Nitrous Oxide Emissions from an Irrigated Almond Orchard

Project No.: **09-AIR2-Smart**

Project Leader: David R. Smart
Associate Professor
Department of Viticulture and Enology
UC Davis
One Shields Ave.
Davis, CA 95616
(530) 754-7143
drsmart@ucdavis.edu

Project Cooperators and Personnel:
Daniel L. Schellenberg, Christine M. Stockert
Maria del Mar, and Alsina Marti, UC Davis

Objectives:

1) To compare N_2O emissions from two different forms of nitrogen (N) fertilizer, urea ammonium nitrate and calcium ammonium nitrate.
2) To evaluate temporal variability of N_2O emissions with respect to environmental factors such as volumetric water content and temperature.
3) To determine temporal dynamics of N_2O emissions with respect to soil inorganic N pools during a soil drying period.

Interpretive Summary:

Nitrous oxide (N_2O) emissions were the greatest within hours (24-48) of a fertirrigation event. There appears to be greater flux of N_2O emission from urea ammonium nitrate (UAN) as compared to calcium ammonium nitrate (CAN), however statistical significance has not been confirmed and further analysis will be conducted to confirm or reject this observation. Nitrous oxide emissions appear to be driven by the size of the inorganic pool of N and by temperature. The rate of N_2O emissions was different during predawn, morning and late afternoon sampling rounds. Furthermore, faster soil drying rates in June compared to April appear to lead to greater N_2O emissions. Our efforts to model spatial N_2O emissions indicate emissions from our orchards may be lower than for other agricultural systems.

(For additional research related to this project please see:
PREC 2 Brown – Development of Leaf Sampling and Interpretation Methods for Almond/Development of a Nutrient Budget Approach to Fertilizer Management in Almond)
HORT 11 Shackel/Sanden – Fertigation: Interaction of Water and Nutrient Management
HORT 11(b) Sanden/Shackel – Fertigation: Interaction of Water & Nutrient Management – Kern Co.
HORT 13 Lampinen - Development and Testing of a Mobile Platform for Measuring Canopy Light Interception and Water Stress in Almond)

Materials and Methods:

Temporal Variation in N_2O Emissions

Sampling was conducted during the spring, summer and fall of 2009 at Paramount Farming Company's Belridge Almond Ranch hear Lost Hills, CA on a sandy (sandy-clay) loam soil under fanjet irrigation. University of California Cooperative Extension, Bakersfield, under the expert guidance of Blake Sanden determined the timing of irrigation and fertirrigation applications. The experimental design was a randomized block design with two treatments and five blocks for a total of ten field plots. The treatments were UAN and CAN at a rate of 200 lb/acre N split into 40 lb/acre N in February and October (data not presented) and 60 lb/acre N in April and June (data presented herein). We sampled following the fertigation events for four and eight days in April and June, respectfully, with periodic sampling in July, August and September.

In each plot, one 8-inch polyvinyl chloride (PVC) ring placed mid-way between fanjet applicators remained in the same location. In April, we conducted multiple daily rounds to see when peak flux occurred. In June, July and August, we captured peak fluxes during late afternoon when air temperature peaked and in June predawn and morning fluxes were captured during lower daily temperatures. Nitrous oxide gas sampled from a 3.3-L plastic chamber placed over the ring was removed from the headspace at 0, 50 and 100 min with syringes and injected in evacuated vials. Analysis of N_2O showed a linear flux using the aforementioned sampling method. A digital multimeter (FLUKE, Omega Engineering) attached to a thermocoupler inserted into the headspace determined chamber temperature and a digital 8-inch thermometer was used for soil temperature.

Soil samples collected in adjacent plots of the same treatment were extracted to 30 cm depth, removed of roots and debris, and mixed. An aliquot of soil placed into soil tins weighed, dried at $105^{O}C$ for 48 h and reweighed was used to determine the gravimetric water content. Standard cores of 325 cm^3 were used to determine soil bulk density and to calculate volumetric water content (VWC). A separate aliquot of soil placed in cups containing 2M KCl was used to determine soil NH_4^+ and NO_3^- using a flow injection analyzer method.

Spatial Variation in N_2O Emissions

In order to characterize spatial variability of N_2O emissions around a drip irrigation emitter, transects were established to outline flux chamber positions along the planted row (berm) and across the row and into the alley, or parallel and perpendicular, respectively, to the vine/tree row. Transects crossed each other at the drip irrigation emitter. Nitrous oxide emissions from each of three repetitions of 7 flux chambers x 2 transects (n = 3) were modeled according to a Gaussian distribution. Then, each distribution was rotated through a central pivot created at the measurement taken from the drip zone, which corresponded to the peak flux rate and inflection of the modeled distribution. This was compared with a two dimensional grid where each cell in the grid was populated using a stochastic approach by statistically constraining estimates of emissions based on observations across each transect, where

$$z = 1/\sqrt{2\pi}\, e^{(x^2+y^2)/2}$$

z is the N_2O emission rate and x and y is the respective estimates of N_2O emission based on the modeled values.

