NITROGEN FERTILIZATION EFFECTS ON NITROUS OXIDE EMISSIONS FROM IRRIGATED CROPPING SYSTEMS[1]

Ardell D. Halvorson, Stephen J. Del Grosso, and Curtis A. Reule
USDA, Agricultural Research Service, Fort Collins, CO
Ardell.Halvorson@ars.usda.gov (970) 492-7230

ABSTRACT

We evaluated the effects of N fertilization and irrigated crop management practices on nitrous oxide (N_2O) emissions. Emissions were monitored from several irrigated cropping systems receiving N fertilizer rates (0, 67, 134, and 246 kg N/ha) during the 2006 growing season and N rates of 0 and 246 kg N/ha on corn plots, 0 and 156 kg N/ha on barley plots, and 0 and 56 kg N/ha on the dry bean plots during the 2007 growing seasons. Cropping systems included: conventional-till (CT) continuous corn (CC) (CT-CC); no-till (NT) CC (NT-CC); NT corn-dry bean (NT-CDb); and NT corn-barley (NT-CB). All plots were in corn in 2006, with a polymer-coated urea, ESN®[1], being applied at half the N rate at corn emergence and half as dry urea in mid-June followed by irrigation, both banded on the soil surface in the corn row. In 2007, ESN® and urea were applied at the full N rate at corn emergence to separate plots in the CT-CC and NT-CC rotations and urea and SuperU®[1] were applied to separate plots after barley emergence in the NT-CB rotation and at dry bean emergence in the NT-CDb plots. N_2O fluxes were measured during the growing season using static, vented chambers, one to three times per week, and a gas chromatograph analyzer. Linear increases in N_2O emissions were observed with increasing N-fertilizer rate in 2006. Growing season N_2O emissions in 2006 were greater from the NT-CDb system than from the other cropping systems. In 2006 and 2007, N_2O emissions tended to be greater from the CT-CC system than from the NT-CC system. Application of ESN® and SuperU® fertilizers resulted in reduced N_2O emissions in the NT systems. Spikes in N_2O emissions following N fertilizer application were greater with urea than with the ESN® or SuperU® fertilizers. The ESN® and SuperU® fertilizer N products showed potential for reducing N_2O emissions from irrigated cropping systems in 2007. These first year results indicate that N sources need to be evaluated further to determine their value in reducing N_2O emissions in cropping systems.

INTRODUCTION

Agriculture contributes approximately 78% of total U.S. N_2O emissions (USEPA, 2007). Nitrous oxide, the principal non-CO_2 greenhouse gas, is produced in soil through nitrification and denitrification (Follett, 2001, Mosier, 2001). Nitrogen fertilizer application generally increases N_2O production in irrigated cropping systems (Mosier et al., 2006). The global warming potential (GWP) of N_2O is approximately 296 times greater than that of CO_2 (IPCC, 2001), thus the importance of developing methods to reduce N_2O emissions in agricultural systems. Data available for analyzing the impact of N_2O emissions on GWP in irrigated crop production systems is limited. There is a

[1] Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product by the authors or the USDA, Agricultural Research Service.

high uncertainty associated with N_2O flux data which dictates a high uncertainty in net GWP estimates (Walters, 2005; Mosier et al., 2006).

Research reported by Mosier et al. (2006) from irrigated cropping systems showed a sharp rise in N_2O emissions almost immediately following N fertilization with urea-ammonium nitrate (UAN) fertilizer in CT-CC, NT-CC, and NT-CSb (corn-soybean) cropping systems. The N_2O emissions following N fertilization declined to near background levels in about 40 to 50 days and remained there for the rest of the growing season and non-crop period, until N fertilization of the next crop. Including soybean in rotation with corn resulted in greater N_2O emissions during the corn phase of the NT-CSb rotation than in CT-CC and NT-CC rotations. Growing season N_2O emissions increased linearly with increasing rate of N fertilization. Walters (2005) also showed higher N_2O emissions during the corn year following soybean in a corn-soybean rotation in Nebraska.

