Nitrogen Source and Placement Affect Soil Nitrous Oxide Emissions from Irrigated Corn in Colorado

By Ardell D. Halvorson and Stephen J. Del Grosso

Research shows that N fertilizer source affects growing season soil N_2O emissions from irrigated corn systems in Colorado. Use of controlled-release and stabilized N sources reduced N_2O emissions under NT and ST corn production systems up to 66% when compared to commonly used urea and up to 43% compared to UAN. Urease and nitrification inhibitor additions to urea and UAN resulted in significant reductions in N_2O emissions, as did polymer-coated urea. Surface broadcast application of N sources resulted in lower N_2O emissions than surface band applications. Choice of N source and placement can be valid management alternatives for reducing N_2O emissions to the environment in semi-arid areas.

Nitrogen fertilization is essential for optimizing crop yields and economic returns in irrigated cropping systems in the Central Great Plains area of the USA. However, N application generally increases the emissions of the potent greenhouse gas, N_2O, from these systems. Nitrous oxide is produced through nitrification and denitrification processes in the soil. Agriculture contributes approximately 67% of the total anthropogenic N_2O emissions in the USA. Information on how N fertilizer source might affect soil N_2O emissions from semi-arid, irrigated cropping systems is limited. Halvorson et al. (2008, 2009, 2010a, 2010b) showed N rate, N source, tillage, and crop rotation influence N_2O emissions from semi-arid, irrigated cropping systems in northern Colorado.

This article presents a summary of the effects of N source on soil N_2O emissions from studies conducted from 2009 to 2011 within NT and ST irrigated corn systems located near Fort Collins, Colorado on a Fort Collins clay loam soil. Nitrogen rates were 0 and 202 kg N/ha (0 and 180 lb N/A). Nitrogen sources compared to the commonly used granular urea (46% N) and liquid UAN (32% N) included a controlled-release polymer-coated urea (ESN®), stabilized urea and UAN products containing nitrification and urease inhibitors (SuperU and UAN+AgrotainPlus®), and UAN containing a slow release N source (Nfusion®). A subsurface band ESN treatment (ESNssb) was also included. Each N source, except ESNssb, was surface band applied at corn emergence and watered into the soil the next day with a linear move sprinkler irrigation system. Nitrous oxide fluxes were measured two to three times per week during the growing seasons using vented static chambers and a gas chromatograph analyzer (see photos). Details on methodology can be found in Halvorson et al. (2011) and Halvorson and Del Grosso (2012).

Dr. Ardell Halvorson (foreground) analyzing gas samples from field plots on a gas chromatograph (photo by S. Ausmus, USDA-ARS photographer).

Nitrogen Source Effects on N_2O Emissions

Nitrous oxide fluxes increased within days following the application of all N sources except for ESN, which had a delayed release of N_2O. An example of the cumulative change in N_2O flux for several N sources with time during the 2010-growing season for NT is shown in **Figure 1**. Urea and UAN reached 80% of their growing season N_2O emissions 24 and 23 days after N application, respectively. UAN+AgrotainPlus and SuperU reached 80% of their growing season emissions 40 and 46 days, respectively, after N application. Nitrous oxide emissions from ESN and ESNssb followed a different pattern from the other N sources, remaining low until mid-June when N_2O-N fluxes started to increase. The ESNssb and ESN treatments reached 80% of their growing season emissions 65 and 70 days after N application, respectively.

Total cumulative growing season N_2O-N fluxes during the corn growing season are shown in **Figure 2** for ST for all N sources evaluated, plus a blank treatment (no N ap-

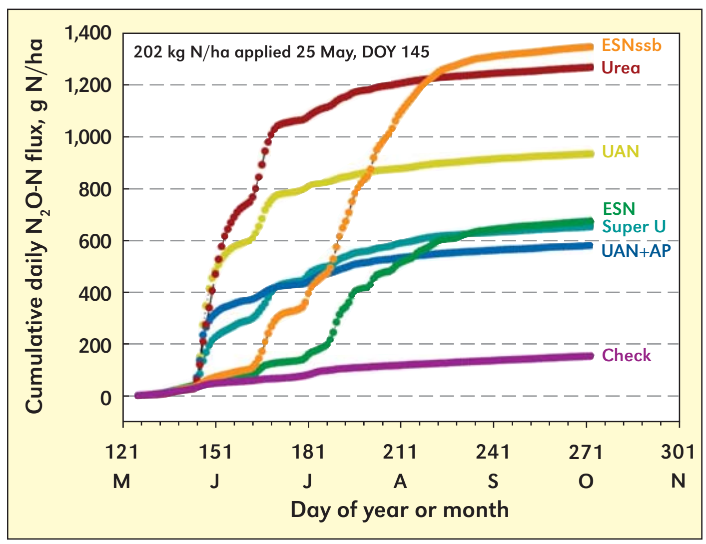

Figure 1. Cumulative growing season soil nitrous oxide (N_2O) emissions with time as a function of N fertilizer source applied on day-of-year (DOY) 145 near Fort Collins, Colorado (Halvorson and Del Grosso, 2012).

