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

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Research shows that N fertilizer source affects growing season soil N₂O emissions from irrigated corn systems in Colorado. Use of controlled-release and stabilized N sources reduced N₂O 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 N₂O emissions, as did polymer-coated urea. Surface broadcast application of N sources resulted in lower N₂O emissions than surface band applications. Choice of N source and placement can be valid management alternatives for reducing N₂O 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, N₂O, from these systems. Nitrous oxide is produced through nitrification and denitrification processes in the soil. Agriculture contributes approximately 67% of the total anthropogenic N₂O emissions in the USA. Information on how N fertilizer source might affect soil N₂O 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 N₂O emissions from semi-arid, irrigated cropping systems in northern Colorado.

This article presents a summary of the effects of N source on soil N₂O 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).

Nitrogen Source Effects on N₂O Emissions

Nitrous oxide fluxes increased within days following the application of all N sources except for ESN, which had a delayed release of N₂O. An example of the cumulative change in N₂O 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 N₂O 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 N₂O-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 N₂O-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-
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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$_2$O-N emissions from the controlled-release N fertilizers and UAN were significantly lower than dry granular urea. The ESNssb treatment had significantly higher N$_2$O emissions than the UAN+Nfusion, UAN+AgrotainPlus, blank, and check treatments. The UAN+AgrotainPlus and UAN+Nfusion treatments had lower N$_2$O emissions than UAN. The check treatment had the lowest level of growing season N$_2$O-N emissions, with the blank being similar to the check. Compared to dry granular urea, UAN+AgrotainPlus reduced N$_2$O-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$_2$O-N emissions 49%, UAN+Nfusion 26%, SuperU 19%, and ESN 12%. Nitrification was thought to be the main pathway of N$_2$O loss in our studies. Similar differences in growing season N$_2$O 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$_2$O emissions from the ST and NT systems being similar (Halvorson and Del Grosso, 2012). Therefore, we combined the NT and ST N$_2$O data sets to obtain an overall average growing season N$_2$O 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$_2$O-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$_2$O-N emissions 66%, SuperU 50%, ESN 53%, UAN 42%, and ESNssb 23%. Compared to liquid UAN, UAN+AgrotainPlus reduced N$_2$O-N emissions 43%, ESN 19%, and SuperU 14%. Growing season N$_2$O-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$_2$O-N loss per unit of N applied was highest for urea and lowest for UAN+AgrotainPlus. The growing season N$_2$O-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$_2$O-N emissions resulting from N fertilizer application.

N$_2$O Emissions as a Function of Grain Yield

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

Figure 2. Average (2009 and 2010) growing season soil nitrous oxide (N$_2$O) 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$_2$O) 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).

Figure 4. Growing season soil nitrous oxide (N$_2$O) 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.
Growing season N losses as N\textsubscript{2}O-N were consistently < 0.5% of continuous corn cropping systems when compared to urea; and have significant potential to reduce N\textsubscript{2}O-N emissions per unit data show that the controlled-release fertilizers investigated is not an economically sustainable management practice. These urea and ESNs. On an agronomic basis, the N\textsubscript{2}O emissions efficiency for ESN, SuperU, and UAN+AgrotainPlus than for grain yield and N uptake showed greater agronomic N use treatment had the lowest level of N\textsubscript{2}O emissions per t grain, but emissions per t grain than UAN, ESN, and SuperU. The check emissions per t grain than ESN (55 g N\textsubscript{2}O-N/t grain), SuperU (87 g N\textsubscript{2}O-N/t grain) treatment had greater N\textsubscript{2}O 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\textsubscript{2}O 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 ESN. On an agronomic basis, the N\textsubscript{2}O emissions per unit of grain yield were highest for urea (115 g N\textsubscript{2}O-N/t grain) and lowest for UAN+AgrotainPlus (36 g N\textsubscript{2}O-N/t grain). The ESN (87 g N\textsubscript{2}O-N/t grain) treatment had greater N\textsubscript{2}O emissions per t grain than ESN (55 g N\textsubscript{2}O-N/t grain), SuperU (56 g N\textsubscript{2}O-N/t grain), UAN+AgrotainPlus, and the check (19 g N\textsubscript{2}O-N/t grain) treatments. UAN+AgrotainPlus had lower N\textsubscript{2}O emissions per t grain than UAN, ESN, and SuperU. The check treatment had the lowest level of N\textsubscript{2}O 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\textsubscript{2}O-N emissions per unit of grain production within irrigated corn production systems in the Central Great Plains.

### Band versus Broadcast N and N\textsubscript{2}O 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\textsubscript{2}O emissions under irrigated, corn production. Band applied N had a higher (45%) N\textsubscript{2}O emission than broadcast N averaged over 3 site-years (Figure 5) (A. Halvorson and S. Del Grosso, unpublished data). Understanding the reasons why N\textsubscript{2}O emissions were higher with banded than with broadcast N application will require that N placement effects on N\textsubscript{2}O 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\textsubscript{2}O emissions from agricultural systems.

### Summary

All controlled-release N fertilizers and UAN reduced growing season N\textsubscript{2}O 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\textsubscript{2}O-N were consistently < 0.5% of

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**Figure 5.** Nitrogen source and placement effects on soil nitrous oxide (N\textsubscript{2}O) 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).

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**References**


