Nitrogen Rate and Source Effects on Nitrous Oxide Emissions from Irrigated Cropping Systems in Colorado

By Ardell D. Halvorson, Stephen J. Del Grosso, and Francesco Alluvione

Research shows that application of N fertilizer increases nitrous oxide (N_2O) emissions linearly from irrigated cropping systems in Colorado. Conventional-till continuous corn had a higher level of N_2O emissions than no-till continuous corn. Inclusion of soybean or dry bean in the no-till corn rotation increased the level of N_2O emissions during the corn year of the rotation. Use of controlled release and stabilized N sources reduced N_2O emissions under no-till when compared to urea and UAN fertilizer sources. Results of this work indicate that there are crop and fertilizer N management alternatives to reduce N_2O emissions from irrigated systems.

Nitrogen application generally increases N_2O emissions from irrigated cropping systems in the Central Great Plains (Mosier et al., 2006; Snyder et al., 2007; Halvorson et al., 2008a). Nitrous oxide is the principal non-carbon greenhouse gas emitted from soils and is produced through nitrification and denitrification processes in the soil. Agriculture contributes approximately 78% of the total N_2O emissions in the USA (Snyder et al., 2007). Snyder et al. (2007) presented an extensive review of greenhouse gas emissions from cropping systems, but little information was available on the effects of N fertilization on N_2O emissions from semi-arid, irrigated cropping systems in the western U.S.

The purpose of this article is to share our experiences with N_2O emissions from irrigated cropping systems located near Fort Collins, Colorado on a Fort Collins clay loam soil (Aridic Haplustalf). Studied cropping systems included conventional plow tillage continuous corn (CT-CC), no-till continuous corn (NT-CC), and no-till corn-soybean or dry bean (NT-CB) with N rates varying from 0 to 246 kg N/ha (0 to 220 lb N/A). From 2002 through 2006, N_2O emissions were measured from the CT-CC and NT-CC systems receiving N rates of 0, 67, 134, and 202+ kg N/ha. The highest N rate varied with year (202, 224, and 246 kg N/ha in 2002, 2003-2004, and 2005-2006, respectively). The N source was UAN (32%) from 2002 through 2005 which was subsurface band applied prior to crop planting with 33 cm (13 in.) band spacing parallel to the crop row. In 2005, the N was split applied with half the N rate applied as UAN prior to crop planting and the second half as a broadcast polymer-coated urea (ESN®, Agrium Advanced Technologies, Sylacauga, Alabama) in mid-June. In 2006, half the N rate was band-applied as ESN® near the corn row at corn emergence and the second half band applied in mid-June as dry granular urea followed the next day by irrigation. In the NT-CB rotation, N_2O fluxes were only measured in the 0 and high N rates each year. The high N rate applied to soybean and dry bean was 56 kg N/ha (50 lb N/A) in 2003 and 2005 with the entire N rate applied preplant as UAN. Nitrous oxide fluxes were measured during the growing seasons using vented static chambers (1 to 3 times per week; see photos) and an automated gas chromatograph analyzer. (See Mosier et al., 2006 and Halvorson et al., 2008a for more details on methodology).

The effects of N rate on growing season N_2O emissions from the irrigated CT-CC, NT-CC, and NT-CB rotations from 2002 through 2006 are shown in **Figure 1**. The average cumulative N_2O emissions across growing seasons were greater for CT-CC than for NT-CC, with N_2O emissions increasing with increasing N rate. For the NT-CB rotation in **Figure 1**, we assumed that a linear relationship existed between the low and high N rates. As shown in **Figure 1**, N_2O emissions with NT-CB rotation during the corn years were greater and parallel to the NT-CC cumulative emissions. During the bean years of the NT-CB rotation, N_2O emissions tended to be greater in the NT-CB rotation than in the continuous corn rotations at the 56 kg N/ha rate of N application. Thus, N rate, tillage, and crop rotation influence N_2O emissions from semi-arid, irrigated cropping systems in northern Colorado.

