CROP MANAGEMENT EFFECTS ON NITROUS OXIDE EMISSIONS FROM IRRIGATED SYSTEMS[1]

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ABSTRACT

The paper objective is to present an overview of the greenhouse gas research results from tillage and N fertility studies conducted by USDA-ARS on irrigated cropping systems near Fort Collins, Colorado from 2002–2010. Within agronomic N rates needed to optimize irrigated crop yields in the Central Great Plains, a linear increase in growing season nitrous oxide (N_2O-N) emissions was observed from a clay loam soil with increasing fertilizer N rate. Averaged over a 5 yr period (2002-2006), N_2O-N emissions were greater from a conventional-till continuous corn (CT-CC) production system than from a no-till continuous corn (NT-CC) production system. Adding soybean or dry bean to the rotation resulted in increased growing season N_2O-N emissions during the corn year of the corn-bean rotation when compared to CT-CC or NT-CC systems. Fertilizer N source effects on growing season N_2O-N emissions were also evaluated. Emissions were monitored from several inorganic N fertilizer sources (urea, ESN[1], Duration III[1], SuperU[1], UAN, UAN+AgrotainPlus[1], UAN+Nfusion[1]) from 2007-2010. Comparing N_2O-N emissions (2007-2008) from urea and ESN in CT-CC and NT-CC cropping systems, N_2O-N emissions were not different between urea and ESN in the CT-CC system; however, N_2O-N emissions were significantly less with ESN than with urea in the NT-CC system. Emissions from urea and ESN were significantly less in the NT-CC system than in the CT-CC system. Growing season N_2O-N emissions from SuperU (a stabilized N source) was significantly less than from urea in NT corn-barley and NT corn-dry bean rotations in 2007 and 2008. The effects of several enhanced-efficiency N sources on growing season N_2O-N emissions were compared in a NT-CC system in 2007 and 2008. The enhanced-efficiency N fertilizers and UAN reduced growing season N_2O-N emissions compared to urea, with the SuperU and UAN+AgrotainPlus having lower emissions than UAN. In 2009 and 2010, the enhanced efficiency N sources were compared in a strip-till (ST), irrigated continuous corn production system. Averaged over 2 yr, all N sources had significantly lower growing season N_2O emissions than dry granular urea, with UAN+AgrotainPlus having lower emissions than UAN. The check treatment with no N applied had the lowest level of emissions in all years. Cumulative increases in daily N_2O-N fluxes were more rapid for urea and UAN than the other N sources following N fertilizer application. The enhanced efficiency

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fertilizers (polymer-coated, stabilized, and slow release) sources showed potential for reducing N_2O-N emissions in semi-arid, irrigated cropping systems in the Central Great Plains.

INTRODUCTION

Nitrous oxide is produced in soils through nitrification and denitrification processes with agriculture contributing approximately 67% of the total U.S. N_2O emissions (USEPA, 2010). Nitrous oxide has a global warming potential (GWP) approximately 298 times greater than CO_2, thus it is important to develop methods to reduce N_2O-N emissions in agricultural systems. Available data for analyzing N_2O-N emissions impact on GWP in irrigated crop production systems is limited (Mosier et al., 2006; Snyder et al., 2009; Archer and Halvorson, 2010). Venterea et al. (2005, 2010) found N source influenced N_2O emissions from corn production systems in Minnesota with greatest N_2O emissions from anhydrous ammonia application compared to UAN and urea. Hyatt et al. (2010) reported equal potato yields with a single application of polymer-coated urea products compared to 5-6 smaller applications of urea during the growing season, with slightly lower growing season N_2O-N emissions with the polymer-coated urea products. This paper presents a brief summary of key results from several greenhouse gas projects conducted by USDA-ARS near Fort Collins, Colorado on a Fort Collins clay loam soil from 2002 through 2010, emphasizing the N_2O-N emissions. Details of the studies can be found in the references cited.

KEY FINDINGS

Tillage, Cropping System, N Rate Studies

Nitrogen fertilizer application generally increased N_2O-N emissions linearly with increasing N rate from irrigated conventional-till continuous corn (CT-CC) and no-till continuous corn (NT-CC) production systems in the Central Great Plains (Mosier et al., 2006; Halvorson et al., 2008; Halvorson et al., 2009) as shown in Fig. 1. Averaged over 5 years (2002-2006), N_2O-N emissions tended to be lower from the NT-CC system than from the CT-CC system. Including soybean or dry bean in a NT rotation with corn resulted in greater N_2O-N emissions during the corn phase of the rotation than in CT-CC and NT-CC rotations. The magnitude of N_2O-N emissions varied from year to year with varying climatic conditions. To convert kg N ha^{-1} to lb N $acre^{-1}$ divide by 1.12; to convert g N ha^{-1} to lb N $acre^{-1}$ divide by 1120.

