

Assessment of Baseline Nitrous Oxide Emissions in Response to a Range of Nitrogen Fertilizer Application Rates in Corn Systems

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PROBLEM: There is little doubt that the increase in the greenhouse gas nitrous oxide (N_2O) in the atmosphere is mainly due to the use of fertilizer and manure (Davidson 2009). In California, N_2O contributes about one third of the total GHG emissions from California's agriculture sector. With the passage of the Global Warming Solutions Act (AB 32), quantifying N_2O emission from California agricultural land is vital to determining GHG emission budgets needed to address the mandated reduction in GHG emissions by 2020. Meta-analyses based on over 1000 studies found that fertilizer nitrogen (N) application rates have significant effects on N_2O emissions (Bouwman et al. 2002; Eichner 1990; Stehfest and Bouwman 2006). Moreover, the difference between the mineral available N and crop N uptake seems to have an even greater influence on N_2O emissions than the absolute amount of fertilizer applied. Therefore, assessing both N fertilizer use by the crop and N_2O emissions are needed to develop management practices that mitigate N_2O while maintaining yield potential.

Among California's field crops, corn has the largest acreage (610,000 acres). To-date, some studies to develop annual N_2O emission budgets for corn systems under CA specific conditions are under way. For example, N_2O emissions from forage production systems (silage corn) receiving dairy manure, liquid manure ('lagoon water'), and synthetic fertilizer are being assessed in a project funded by the California Air Resources Board (CARB) ("Assessment of Baseline Nitrous Oxide Emissions in California's Dairy Systems," 2010-2013, PIs W.R. Horwath, M. Burger, S. Pettygrove), and the effects of nitrification inhibitors and spacing of fertilizer bands on N_2O emissions in corn systems are evaluated in another CARB project ("Evaluating Mitigation Options of Nitrous Oxide Emissions in California Cropping Systems," 2012-2014, PIs M. Burger, W.R. Horwath, J. Six). However, **missing is a systematic, controlled investigation on the effect of N fertilizer levels on N_2O emissions in irrigated corn production.** Research has shown that N_2O emissions increase sharply in response to N additions that exceed crop N needs (Edis et al. 2008; McSwiney and Robertson 2005). Therefore, a systems approach that simultaneously evaluates N_2O emissions, crop performance, N use efficiency, and potential environmental impacts with various levels of N fertilizer applications is needed to **develop best management practices that minimize N_2O emissions without sacrificing corn yield potential.**

OBJECTIVES: The goals of this project are to (1) determine the annual N_2O emissions in response to a range of N fertilization rates in an irrigated corn cropping system; (2) calculate yield-scaled N_2O emissions (e.g. $g N_2O-N g^{-1} N_{harvested}$) and N_2O emission factors (EF) for each fertilizer level; (3) determine the nitrogen use efficiency (defined as the ratio of N yield of the corn crop to applied N) and optimum N rate (economic N yield) of the corn crop; (4) identify key environmental conditions affecting N_2O flux. The N_2O emission data and the yield response to the varying N fertilizer levels can be used to develop best management practices and to calibrate and validate models, which are currently calibrated for other CA field crops and perennial systems.

PROJECT PLAN: This is a two-year (2013-2014) research project that will be conducted on grower fields. The following tasks will be carried out:

1. Site selection. A furrow-irrigated corn production site of a collaborating grower in the Sacramento or San Joaquin Valley will be chosen. The goal is to select a field with a soil texture and organic matter content representative for a large percentage of corn acreage.

2. Experimental design. We will set up five fertilizer N treatments, consisting of a pre-plant N-P-K and an urea ammonium nitrate (UAN) side dress addition in a randomized complete block design. Nitrogen will be applied at a rate of 0, 75, 150, 225, and 300 lbs N/acre to microplots of 10m length and six rows width. Each fertilizer N treatment will be replicated three times.

3. N₂O flux measurements. Static chamber techniques (Hutchinson and Livingston 1993) will be used to take N₂O flux measurements. We have experimented with various combinations of flux chambers and bases in furrow-irrigated corn systems and typically use three chambers installed in different locations of each replicate. Gas samples will be removed via syringe and needle at regular intervals (e.g. 0, 30 and 60 min) and stored in evacuated glass vials with butyl rubber septa. The samples will be analyzed by a Shimadzu gas chromatograph linked to an auto sampler. Intensive N₂O monitoring will take place after N fertilization and irrigation or rainfall events and will continue until N₂O fluxes subside to background levels. When N₂O flux has receded and soils are relatively dry, measurements will be taken less frequently.

4. Ancillary data & yield measurements. Soil and air temperature, and soil moisture will be recorded during each gas sampling. Inorganic N in the top 60 cm will be measured pre-plant and post-harvest. For the remainder of the time inorganic N will be measured to a depth of 15 cm. Bulk density in the 0-15 cm layer will be determined seasonally. The ancillary data will be used to characterize the environmental factors that control N₂O emissions. Corn yields will be measured by hand harvest. Crop N uptake and harvested grain will be determined from yield data and concentrations of N in subsamples of biomass and grain. Tissue N will be measured by a carbon and nitrogen analyzer (Costech Analytical Technologies, Valencia, CA).

5. Calculations & deliverables. We will calculate annual N₂O emissions by assuming that the measured fluxes represent mean daily fluxes, and that mean daily fluxes change linearly between measurements. Differences between treatments will be assessed using ANOVA and standard mean separation procedures. For the yield-scaled N₂O emissions, N₂O-N will be divided by grain-N (per unit area). The emission factors will be calculated as the amount of N₂O-N divided the amount of fertilizer N applied (per unit area). Apparent N use efficiency will be calculated as grain N content divided by applied fertilizer N (per unit area). The economic N yield will be defined as the least amount of fertilizer N necessary to obtain the highest yield at this site.

BENEFITS TO FREP GOALS: (1) The project is directed towards CDFA's and FREP's mission to advance the agronomically sound and environmentally safe use of fertilizers. (2) Recommendations for best management practices for an important field crop will be developed through a comprehensive approach addressing greenhouse gas emissions, fertilization practices, and agronomic outcomes. (4) Data will be collected to calibrate and validate process models that can be used to predict the impact of N fertilizer rates on N₂O emissions. (5) The project will address air quality by improving our understanding of N₂O emission profiles for an important Central Valley crop.

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