH4. Such mixotrophic activity by CH4 oxidizing bacteria (MOB) has been found in other studies (e.g., Conrad, 2009; Dunfield et al., 2010; Dedysh & Dunfield, 2011; Fender et al., 2012). On the basis of the correlation between DOC and CH4 oxidation rates, we speculated that facultative use of DOC by MOB increased CH4 oxidation in the wet season. In their Letter to the Editor, Zhou et al. (2013) proposed an alternative hypothesis that explains lower rates of CH4 oxidation in dry seasons than wet seasons: ethylene produced by water-stressed plants inhibits CH4 oxidation during dry seasons. This intriguing hypothesis, which thus far is unsupported by data, warrants thorough investigation, but we desire to respond to several issues raised by their commentary on our manuscript.

We absolutely agree with Zhou et al. (2013) that ‘more specific experimental work is needed’ before definitively linking DOC and CH4 oxidation. With this in mind, we posed the title of our manuscript as a question and repeatedly encouraged further investigation. Our results were unexpected and novel because they demonstrated soil CH4 oxidation rates in semiarid ecosystems to be independent of soil physical conditions but related to DOC concentration. Here, we consider the hypothesis (that inhibition of CH4 oxidation by plant-derived ethylene explains our seasonal patterns of CH4 oxidation) proposed by Zhou et al. (2013) in light of our original manuscript and other data, we have gathered from the same study system.

Conclusive evidence for CH4 inhibition by other substrates is generally elusive. A meta-analysis of ammonium (NH4) inhibition of CH4 oxidation, probably the most well-studied example of CH4 oxidation inhibition, demonstrated equivocal effects of NH4 (whether alone or in combination with other N forms) on CH4 oxidation (Aronson & Helliker, 2010). Is there a stronger case for ethylene inhibition of CH4 oxidation? A study cited as evidence for ethylene inhibition of CH4 oxidation by Zhou et al. (2013) observed ethylene production from anaerobic decomposition of organic matter in wet periods (Xu & Inubushi, 2009) rather than ethylene production from water-stressed plants during dry periods. Yet, we measured the highest rate of CH4 oxidation in the wet season, and it occurred in fine textured soils with greater possibility of anaerobic conditions than other coarser-textured soils we measured. Because the concentration of ethylene required to inhibit CH4 oxidation varies substantially (Xu & Inubushi, 2009), the effect of ethylene on CH4 oxidation, if it exists at all, is likely variable as well. Unfortunately, at this time, no direct evidence exists to suggest that water-stressed plant roots emit sufficient ethylene to inhibit CH4 oxidation.

We can also reconsider another study (Sullivan et al., 2012) in light of the proposed relationship between CH4 oxidation rates and ethylene. Ethylene has been shown to inhibit NH4 oxidation (McCarty & Bremner, 1991; Xu & Inubushi, 2009) as well as CH4 oxidation. In a parallel but separately published experiment from the same study sites and using soil from the same cores as the CH4 measurements in Sullivan et al. (2013), Sullivan et al. (2012) demonstrated that potential NH4 oxidation (potential nitrification) in dry soils was equal to or greater than NH4 oxidation in wet soils. Based on the hypothesis proposed by Zhou et al. (2013), we would expect dry season ethylene production to suppress NH4 oxidation as well as CH4 oxidation, but this was not the case.

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Finally, the stimulation of CH$_4$ oxidation by DOC and the inhibition of CH$_4$ oxidation by ethylene are not mutually exclusive hypotheses. If it is ultimately shown that stressed plants inhibit CH$_4$ oxidation via ethylene production, stressed plants may also exude less oxidized C belowground in dry seasons. However, in the wet season, facultative use of DOC by CH$_4$ oxidizers AND reduced ethylene inhibition may increase CH$_4$ oxidation.

Smith (1976) described ethylene thus: ‘Important, far-reaching claims have been made about its role in soil biology.’ Unfortunately, the link between plant stress, ethylene production, and CH$_4$ oxidation is still largely conceptual. We recommend future investigators experimentally manipulate soil DOC with compounds that mimic root exudates and microbially derived solutes and measure responses of soil CH$_4$ oxidation. Ideally, such a study will have both field (observational) and laboratory-based (mechanistic) components. We encourage the future research endeavors described by Zhou et al. (2013) and others designed to elucidate the relative effects of DOC and ethylene on CH$_4$ oxidation.

References