USDA-ARS technician Jessi Bishop collecting greenhouse gas samples from NT-CB plots for laboratory analysis on gas chromatograph.

During the 2005 and 2006 growing seasons when two N sources were used each year, it was noted (Halvorson et al., 2008a) that when ESN® was used, there were small N_2O emission peaks later in the growing season (July and August) that were not generally present when ESN® was not used (2002 – 2004). The normal response observed was for N_2O emission to increase within a few days of UAN application and then decline toward background levels in about 40 days. In 2005, N_2O emissions increased within a few days of UAN application, but small N_2O emission peaks continued to appear into the later part of the growing season (July-August) as a result

Abbreviations and notes for this article: N = nitrogen, 1.12 kg N/ha = 1 lb N/A; 1 Mg/ha = 15.9 bu corn/A.

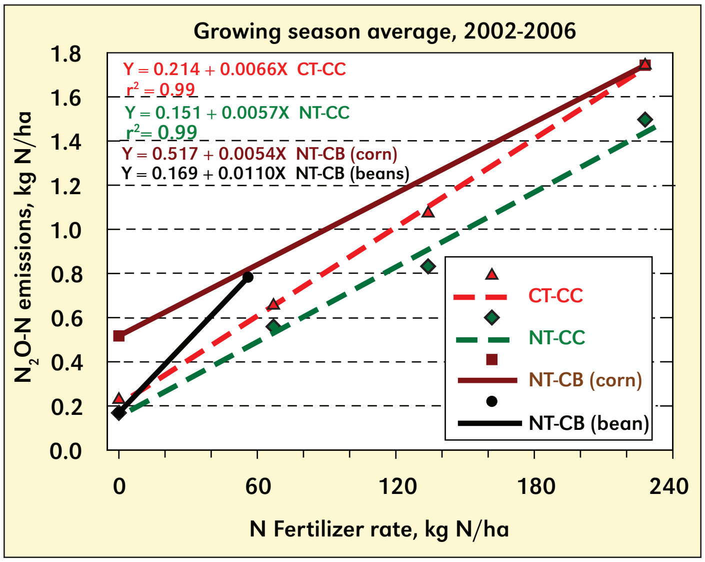

Figure 1. Average growing season N_2O emissions as a function of N fertilizer application rate from 2002 through 2006 near Fort Collins, Colorado (Mosier et al., 2006; Halvorson et al., 2008a).

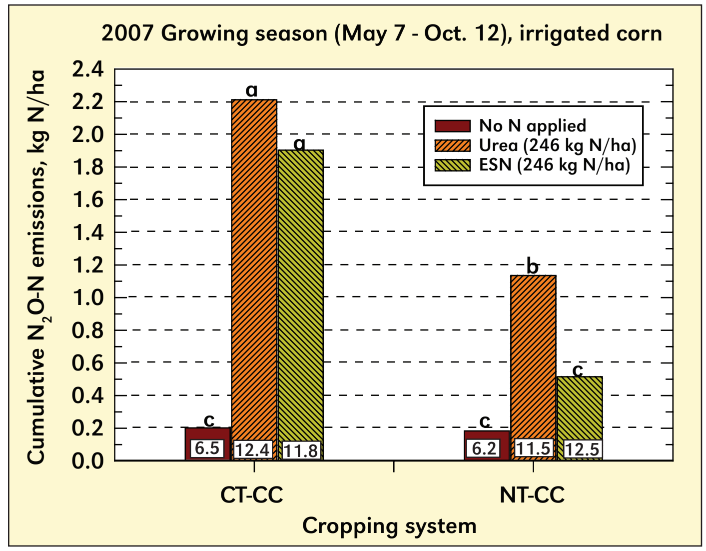

Figure 2. Growing season N_2O emissions in 2007 as a function of conventional-till (CT) and no-till (NT) production systems and N source near Fort Collins, Colorado (Halvorson et al., 2008b). Average grain yields (Mg/ha) are shown in a white box within each bar. (1 Mg/ha = 15.9 bu/A). Bars with same letters above are not significantly different at p = 0.05.