Results and Discussion:

Temporal Variation in N_2O Emissions

Nitrous oxide emissions after the two fertigation events showed distinct differences. In April, N_2O emissions peaked at 50 ug m^{-2} hr^{-1} for CAN and up to 95 ug m^{-2} hr^{-1} for UAN. In June, N_2O emissions peaked at 150 ug m^{-2} hr^{-1} for CAN and about 400 ug m^{-2} hr^{-1} for UAN (**Figure 1**). In June, sampling rounds were conducted predawn, in the morning and late afternoon to capture fluxes at different times of day. Each consecutive round led to an emissions decline but each at a different rate (**Figure 2**). In July, August and September, N_2O emissions were far lower with peak fluxes of 7ug m^{-2} hr^{-1}. Our results indicate that N_2O emissions from almond orchards occur, in general, after fertilizer applications. These events have lasted from 36 (**Figure 4**) up to 100 hours (**Figure 2**). Our results confirm the requirement to focus intensive measurements after fertilizer applications to accurately quantify emissions. Furthermore, substantial potential may exist to reduce N_2O emissions by focusing on mode of application and environmental conditions.

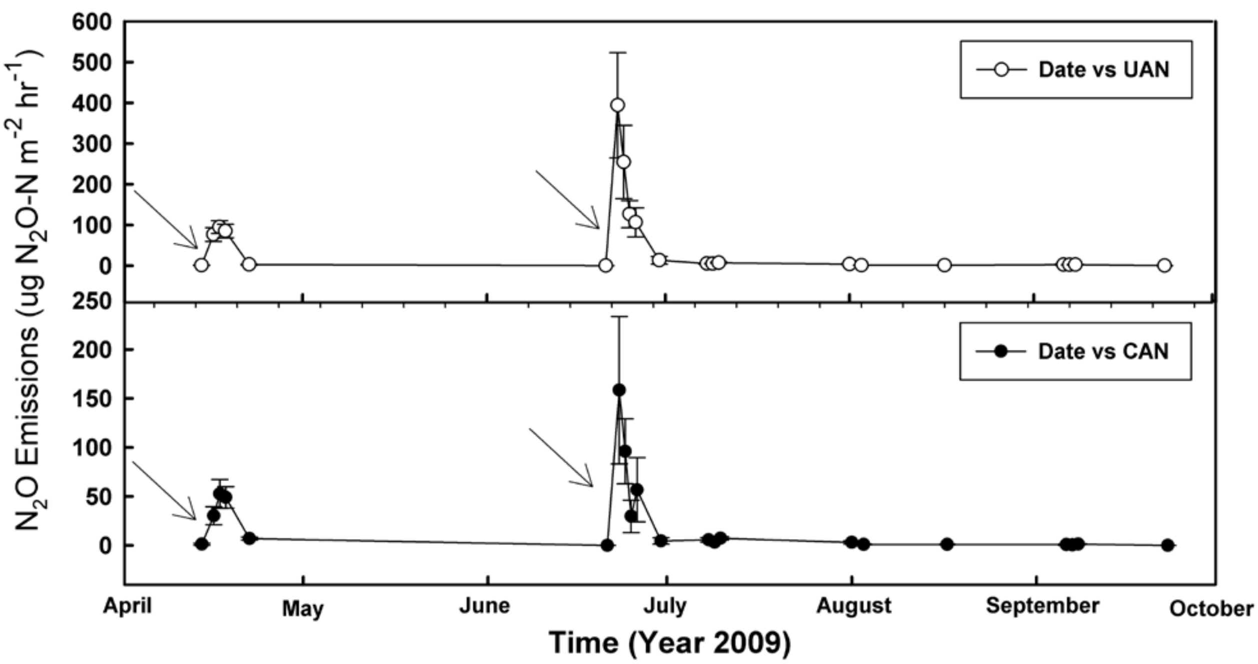

Figure 1. Nitrous oxide emissions after application of 60 lb per acre urea ammonium nitrate (UAN) and calcium ammonium nitrate (CAN). Arrows indicate timing of N fertilizer application in Lost Hills, CA 2009.