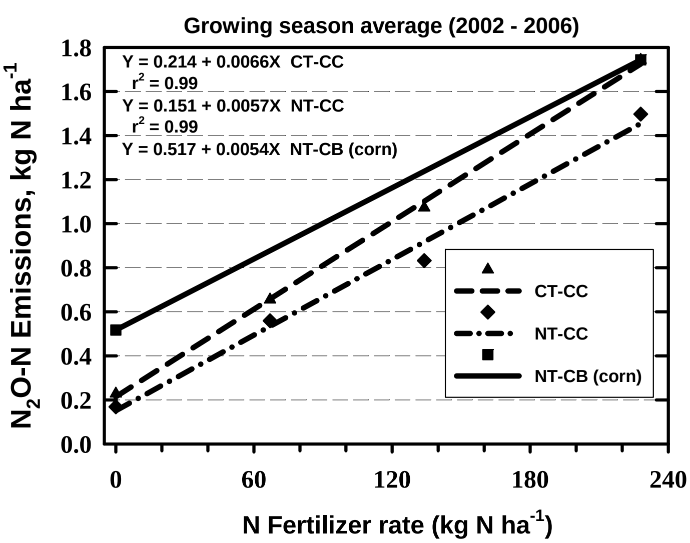

Fig. 1. Growing season N_2O-N growing season emissions as function of N fertilizer rate and cropping system. (Halvorson et al., 2009.)

Research reported by Mosier et al. (2006) and Halvorson et al., (2008, 2010a,b) from irrigated cropping systems exhibited a sharp rise in N_2O-N emissions within days following N fertilization with urea-ammonium nitrate (UAN) or dry granular urea fertilizers in CT-CC, NT-CC, and NT-CSb/Db (corn-soybean/dry bean) cropping systems. The N_2O emissions stabilized to near background levels in about 40-45 days following N fertilization and were minimal for the rest of the growing season and non-crop period. A life-cycle analysis of these studies by Archer and Halvorson (2010) showed that adoption of an irrigated, NT-CC system with N rates adequate to optimize grain yields would reduce GWP compared to the CT-CC system. The NT corn-soybean rotation also had lower GWP than the CT-CC system along with greater profit potential.

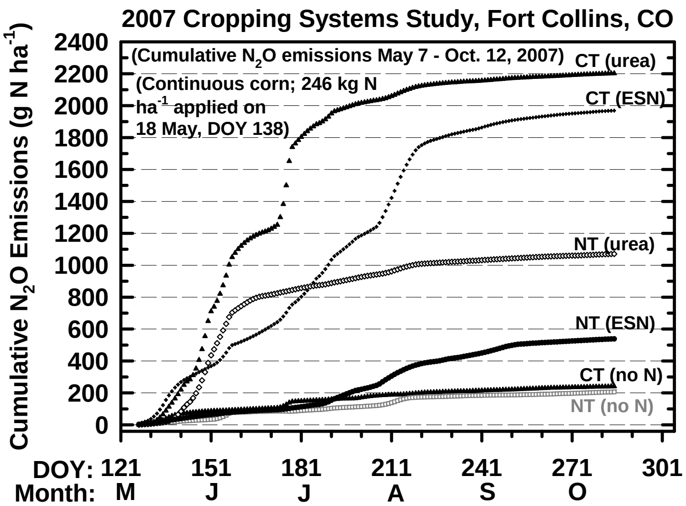

Fig. 2. Cumulative growing season N_2O-N emissions with time (Halvorson et al., 2010a).

Halvorson et al. (2010a) reported reduced N_2O-N emissions from application of a polymer-coated urea and a stabilized urea compared to dry granular urea in irrigated NT cropping systems. Comparisons of cumulative N_2O-N emissions for the polymer-coated urea and dry granular urea in the CT-CC and NT-CC cropping systems are shown in Fig. 2. The CT-CC system had greater N_20-N emissions than the NT-CC system in 2007 and 2008, with no significant difference in N_2O-N emissions between the polymer-coated urea (ESN) and urea in the CT-CC system, but a significant reduction in emissions with ESN compared to urea in the NT-CC system. It is important to note the rapid increase in emissions within days after N application for urea and the reduced N_2O-N emissions until later in the growing season with ESN in both cropping systems. The 2-yr average differences in growing season emissions are shown in Fig. 3.

Halvorson et al. (2010a) also compared a stabilized urea (SuperU) with urea in NT corn-barley and corn-dry bean rotations in 2007 and 2008. SuperU reduced N_2O-N emissions significantly compared to the emissions from urea both years and in both cropping systems.