of the application of the polymer-coated urea (ESN®), which was applied in late June. In 2006, the ESN® was applied at corn emergence with no immediate increase in N_2O emissions, but with a large increase in N_2O emissions within days following application of dry granular urea in mid-June. Again in 2006, we observed small N_2O emission peaks in the later part of the growing season as a result of application of ESN®. As a result of these observations, in 2007 and 2008 we modified our treatments at the full N rate in the NT-CC and CT-CC systems to separate the N sources. Dry granular urea (246 kg N/ha or 220 lb N/A) was applied to plots formerly receiving 34 kg N/ha (30 lb N/A). The polymer-coated urea (ESN®) was applied to plots formerly receiving 246 kg N/ha. The entire N rate was mechanically band applied (see photo on next page) near the corn row at emergence.

Results from the 2007 study comparing N_2O emissions from plots receiving separate urea and ESN® applications in the NT-CC and CT-CC systems are shown in **Figure 2**. As was the case in 2006 (Halvorson et al., 2008a), N_2O emissions were greater in the CT-CC than in NT-CC plots in 2007. Cumulative growing season N_2O emissions from plots treated with dry granular urea and ESN® were not different in the CT-CC system, but were different in the NT-CC system. Under NT-CC,

USDA-ARS technician Sadie Skiles collecting greenhouse gas samples from NT-CC plots in 2008 from N source study for laboratory analysis on gas chromatograph.

ESN® reduced N_2O emissions 55% compared with urea. Similar results were obtained in 2008 (data not shown). Reasons for the differences in N_2O emissions from ESN® between the two tillage systems are not clear. In the CT-CC system, the ESN® granules became covered with soil due to soil splash during rainfall and irrigation events and were partially buried in the soil, which may result in more rapid decomposition of the polymer coating of the ESN® granules with faster and earlier release of urea-N from the granules than in the NT-CC system. The ESN® granules remained on the soil surface underneath the crop residue in the NT-CC system throughout the growing season. In the CT-CC system, the ESN® granules tended to move (float) with water out of the fertilizer band, compared with little movement of the granules from the band in the NT-CC system, increasing the chance for the creation of microsites favorable to N_2O production through granule accumulation in depressed areas and coverage with soil. These factors may contribute to the differences in N_2O emissions from ESN® between tillage systems. These data suggest that tillage system may have a great effect on how N sources influence N_2O emissions from irrigated corn fields.

In addition to the 2007 study reported above, another N source comparison study was initiated in 2007 and continued in 2008 to compare N_2O emissions from plots receiving UAN and urea with controlled release N and stabilized N sources under irrigated NT-CC on a new set of plots at the same location. The controlled release sources were two polymer-coated ureas, ESN® and Duration III®, produced by Agrium Advanced Technologies, Sylacauga, Alabama. The stabilized N sources were SuperU® which is a granulated urea impregnated with a urease and nitrification inhibitor, and UAN treated with AgrotainPlus® (UAN+AP). Both materials were obtained from Agrotain International, St. Louis, Missouri. The SuperU® and AgrotainPlus® contain urease (N-(n-butyl)-thiophosphoric triamide) and nitrification (dicyandiamide) inhibitors. Each N source was hand banded next to the row at corn emergence followed by the application of 12 mm (0.5 in.) of water through the sprinkler irrigation system. The N rate used was 246 kg N/ha (220 lb N/A) in 2007 and 202 kg N/ha (180 lb N/A) in 2008. The N rate was reduced in 2008 to more closely bracket the economic N rate for the NT-CC system (Archer and Halvorson, 2008). In 2008, we also removed part of the corn residue…about 6,000 kg/ha (5,346 lb/A) of the 9,100 kg/ha (8,109 lb/A) produced in 2007) from the NT-CC plots used in this study in an attempt to increase soil temperatures and improve early corn development.

