FIELD MEASUREMENTS OF NITROUS OXIDE EMISSIONS ACROSS A NITROGEN FERTILIZER GRADIENT FOR CORN CROPPING SYSTEMS

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Abstract

Significant reductions in nitrous oxide (N_2O) emissions from corn (Zea maize L.) cropping systems may be possible by reducing N fertilizer inputs with relatively little impact on crop grain yield or economic return. To test this hypothesis, experiments were conducted at 4 locations in corn production in Michigan in 2007. All sites were under a corn-soybean rotation. Prior to planting, six rates of urea fertilizer (0-200 lb ac^{-1}) were broadcast and incorporated into four replicate plots (RCBD) at each of the sites. Field measurements at each site included N_2O emission via static chambers, soil temperature, soil moisture, soil inorganic N (0-4 in), and corn grain yield (to be measured). Measurements were taken immediately prior to fertilization, then on a 7-10 day frequency throughout the growing season. Additional measurements were collected immediately following fertilization, and following rain events at a frequency of every 2-3 days. Preliminary results indicate N_2O fluxes responded to N inputs 7 days post-fertilization, and fluxes stayed relatively high for the next 7 weeks. Initial results also confirmed N_2O flux tended to increase with increasing N fertilizer rate.

Introduction

The loss of N_2O from agriculture systems is a growing concern. Conversion of soil N to gaseous oxides of N (NO, NO_2, N_2O) and N_2 gas can significantly contribute to N loss from cultivated soils (Davidson and Kingerlee, 1997; Jambert et al, 1997). Concentrations of N_2O, a potent greenhouse gas, have long been increasing in the lower atmosphere to the order of a 13% increase over the past 200 years (IPCC, 2001 and NRC 2001). Globally, around 50% of anthropogenic N_2O emissions arise from cultivated soils (IPCC, 2001).

The effects of various agriculture practices on N_2O emissions have been widely studied. Crop type, tillage, residue management, soil moisture, soil temperature, and N fertilizer (amount, source, timing, placement) can all influence N_2O emissions. While the relationship between N_2O emission and crop management is complex, the amount of N applied in any production system can significantly influence the resulting N_2O emissions. Previous research has shown that N fertilization results in elevated N_2O flux compared with unfertilized controls (Breitenbeck et al., 1980; Bremner et al, 1981), though more recent efforts have been directed toward understanding N_2O response to increasing amounts of N fertilizer. McSwiney and Robertson (2005) studied N_2O flux in response to incremental N fertilizer addition in continuous corn. They found N rates above a 90 lb N ac^{-1} threshold, where grain yields were maximized, doubled N_2O flux. Similarly, additional research has shown that increasing N fertilizer rates results in an increasing, nonlinear N_2O flux response (Bouwman et al., 2002, Grant et al., 2006).

Substantial reductions in N_2O emissions from cultivated soil will require N management practices that are applicable to large scale production systems. Land in corn production is well suited as a target for potentially reducing agricultural N_2O emissions given the large proportion of area and N fertilizer devoted to these production systems. In this context, N rate studies for corn have the benefit of providing data for improved N rate recommendations and the relationship of N fertilizer management to N_2O emissions.

The objectives of this study are to determine the relationship(s) between N fertilizer rate and N_2O flux for corn grown in production fields, specifically, i) evaluate the impact of over- or under-fertilization, relative to maximum grain yield, on N_2O flux, and ii) determine the economic impact of N fertilizer rates below those needed for maximum yield and relative reductions in N_2O flux (economic potential for crediting program similar to that for carbon).

Approach

Field experiments for measurement of N_2O emissions and model verification were established at four sites in Michigan in April 2007. Two sites are located in Tuscola County, one in Ingham County, and one at the W.K. Kellogg Biological Station (KBS) in Kalamazoo County (Fig. 1). All sites are production fields and have recently been farmed in a corn-soybean cropping system typical for Michigan. All on-farm sites were managed by the cooperating producers as part of the entire field with the exception of N fertilizer management. The KBS site is a Michigan State University experiment station, but is a production-scale field and was managed similarly to the other sites following general production practices and to satisfy the objectives of the study. Typical tillage at the sites included fall chisel plow and a seedbed preparation pass, and weed control included preplant and/or post-emergence herbicides. Corn was planted at each site in either 30- or 28-in row widths at a density of approximately 30000 seeds ac^{-1}.

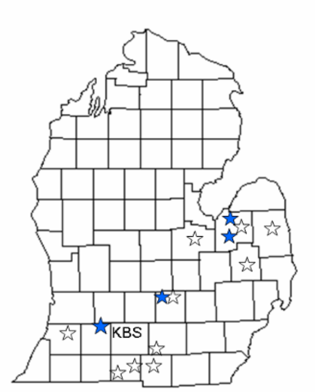

Figure 1. Corn N rate study locations in Michigan in 2007. Solid stars denote locations at which N_2O fluxes are being measured.