Venterea et al. (2005) found N source influenced N_2O emissions from corn production systems in Minnesota with greatest N_2O emissions from anhydrous ammonia application, with significantly lower emissions from UAN, and lowest emissions from broadcast urea. Walters (2005) also reported greater N_2O emissions with anhydrous ammonia application than with other N sources. Mosier et al. (1998) suggested using controlled release fertilizers to mitigate N_2O emissions from agricultural systems by supplying plants with sufficient N to meet their needs yet maintaining a low concentration of mineral N in the soil throughout the growing season to reduce gaseous N loss. Blaylock et al. (2005) reported reduced N_2O emissions from application of a polymer-coated urea (ESN®) when compared to UAN and urea N sources.

Our objectives were: 1) to obtain N_2O emissions data from irrigated cropping systems during the growing season that could be used to test and improve simulation models for irrigated agricultural systems, and 2) evaluate the effects of N management and N source on N_2O emissions from irrigated cropping systems.

MATERIALS AND METHODS

Tillage (CT and NT), crop rotation, and N fertility treatments established in 1999 on a conventional plow tillage, continuous corn field located on a Fort Collins clay loam soil at the Agricultural Research, Development, and Education Center (ARDEC) north of Fort Collins, CO were used in this study. In 2006, corn was grown on all plots. In 2007, corn, barley, and dry bean were grown depending upon rotation. Due to herbicide damage to the dry bean, corn was planted in the dry bean plots on July 5, 2007 with no additional N added. Greenhouse gas samples were collected from four N treatments (0, 67, 134, and 246 kg N/ha) of the CT-CC and NT-CC rotations and two N treatments (0 and 246 kg N/ha) of the CT-CB and CT-CDb rotations in 2006 and two N treatments (0 and 246 kg N/ha) of the NT-CC and CT-CC rotations in 2007. Greenhouse gas samples were also collected from two N rates (0 and 157 kg N/ha) and two N sources (dry urea and SuperU®) for barley (NT-CB rotation) and from two N rates (0 and 56 kg N/ha) and two N sources (dry urea and SuperU®) for dry bean (NT-CDb rotation) in 2007. SuperU® is a finished urea product that is a homogenous blend with urease and nitrification inhibitor included at the time of production, therefore, each SuperU® pellet contains the urease and nitrification inhibitor. The N treatments were arranged in a randomized complete block design with three replications with the same N treatment being applied to the same plot each year. The CT-CC rotation used mechanical tillage (stalk shredder, disk, moldboard plow, roller-mulcher, landplane, etc.) for seed bed preparation. The NT operations were plant, spray, and harvest. Herbicides were used for weed control in all cropping systems. Due to herbicide damage to the dry beans in 2007, corn was planted

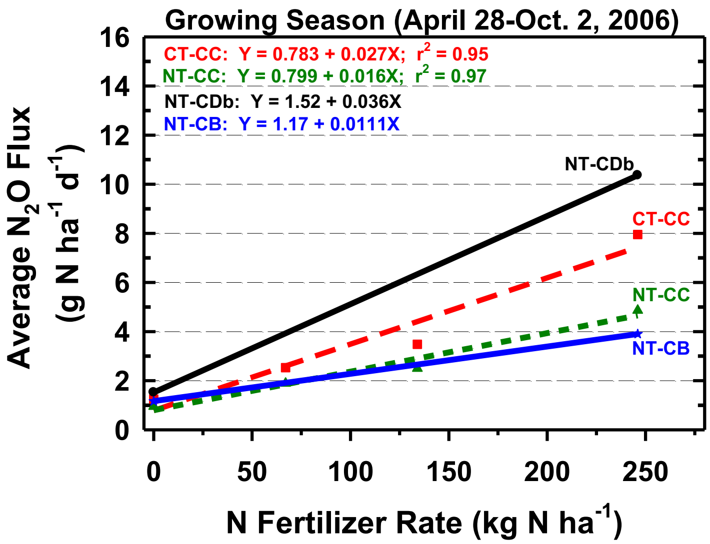

Figure. 1. Growing season average daily N_2O flux as a function of cropping system and N fertilizer rate in 2006.

directly into the dry bean plots on July 5th and harvested for corn silage on Oct. 1, 2007. Other study details are provided by Halvorson et al. (2006, 2008) and Halvorson and Reule (2006, 2007).