Common abbreviations and notes: N = nitrogen; N_2O = nitrous oxide; UAN = urea ammonium nitrate; NT = no-till; ST = strip till.

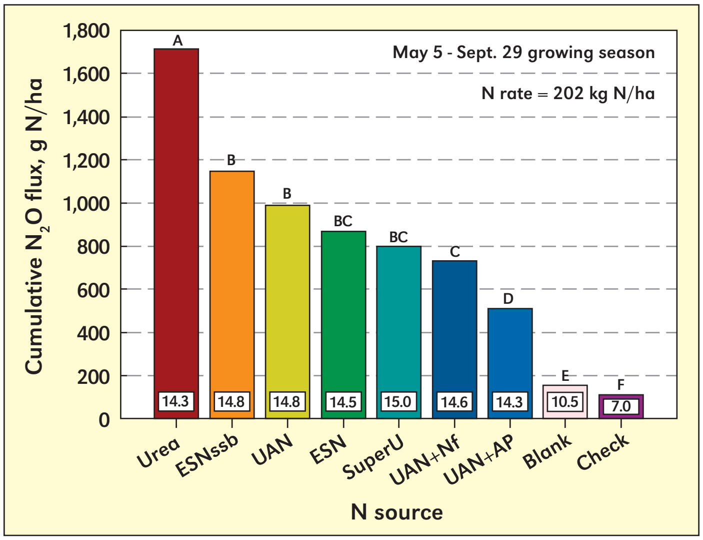

Figure 2. Average (2009 and 2010) growing season soil nitrous oxide (N_2O) emissions as a function of N source in a strip-till, irrigated continuous-corn cropping system near Fort Collins, Colorado (Halvorson et al., 2011). Each N source was surface banded near the corn row at emergence, except ESNssb was subsurface banded. UAN+Nf is UAN plus Nfusion and UAN+AP is UAN plus AgrotainPlus. Average grain yields (t/ha) are shown in a white box within each bar. (1 t/ha = 15.9 bu/A).

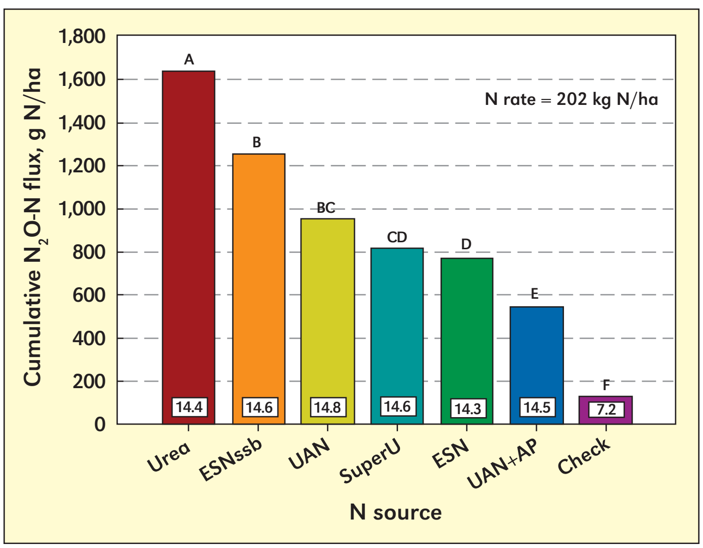

Figure 3. Growing season soil nitrous oxide (N_2O) emissions as a function of N source averaged over strip-till and no-till irrigated corn studies near Fort Collins, Colorado in 2009 and 2010 (Halvorson et al., 2011; Halvorson and Del Grosso, 2012). Average grain yields (t/ha) are shown in a white box within each bar. (1 t/ha = 15.9 bu/A).

plied) located in the same plot area as the N sources and a check treatment (no N applied for 10 years) located in a separate plot. The 2-year average ST growing season N_2O-N emissions from the controlled-release N fertilizers and UAN were significantly lower than dry granular urea. The ESNssb treatment had significantly higher N_2O emissions than the UAN+Nfusion, UAN+AgrotainPlus, blank, and check treatments. The UAN+AgrotainPlus and UAN+Nfusion treatments had lower N_2O emissions than UAN. The check treatment had the lowest level of growing season N_2O-N emissions,