Plots were 15 to 19 ft (6 or 8 rows) wide and 50 ft long, and were arranged in a randomized complete block design with 4 replications of six N treatments. Nitrogen treatments included 0, 40, 80, 120, 160, and 200 lb N ac^{-1}. Granular urea ($CO(NH_2)_2$; 46% N) was surface broadcast applied prior to planting (within 3 days of planting) and was incorporated immediately following application with a relatively shallow cultivation pass (<3 in).

Nitrous oxide fluxes were measured in each plot at each site using the static chamber method as described by McSwiney and Robertson (2005). Chambers were installed prior to fertilization for measurement of background N_2O flux, then were removed temporarily for fertilization and the final cultivation pass. Following this cultivation, chambers were immediately reinstalled in the exact location they were removed. Each chamber measured 11-in diameter by 10.6-in height and was equipped with a removable air-tight lid and septum. Chambers were embedded 3.75 in into the soil and were left in place during the entire growing season. At the beginning of a flux determination, lids were secured onto each chamber and remained in place only during measurement intervals of up to 1.5 hrs. Four gas sample extractions were collected via the septum stopper during the incubation period by transferring 10 mL headspace aliquots to 5 mL vials. Samples (0.5 mL) were analyzed for N_2O using gas chromatography (Hewlett Packard 5890 Series II, Rolling Meadows, IL, USA) within 36 h of collection. Nitrous oxide flux was measured at each site prior to fertilization, within 2 days of fertilization, every other day for 14 days following fertilization, and then every 10-14 days until fluxes diminished.

A composite soil sample (0-6 in, 10 cores) was collected from each site, prior to fertilization, for determination of soil nutrient status (P, K, pH, Ca, Mg, organic matter, inorganic N). Additional soil samples were collected from each plot individually during each gas sampling event. Ten, 1-in i.d. cores (0-4 in depth) were randomly collected and combined from each plot to make a composite sample. Composite samples were then dried at 100°F, ground to pass a 2-mm sieve, and analyzed for NO_3 and NH_4 by flow injection analysis of 1 M KCl extracts (QuickChem methods, Lachat Instruments, Milwaukee, WI). Volumetric soil moisture status was determined within each plot at each gas sampling event using time domain reflectometry (TDR). A TRIME-EZ (Mesa Systems Co., Medfield, MA, USA) TDR probe was used for soil moisture determination by sampling to a depth of 10 cm.

Summary

Preliminary results from Tuscola Site 1 and Site 2 are presented in figures 2 and 3. Nitrous oxide flux responded to N inputs 7 days post-fertilization, and flux concentrations remained relatively high for the next 7 weeks. Generally, N_2O flux increased with increasing N rate. The pending results for yearlong accumulative N_2O flux per N rate treatment will provide more comprehensive insight into the total amount of N_2O released. Statistical analysis of flux data had not yet been completed at publication of this report, and yield data have not yet been collected.