Greenhouse gas fluxes were monitored one to three days per week during the 2006 and 2007 growing seasons in the designated N treatments. A vented chamber technique was used to collect the gases in the field and a gas chromatograph used to analyze for gas concentration as described by Mosier et al. (2006).

RESULTS

Greenhouse Gas Fluxes. Average daily N_2O fluxes for the growing season increased with increasing N rate in both the CT-CC and NT-CC systems (Fig. 1) in 2006, similarly to that reported for previous years (Mosier et al., 2006; Halvorson et al., 2008). As shown in Fig. 1, the NT-CDb rotation had a greater daily N_2O flux than the other rotations during this corn year. The daily N_2O flux in the NT-CB rotation was similar to the NT-CC rotation. Based on previous results, we assumed that the increase in daily N_2O flux with increasing N rate was linear for the NT-CDb and NT-CB rotations with only the lowest and highest N rates monitored.

The 2006 daily N_2O fluxes for the CT-CC and NT-CC 0 and 246 kg/ha N rates are shown in Fig. 2. The daily N_2O flux prior to N fertilization was similar for the zero and 246 kg N/ha treatments for all rotations. The first half of the 246 kg/ha N rate was applied as ESN® just after corn emergence on May 17th (DOY 137). The N_2O emission stayed near background levels until a noticeable spike in emissions about DOY 160. We are not sure what caused this spike, because a similar spike was observed in the check plots (0 kg N/ha). On DOY 163, June 12th, the second half of the N rate was applied as urea, followed immediately with a sharp rise in N_2O emissions. By DOY 180, N_2O emissions had declined to near background levels following the urea application, similar to that reported for UAN application by Mosier et al. (2006). On about DOY 190, smaller spikes in N_2O emissions were observed, with greater spikes in the CT-CC treatments than in the NT-

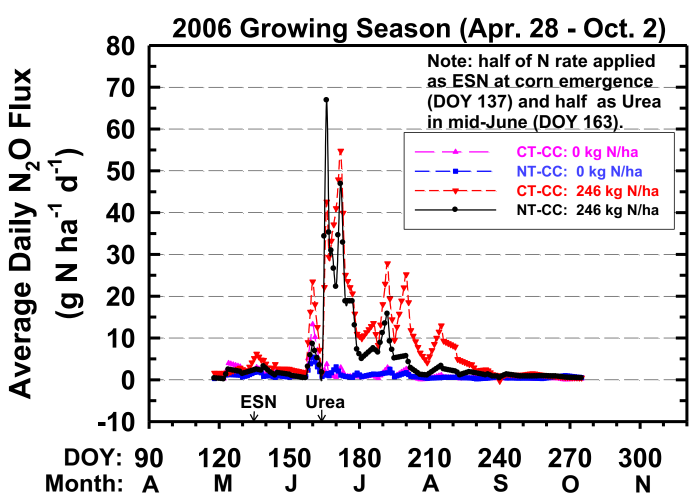

Figure 2. Average daily N_2O flux during the 2006 growing season for the 0 and 246 kg/ha N rates for the CT-CC and NT-CC treatments.

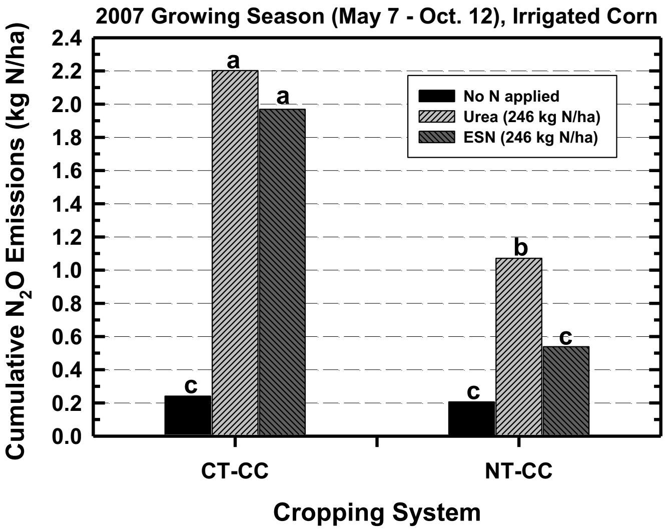

Figure 3. Cumulative N_2O emissions during the 2007 growing season as a function of N source and cropping system.