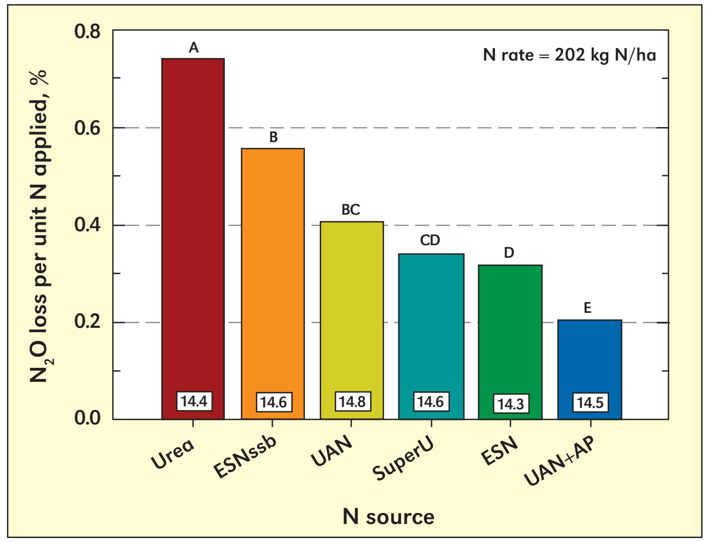

Figure 4. Growing season soil nitrous oxide (N_2O) loss per unit of N applied as a function of N fertilizer source averaged over strip-till and no-till irrigated corn production systems in 2009 and 2010 near Fort Collins, Colorado (Halvorson and Del Grosso, 2012). Average grain yields (t/ha) are shown in a white box within each bar.

with the blank being similar to the check. Compared to dry granular urea, UAN+AgrotainPlus reduced N_2O-N emissions 70% in the ST system, UAN+Nfusion 57%, SuperU 53%, ESN 49%, UAN 42%, and ESNssb 33%. Compared to liquid UAN, UAN+AgrotainPlus reduced N_2O-N emissions 49%, UAN+Nfusion 26%, SuperU 19%, and ESN 12%. Nitrification was thought to be the main pathway of N_2O loss in our studies.

Similar differences in growing season N_2O emissions were observed among N sources in the NT system, which did not include UAN+Nfusion, as those observed in the ST system. Combining the ST and NT data sets showed that there was no tillage x N treatment interaction, with the N_2O emissions from the ST and NT systems being similar (Halvorson and Del Grosso, 2012). Therefore, we combined the NT and ST N_2O data sets to obtain an overall average growing season N_2O emissions for the common N sources from both tillage systems to provide 4 site-years of observations (**Figure 3**). All N sources had growing season N_2O-N emissions lower than urea. Surface banded ESN and UAN+AgrotainPlus had lower emissions than UAN. Compared to dry granular urea, averaged across tillage systems and years, UAN+AgrotainPlus reduced N_2O-N emissions 66%, SuperU 50%, ESN 53%, UAN 42%, and ESNssb 23%. Compared to liquid UAN, UAN+AgrotainPlus reduced N_2O-N emissions 43%, ESN 19%, and SuperU 14%. Growing season N_2O-N losses were consistently <0.4% of N applied for the controlled-release N sources and UAN, except ESNssb (0.55%), with urea having a loss of 0.74% (**Figure 4**). The N_2O-N loss per unit of N applied was highest for urea and lowest for UAN+AgrotainPlus. The growing season N_2O-N emissions from the application of a unit of the controlled-release N fertilizer in this study were considerably lower (<0.5%) than the default 1% from Tier I methodology of IPCC (2006) used to estimate yearly N_2O-N emissions resulting from N fertilizer application.

