Nitrification and denitrification pools of N_2O: Acetylene inhibition study

Kirill Kostyanovsky (kirya.kostyanovsky@wsu.edu) WSU, Dave Huggins USDA-ARS, Claudio Stockle WSU, Tina Karimi WSU, and Sarah Waldo WSU

Soil moisture is one of the factors affecting emissions of nitrous oxide (N_2O), a highly potent greenhouse gas that is a major contributor to climate change from agricultural land. Water present in soil fills the pore space, decreasing the oxygen concentration and creating anoxic conditions that favor reductive processes. Dry soil allows for higher oxygen levels, resulting in an increase in oxidative processes. N_2O is a by-product of ammonia oxidation (nitrification) and reduction in nitrate (denitrification), which occur under oxidative and reductive conditions, respectively. To be able to mitigate the effects of agricultural practices on global climate change, it is necessary to assess nitrification and denitrification pools of N_2O. We used a well-known substrate, acetylene, to prevent nitrification and therefore eliminate the respective pool of N_2O by deactivating the ammonia monooxyhygenase enzyme, which catalyzes the ammonia oxidation process. The inhibition reaction happens at 0.1 to 10Pa (0.01%) concentrations of acetylene. At 100Pa (0.1%) concentrations, acetylene also affects denitrification by inhibiting the reduction of N_2O to nitrogen gas.

IMPACT

To mitigate the effects of agricultural practices on global climate change, it is necessary to assess nitrification and denitrification pools of nitrous oxide (N_2O). The study helps us understand the scale of these processes in the irrigated system. This experiment is designed to develop best predictions for the sources of N_2O emissions at variable moisture levels.

We evaluated the effects of acetylene injection in situ, with nitrogen and repeat water additions, on carbon dioxide (CO_2) and N_2O emissions in the long-term no-tillage winter wheat site at Palouse Conservation Field Station in Pullman, WA. We implemented two Li-Cors 8100A coupled with two LGR 23r N_2O analyzers in continuous flow through a chamber system for monitoring CO_2 and N_2O emissions in the short-term microplot study between September 11 and 21, 2013. On September 11, 2013, we established the treatments with and without ammonium nitrate (NH_4NO_3) at at 150 kilograms N per hectare (134 pounds N per acre) fertilization and acetylene injection at 0.01% immediately following additions of water to saturation and fertilization (0 hours), as well as 12 hours and 24 hours later. On September 15, 2013, we modified the nonfertilized treatments to include ammonium nitrate (NH_4NO_3) at 134 134 pounds N per acre fertilizer and modified the acetylene levels to include the 0.1%, 0.01%, and no acetylene levels. We repeatedly added water to the plots to saturation in order to obtain the N_2O emissions at a range of moisture levels (Figure 1).

A soil core incubation was established concurrently with the in situ acetylene injection study, because this technique is widely used by researchers to obtain nitrification to denitrification as well as potential denitrification ratios to predict actual and potential denitrification for field chamber data. Soil cores from a depth of 8 inches (20 centimeters) were placed in 12 inch (30 centimeter) clear plastic tubes, which were inserted in soil in the field adjacent to the chamber study. We established the soil core treatments at 150 kilogram N per acre at 0.01% of acetylene and no acetylene at 90%, 60%, and 30% water-filled pore space (WFPS), as well as 0.1% of acetylene at 90% WFPS. The cores

Automated static chambers monitor greenhouse gas emissions on microplots for a study designed to help predict sources of nitrous oxide emissions at different moisture levels. Photo by Kirill Kostyanovsky.

were maintained sealed for 22 hours at a time; an air sample from the headspace of each core was then collected and analyzed in the laboratory on a gas chromatograph for N_2O concentration. The experiments were conducted following harvest during the times most likely to be affected by increased temperatures.

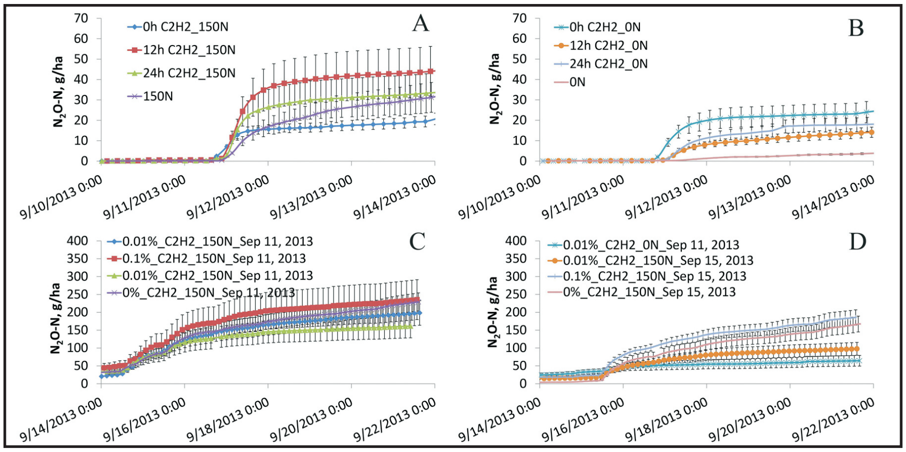

Figure 1. *Emissions of nitrous oxide with and without additions of ammonium nitrate 134 pounds NH_4NO_3-N per acre and acetylene injection in situ in the chamber microplot study.*