CC treatments. We suspected that the later growing season peaks in N_2O emissions were the result of the delayed N release from the ESN® applied on May 17th. This stimulated us to change our N management practices in 2007, with the application of urea and ESN® to separate plots. Based on the 2007 observations (data not shown), the late N_2O peaks in 2006 were probably the result of N release from the ESN.

In 2007, the N_2O emissions were greater from the CT-CC system than from the NT-CC system (Fig. 3), similar to that shown in Fig. 1 for 2006. The cumulative N_2O emissions for the 2007 growing season in the CT-CC system with urea application were twice the emissions of urea in the NT-CC system. The N_2O cumulative emissions with ESN® application were more than 3 fold greater in the CT-CC system than in the NT-CC system. N_2O emissions with urea application were significantly greater in the NT-CC system than with ESN® application in 2007. The reason for the small difference in N_2O emissions between N sources in the CT-CC system is not clear. In the CT-CC system, the ESN® pellet became incorporated in the soil with rainfall and irrigation events. This may have enhanced the release of N from the ESN® pellet resulting in a greater concentration of available N for microbial nitrification and denitrification during the growing season. The increase in N_2O emission peaks from ESN® application came later in the growing season, similar to the 2006 observations (Fig. 2) when compared to an immediate rise in N_2O emissions following urea application. Corn grain yields in 2007 did not vary with N source in the CT-CC system, but were significantly greater with ESN® than with urea in the NT-CC system.

In 2007, N_2O emissions from the application of 157 kg N/ha of urea and SuperU® N sources to barley in the NT-CB rotation were compared (Fig. 4) as well as the application of both N sources at a rate of 56 kg N/ha to dry bean in the NT-CDb rotation (Fig. 5). In both the barley and dry bean/corn plots, N_2O emissions were significantly lower when SuperU® was applied compared to dry granular urea. The urease and nitrification inhibitors were effective in reducing N_2O emissions immediately following N application. Barley grain yields and corn silage yields did not vary significantly between N sources in 2007.

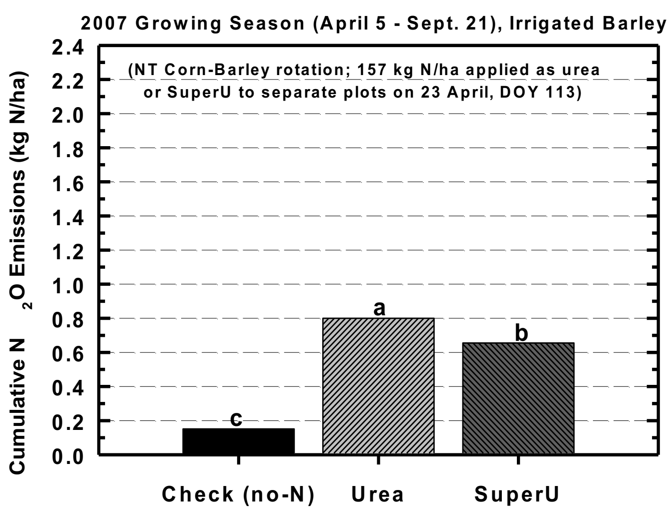

Figure 4. Cumulative N_2O emissions during 2007 growing season as a function of N source applied to barley in irrigated NT-CB rotation.

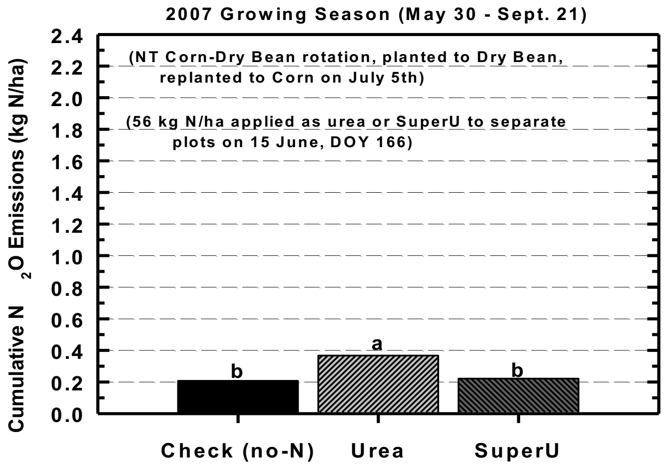

Figure 5. Cumulative N_2O emissions during 2007 growing season as a function of fertilizer N sources applied to dry bean/corn in NT-CDb rotation.