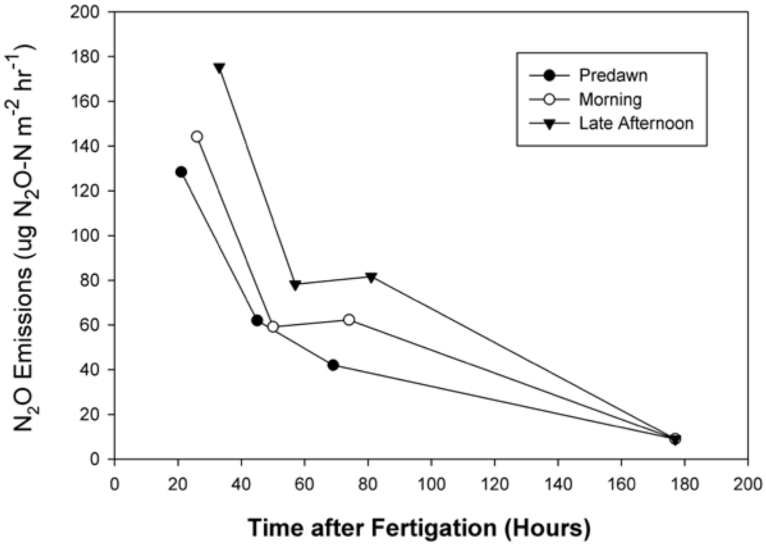

Figure 2. Sampling of N_2O emissions during predawn (5am), morning (10 am) and late afternoon (3 pm) sampling rounds in Lost Hills, CA June 2009.

In June, VWC peaked on day 1 after the fertigation event and appeared to mimic the concentration of NH_4^+. On the other hand, concentrations of NO_3^- showed a steady increase over the same period of time (**Figure 3**). N_2O emissions are regulated by aerobic and anaerobic conditions, in addition to soil inorganic N (Khalil et al., 2004; Li et al., 2002). These results may indicate that immediate N_2O fluxes may be the result of denitrification due to increased VWC followed by a greater contribution of nitrification after soil drying (Panek et al., 2000).

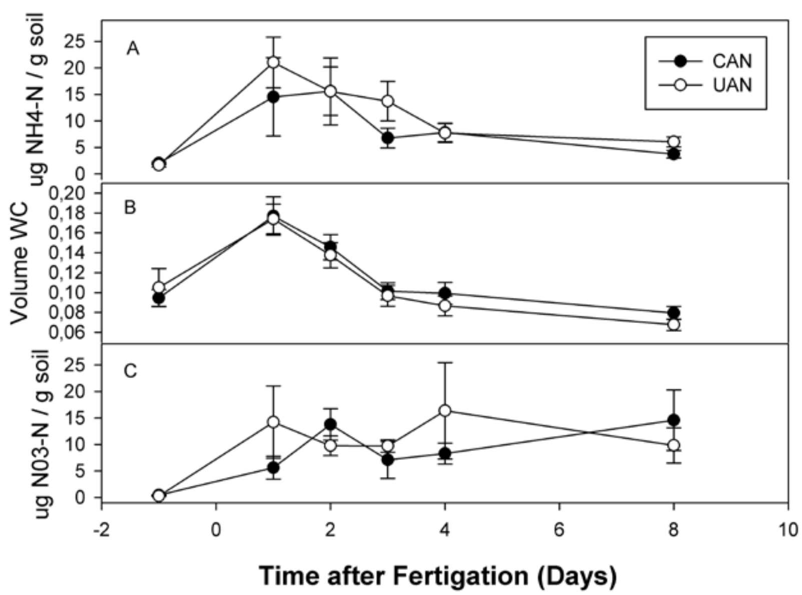

Figure 3. Soil concentrations of ammonium (NH_4+), volumetric water content (Volume WC) and soil concentrations of nitrate (NO_3^-) during 8 days after a fertirrigation event at Day 0 in Lost Hills, CA June 2009.

Spatial Variation in N2O Emissions

Spatial variation in N_2O emissions was notable and predictable. Shown in **Figure 4** is a summary of N_2O emissions from the irrigation and fertigation drip zone as compared to the alley or tractor row for a fertigation event. Note that emissions throughout the orchard are more uniform for the microjet system. Finally, three dimensional models in **Figure 5** will be used to spatially quantify N_2O emissions by querying temporal distributions shown in **Figure 2**.