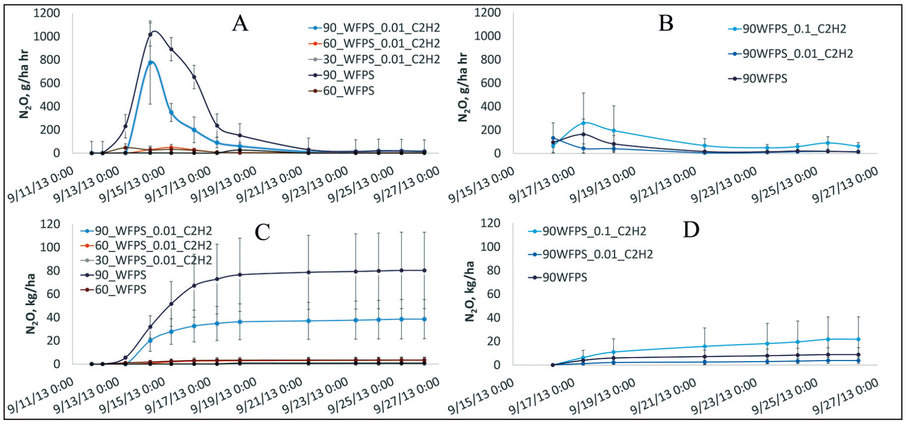

Figure 2. *Levels of nitrous oxide with and without additions of 134 pounds NH_4NO_3-N per acre and acetylene additions in the soil core incubation study.*

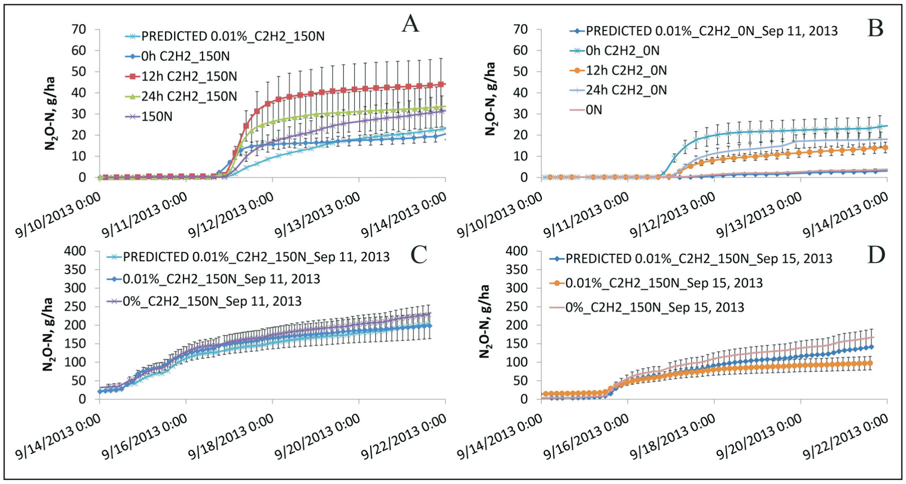

Figure 3. *Predicted levels of denitrification-borne nitrous oxide (N_2O) compared to in situ levels of N_2O with and without additions of 134 pounds NH_4NO_3-N per acre and acetylene injection in situ in the chamber microplot study.*

The initial nitrogen fertilization and additions of water resulted in higher N_2O emissions from the fertilized treatments than from the treatments with no fertilizer added. Effects of acetylene injection timing on N_2O emissions were detected only from the injection at 0 hours, likely due to acetylene efficiently penetrating the soil pore space only prior to saturation with water during the first several days of the study (Figures 1a and 1b). Further repeat additions of water and acetylene injections resulted in decreased N_2O emissions from all 0.01% acetylene treatments compared to no acetylene treatment, and in increased N_2O levels in 0.1% acetylene treatments (Figures 1c and 1d). This showed that multiple water additions and acetylene injections could be efficient in blocking nitrification and reduction of N_2O to N_2.

The levels of N_2O were highest in the 90% WFPS with no acetylene treatment in the soil core incubation study (Figures 2a and 2c). This was indicative of both nitrification- and denitrification-borne N_2O production upon initial wetting at near saturation levels. The fraction of N_2O originating from denitrification was 0.93 at 60% WFPS, 0.48 at 90% WFPS, and 0.1 at 30% WFPS. This was likely due to the slow rate of nitrification in the 90% WFPS treatment, resulting in prolonged nitrification-borne N_2O emissions compared to the 60% WFPS treatment, which favors faster nitrification due and yet had sufficient moisture levels for denitrification to occur. Denitrification potential at 90% WFPS was two times higher than actual N_2O emissions and eight times higher than the level of N_2O from denitrification (Figures 2b and 2d). Predicted levels of denitrification based on the core incubation data matched well with the measured denitrification levels after several water additions and acetylene injections (Figure 3). Our data showed that 85% to-88% of all N_2O emissions in the field study originated from denitrification.

Overall, the soil core incubation experiment demonstrated much higher rates of N_2O emissions than the in situ chamber microplot study. Lower cumulative rates of N_2O in the microplot study were likely a result of short-lived spikes in soil moisture due to drainage, even with repeat water additions. Another likely factor was decreased retention of ammonia and nitrate in the soil due to rapid nitrification and leaching of nitrogen with added water. The study showed that in situ chamber measurements are required to obtain realistic N_2O emission values.