N_2O Emissions as a Function of Grain Yield

Grain yields did not vary with N source (**Figure 2** and

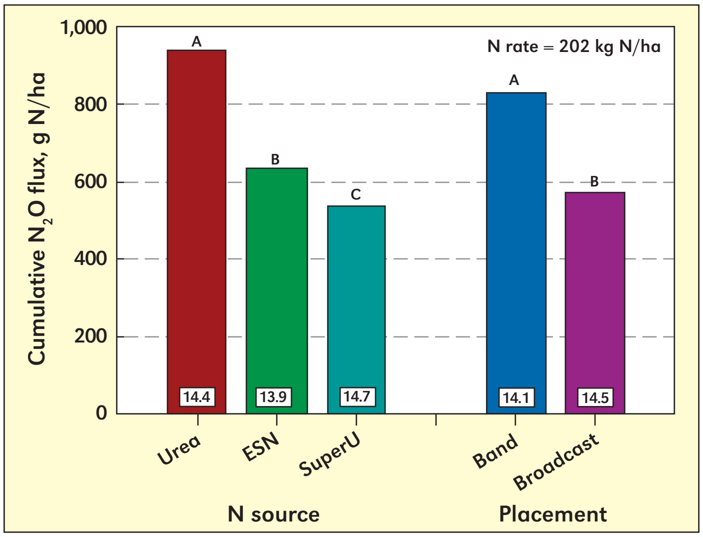

Figure 5. Nitrogen source and placement effects on soil nitrous oxide (N_2O) emissions when averaged over strip-till and no-till systems (3 site-years). Average grain yields (t/ha) are shown in a white box within each bar. (1 t/ha = 15.9 bu/A).

3) in our studies. Expressing N_2O emissions as a function of grain yield and N uptake showed greater agronomic N use efficiency for ESN, SuperU, and UAN+AgrotainPlus than for urea and ESNssb. On an agronomic basis, the N_2O emissions per unit of grain yield were highest for urea (115 g N_2O-N/t grain) and lowest for UAN+AgrotainPlus (38 g N_2O-N/t grain). The ESNssb (87 g N_2O-N/t grain) treatment had greater N_2O emissions per t grain than ESN (55 g N_2O-N/t grain), SuperU (56 g N_2O-N/t grain), UAN+AgrotainPlus, and the check (19 g N_2O-N/t grain) treatments. UAN+AgrotainPlus had lower N_2O emissions per t grain than UAN, ESN, and SuperU. The check treatment had the lowest level of N_2O emissions per t grain, but is not an economically sustainable management practice. These data show that the controlled-release fertilizers investigated have significant potential to reduce N_2O-N emissions per unit of grain production within irrigated corn production systems in the Central Great Plains.

Band versus Broadcast N and N_2O Emissions

Three N sources, urea, SuperU, and ESN were surface band and broadcast applied to ST (2010 and 2011) and NT (2011) corn plots to evaluate the effects of N placement on N_2O emissions under irrigated, corn production. Band applied N had a higher (45%) N_2O emission than broadcast N averaged over 3 site-years (**Figure 5**) (A. Halvorson and S. Del Grosso, unpublished data). Understanding the reasons why N_2O emissions were higher with banded than with broadcast N application will require that N placement effects on N_2O emissions be evaluated further under other soil, cropping system, and climatic conditions to obtain a broader perspective on the effects of N placement on N_2O emissions from agricultural systems.

Summary

All controlled-release N fertilizers and UAN reduced growing season N_2O emissions from irrigated, ST and NT continuous corn cropping systems when compared to urea; and UAN+AgrotainPlus did so consistently in comparison to UAN. Growing season N losses as N_2O-N were consistently < 0.5% of N applied for all controlled-release N sources and UAN, with urea having a loss of < 0.8%. Expressing N_2O emissions as a function of grain yield and N uptake showed greater agronomic N use efficiency for the controlled-release N fertilizers than for urea, although N source did not affect corn yields. This study shows that N source can affect N_2O-N emissions following N fertilizer application. The fertilizer-induced component of N_2O-N emissions was reduced up to 66% by using controlled-release N sources in our semi-arid, irrigated corn studies. The degree of reduction may vary strongly in more humid regions depending on cropping system, tillage, and site-specific conditions. Choice of N source and placement can be valid management alternatives for reducing N_2O emissions to the environment in semi-arid areas. Our results suggest that irrigated soils in semiarid climates have relatively low N_2O-N losses provided irrigation is well-managed to avoid water logged conditions and potential for denitrification. Additional work is needed to verify the effectiveness of these fertilizer sources in reducing N_2O emissions in other rainfed and irrigated cropping systems, especially in humid areas with large amounts of untimely spring rainfall, which can contribute to N_2O losses through denitrification. The principle of applying the right N source, at the right rate, at the right time, in the right place (4R Nutrient Stewardship) becomes a key management decision for optimizing crop yields and economic returns while protecting the environment. BC

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Dr. Halvorson (e-mail: Ardell.Halvorson@ars.usda.gov) and Dr. Del Grosso are with USDA-ARS, 2150 Centre Ave, Bldg. D, Ste. 100, Fort Collins, Colorado, 80526.

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