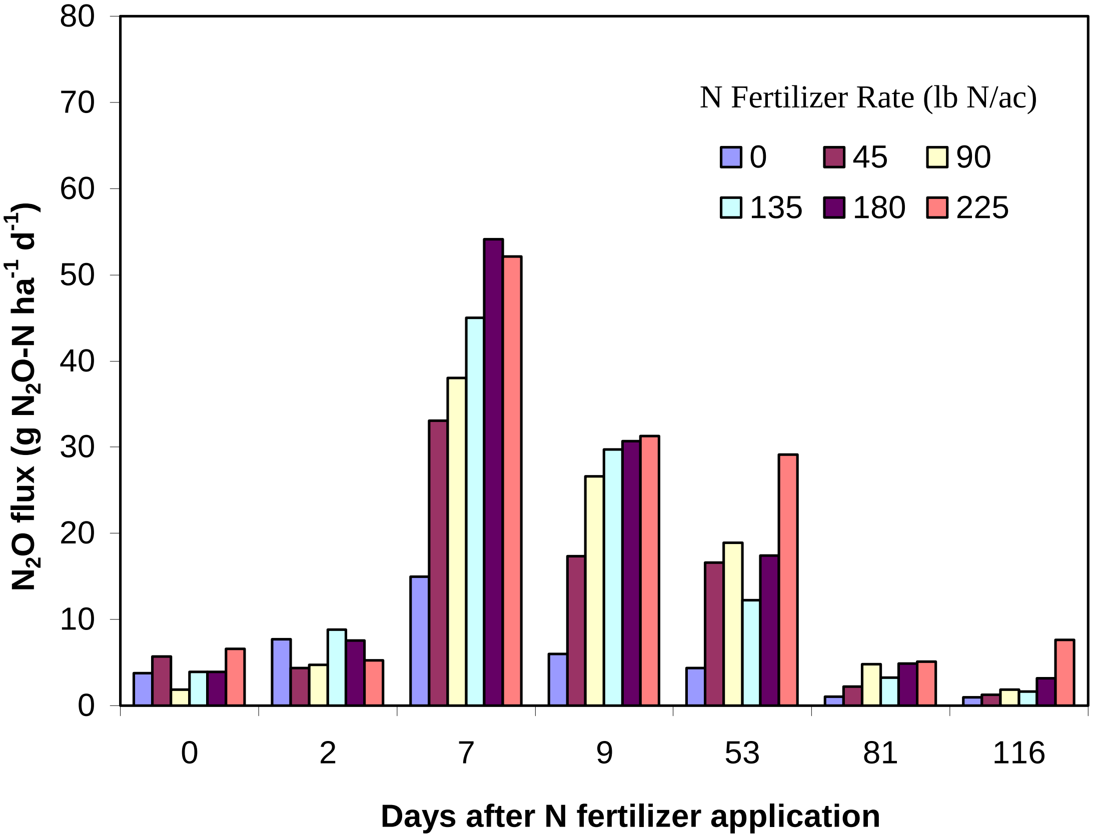

Figure 2. Nitrous oxide flux (g N_2O ha^{-1} d^{-1}) in relation to N fertilizer rate and days after N fertilizer application at Tuscola Site 1 during the 2007 growing season.

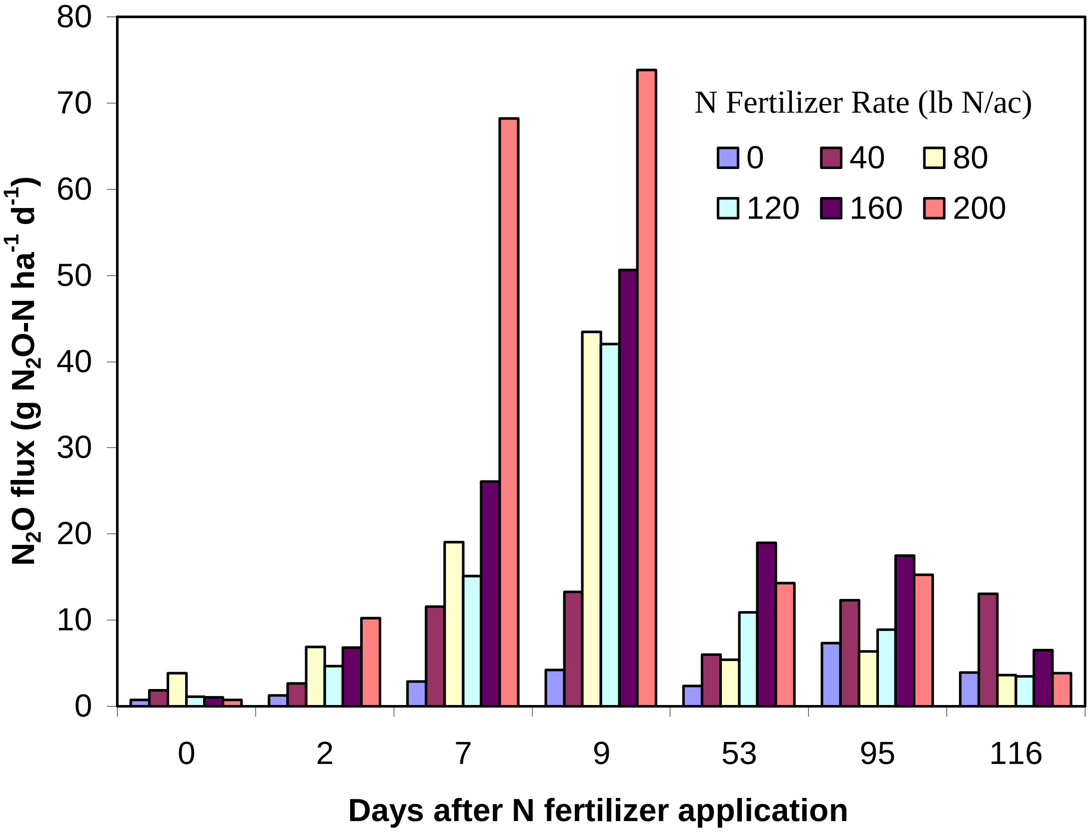

Figure 3. Nitrous oxide flux (g N_2O ha^{-1} d^{-1}) in relation to N fertilizer rate and days after N fertilizer application at Tuscola Site 2 during the 2007 growing season.

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