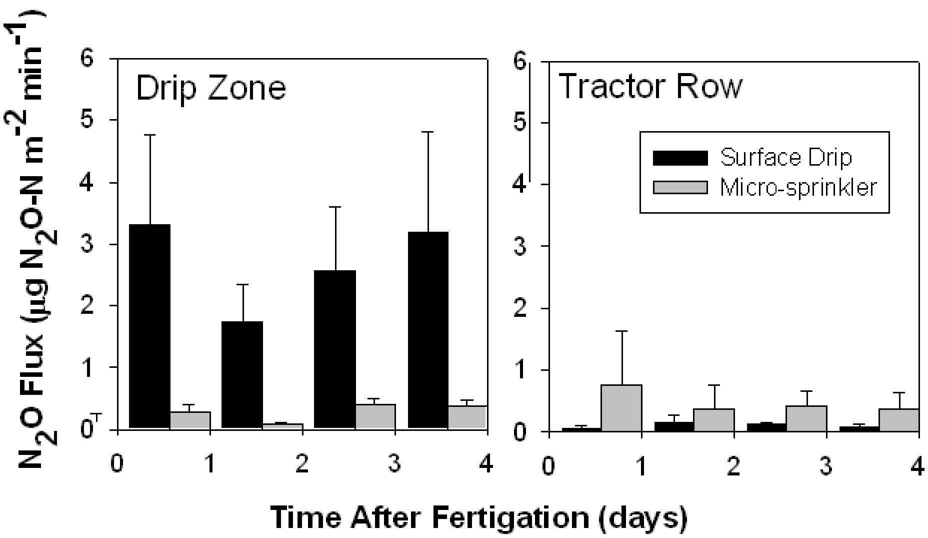

Figure 4. Soil N_2O emissions from surface drip and fanjet system before, during and after application of 60 lbs/acre urea ammonium nitrate (UAN). Samples were obtained from around the Nickels Soil Laboratory orchard within the drip zone and within the tractor row in Arbuckle, CA.

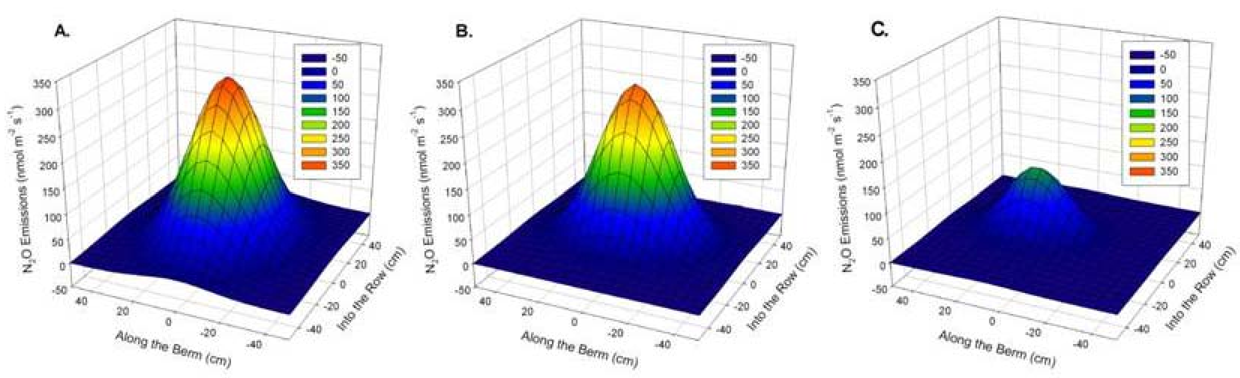

Figure 5. Shown are modeled emissions for a simulated 15 lb per acre N fertigation event in November 2007. Data was used to develop models in two dimensions and to spatially constrain emissions following an overnight fertigation event for 9:00 a.m. (A), 12:00 p.m. (B) and 3:00 p.m. (C).

Conclusions:

Future work will help identify the mechanisms behind the higher fluxes of UAN compared to CAN. Furthermore, we will continue sampling different areas of the orchard floor to conduct a comprehensive spatial evaluation of N_2O emissions. Finally, continued research into emissions rate as related to temperature, VWC and inorganic soil N content will further aid the construction of an annual budget of N_2O emissions for irrigated almond orchards.

References:

Khalil, K., B. Mary, and P. Renault. 2004. Nitrous oxide production by nitrification and denitrification in soil aggregates as affected by O_2 concentrations. Soil Biology and Biochemistry 36:687-699.

Li, X., T. Nishio, Y. Uemiya, and K. Inubushi. 2002. Gaseous losses of applied nitrogen from a corn field determined by 15N abundance of N_2 and N_2O. Communications in Soil Science and Plant Analysis 33:2715-2727.

Panek, J.A., P.A. Matson, I. Ortiz-Monasterio, and P. Brooks. 2000. Distinguishing nitrification and denitrification sources of N_2O in a Mexican wheat system using 15N. Ecological Applications 10:506-514.