SUMMARY

Nitrous oxide emissions increased with increasing N rate in all cropping systems, with the NT-CDb rotation having greater emissions than the other rotations in 2006. In 2006 and 2007, N_2O emissions during the growing season were greater in the CT-CC than the NT-CC cropping system with application of 246 kg N/ha. The application of ESN® and SuperU® reduced N_2O emissions significantly from the NT cropping systems in 2007. These first year data suggest that N sources need to be evaluated further to determine their value in reducing N_2O emissions from cropping systems.

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REFERENCES

Blaylock, A.D., G.D. Binford, R.D. Dowbenko, J. Kaufmann, and R. Islam. 2005. ESN®, controlled-release nitrogen for enhanced nitrogen efficiency and improved environmental safety. P. 381-390. *In* Proc. 3rd International Nitrogen Conference-Contributed Papers, October 12-16, 2004, Nanjing, China. Z Zhu, K. Minami, and G. Xing, editors. Science Press and Science Press USA, Monmouth Junction, NJ.

Follett, R.F. 2001. Nitrogen transformation and transport processes. p. 17-44. R.F. Follett and J.L. Hatfield (eds), Nitrogen in the Environment: Sources, Problems, and Management. Elsevier Science B.V., Amsterdam, The Netherlands.

Halvorson, A.D., A.R. Mosier, C.A. Reule, and W.C. Bausch. 2006. Nitrogen and tillage effects on irrigated continuous corn yields. Agronomy J. 98:63-71.

Halvorson, A.D., and C.A. Reule. 2006. Irrigated corn and soybean response to nitrogen under no-till in northern Colorado. Agron. J. 98:1367-1374.

Halvorson, A.D., and C.A. Reule. 2007. Irrigated corn and barley response to nitrogen under no-till in northern Colorado. Agron. J. 99: 1521-1529.

Halvorson, A.D., S.J. Del Grosso, and C.A. Reule. 2008. Nitrogen, tillage, and crop rotation effects on nitrous oxide emissions from irrigated cropping systems. J. Environ. Qual. (accepted for publication, 12/2007)

IPCC. 2001. Intergovernmental Panel on Climate Change. Technical Summary of the 3rd Assessment report of Working Group 1. D.L. Albritton and L.G. Meira Filho (Coordinating lead authors). 63p.

Mosier, A.R. 2001. Exchange of gaseous nitrogen compounds between terrestrial systems and the atmosphere. p. 291-309. R.F. Follett and J.L. Hatfield (eds), Nitrogen in the Environment: Sources, Problems, and Management. Elsevier Science B.V., Amsterdam, The Netherlands.

Mosier, A.R., J.M. Duxbury, J.R. Freney, O. Heinemeyer, and K. Minami. 1998. Assessing and mitigating N_2O emissions from agricultural soils. Climate Change. 40:7-38.

Mosier, A.R., A.D. Halvorson, C.A. Reule, and X.J. Liu. 2006. Net global warming potential and greenhouse gas intensity in irrigated cropping systems in northeastern Colorado. J. Environ. Qual. 35:1584-1598.

USEPA. 2007. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2005. EPA 430-R-07-002. U.S. Environmental Protection Agency, 1200 Pennsylvania Ave., N.W. Washington, DC 20460.

Venterea, R.T., M. Burger, and K.A. Spokas. 2005. Nitrogen oxide and methane emissions under varying tillage and fertilizer management. J. Environ. Qual. 34:1467-1477.

Walters, D.T. 2005. Fertilizer nitrogen source and management impacts on greenhouse gas emissions. *In* Proc. 21st North Central Industry and Extension Soil Fertility Conference. Nov. 16-17, 2005, Des Moines, IA. Potash and Phosphate Institute, Brookings, SD.