The 2-year average growing-season cumulative N_2O fluxes are shown in **Figure 3** for each of these N sources. Dry granular urea had the greatest growing season N_2O emission followed by UAN, Duration III®, and ESN® with the SuperU® and UAN+AP treatments having the lowest N_2O emissions. When compared to urea, the controlled release (ESN®) and stabilized N (SuperU®) sources reduced N_2O emissions 33% and 48%, respectively, in this irrigated NT-CC production system. Addition of AgrotainPlus® to the UAN solution reduced N_2O emissions 35% when compared to UAN alone. Application of SuperU® resulted in a 29% reduction in N_2O emissions compared with UAN alone. The check (no N applied) treatment had the lowest level of N_2O emissions during the growing season. These data indicate that selection of N source can have an impact on N_2O emissions from irrigated, no-till production systems. Producers managing their cropping systems to reduce N_2O emissions need to consider using the controlled release and stabilized N sources along with no-till. No-till has been shown to reduce carbon dioxide (CO_2) emissions and increase soil organic matter. Reduction in N_2O and CO_2 emissions will have a positive effect on reducing global warming potential.

Nitrogen application to irrigated crops in the Central Great Plains is essential to attaining optimum yield potential and economic returns on most soils. Deciding how much N to apply, when and how to apply it, and what N source to use are important decisions for optimizing yield and economic returns, while protecting the environment from N pollution by leaching of NO_3-N into groundwater or N_2O emissions as explained above. In our study, N source had little impact on grain yield, but did impact N_2O emissions. Maintaining a low level of available N in the surface soil early in the growing season should contribute to reduced N_2O emissions (Snyder et al., 2007). Thus, the principle of applying the right N source, at the right rate, in the right place, at the right time becomes a key management decision for optimizing crop yields and economic returns while protecting the environment (Roberts, 2007). Soil testing for residual NO_3-N is a critical component in this semi-arid region for determining the right N rate to be used. Previous cropping history and crop management practices also play a key role in efficient use of N (Maddux and Halvorson, 2008). BC

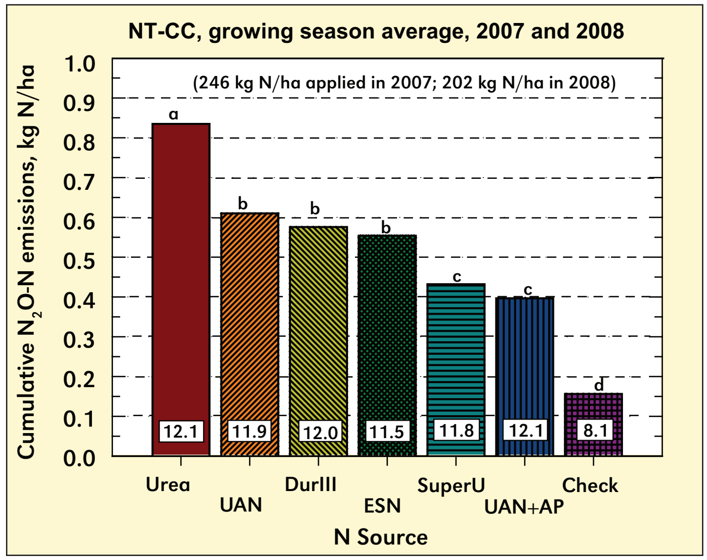

Figure 3. Average (2007 and 2008) growing season N_2O emissions as a function of N source in a no-till continuous corn irrigated cropping system near Fort Collins, Colorado. Each N source was surface banded near the corn row at emergence. Average grain yields (Mg/ha) are shown in a white box within each bar. Bars with same letters above are not significantly different at p = 0.05.

Band applying SuperU® fertilizer to NT-CB rotation in 2008 are, from left, Dr. Halvorson, Francesco Alluvione, Brad Floyd, and Robert D'Adamo.

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