Partitioning Nitrous Oxide (N_2O) Emissions from Ammonia Oxidizing Bacteria (AOB) and Ammonia Oxidizing Archaea (AOA) in Corn and Switchgrass Ecosystems

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Project Goals:

Our goal in this project is to understand the relative importance of ammonia oxidizing bacteria (AOB) and ammonia oxidizing archaea (AOA) as sources of nitrate and nitrifier-derived nitrous oxide (N_2O) in potential bioenergy cropping systems. In particular we aim to understand how AOA and AOB respond to nitrogen fertilizer in switchgrass vs. corn cropping systems. We use 1-octyne, a recently developed and tested chemical inhibitor of AOB (Taylor *et al*., 2013, Taylor *et al*., 2015) to distinguish activities and emissions from AOA vs. AOB.

Abstract:

Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential 300 times higher than CO_2. The atmospheric N_2O abundance has increased from a preindustrial baseline of 270 to 329 ppb_v as of 2016 (http://cdiac.ornl.gov, accessed on December 20, 2016), largely due to human activities. N_2O also reacts with electronically excited oxygen atoms O (^1D) in the stratosphere to form nitric oxide (NO), which catalyzes ozone depletion (Portmann *et al*., 2012). Gross anthropogenic N_2O emissions of 6.2 Tg N_2O-N yr^{-1} are dominated by agriculture (Davidson and Kanter, 2014). As agricultural soils contribute N_2O more than any other anthropogenic components, understanding sources of N_2O from agricultural soils is critically important for developing N_2O mitigation practices (Paustian *et al*., 2016).

Soil N_2O emissions mainly result from two microbial processes including denitrification and nitrification. Nitrification converts ammonia (NH_3) to nitrite (NO_2^-) and nitrate (NO_3), with N_2O as a byproduct (Robertson and Groffman, 2015). Nitrification is performed mainly by two taxa: ammonia oxidizing bacteria (AOB) and ammonia oxidizing archaea (AOA). Recent studies have confirmed that both AOA and AOB are able to produce N_2O (Stieglmeier *et al*., 2014). However, the relative contribution of AOA and AOB to N_2O is still unclear. Our understanding of the mechanisms regulating N_2O production from AOA and AOB is hindered mainly by the difficulties of isolating pure cultured ammonia oxidizers. For example, there is currently only one pure culture of soil AOA (*Nitrososphaera viennensis EN76*) available for physiological studies.

In this study, we examined the seasonal responses of AOA and AOB following nitrogen fertilizer application to annual (corn) and perennial (switchgrass) cropping systems. We took soil samples before and 1, 5, 13, 21, and 42 days after fertilization in late fall of 2015 and spring and summer of 2016. Using 1-octyne as a selective inhibitor targeting AOB in short-term (24h) incubations, we were able to separate the N_2O and NO_3^- contributed by AOA and AOB, respectively.

Our results show that: 1) In both corn and switchgrass ecosystems, AOB were the main contributors to nitrate accumulation in spring and summer (60-75% of accumulated nitrate) while in late fall AOA and AOB contributed equally; 2) AOB dominated N_2O emissions (> 80%) in spring and summer in both corn and switchgrass ecosystems, but in late fall AOA and AOB contributed equally to N_2O in corn while AOB were the major N_2O contributors (60%) in switchgrass ecosystems; 3) AOB but not AOA produced more nitrate in response to fertilization in both corn and switchgrass; the AOB response lasted 42 days; and 4) both AOA and AOB produced more N_2O in response to fertilization in corn but not in switchgrass.

We conclude that AOA and AOB have different responses to nitrogen fertilization in different cropping systems. In most seasons more nitrate and N_2O was produced by AOB than AOA, and AOB also tended to be more responsive to fertilizer additions.

References

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