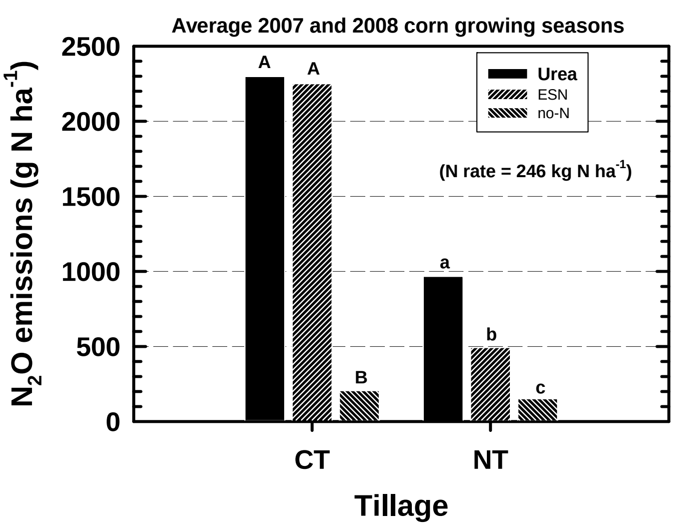

Fig. 3. Average growing season N_2O-N emissions for N sources in CT and NT continuous corn production systems (Halvorson et al., 2010a).

N Source Studies

In 2007 and 2008, N_2O-N emissions resulting from the application of several N sources were compared (Halvorson et al., 2010b). Fertilizer N sources evaluated were urea (46% N), urea-ammonium nitrate (UAN, 32% N), polymer-coated ureas (ESN, 44% N and Duration III, 43% N), a stabilized granular urea (SuperU, 46% N), and a stabilized UAN (UAN plus AgrotainPlus, 32% N). The polymer-coated urea products, ESN and Duration III, are produced by Agrium Advanced Technologies, Inc. SuperU is a finished urea product produced by Agrotain International that is a homogenous blend

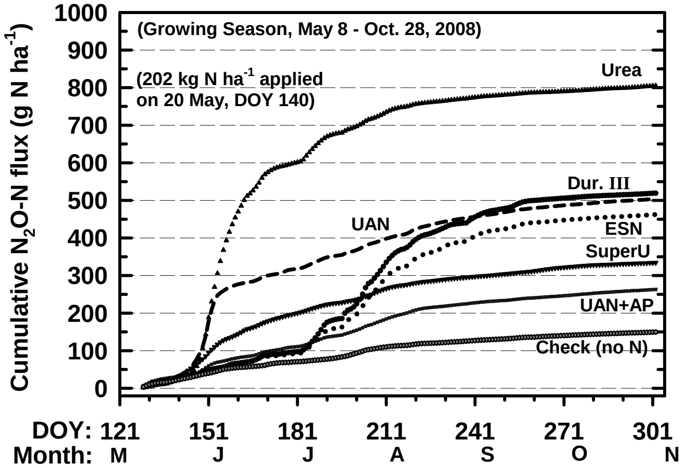

Fig. 4. Cumulative growing season N_2O-N emissions for several N sources (Halvorson et al., 2010b).

with urease (NBPT) and nitrification (DCD) inhibitors included at the time of production. AgrotainPlus includes the same inhibitors as SuperU and is produced by Agrotain International. Cumulative growing season N_2O-N emissions for 2008 are shown in Fig. 4. The rapid rise in N_2O-N emissions following N fertilizer application is very evident for urea and UAN compared to the other N sources. The check treatment with no N applied had the lowest level of growing season N_2O-N emissions. The lower level of emissions with UAN compared to urea probably resulted from the fact that UAN is 33% NO_3-N, and that nitrification is the dominant loss mechanism in our studies, not denitrification. Adding AgrotainPlus to the UAN reduced emissions even more.

The 2-yr average growing season N_2O-N emissions are shown in Fig. 5 for each N source. The effectiveness of N sources in reducing N_2O-N emissions in the NT-CC system compared to urea were in the order: UAN (27%), Duration III (31%), ESN (34%), SuperU (48%), and UAN+AgrotainPlus (53%). Compared to UAN, Duration III (6%) and ESN (9%) reduced N_2O-N emissions only slightly (not significant), but SuperU (29%) and UAN+AgrotainPlus (35%) reduced N_2O-N emissions significantly.

There were only small differences in corn grain yields between N sources in 2007 and 2008, with the exception of the check treatment (no N applied) having significantly lower yields. Averaged over the two years, the UAN treatment had a lower corn grain yield (11.87 Mg ha^{-1}) than urea (12.75 Mg ha^{-1}), but greater than the check treatment (8.92 Mg ha^{-1}). Expressing N_2O-N emissions as a function of grain yield is one way to account for variability in N_2O-N emissions and grain yield for each N source. Urea had the highest level of N_2O-Nemissions per unit of corn grain yield, followed by lower emissions from UAN, Duration III, ESN, and SuperU; SuperU had N_2O-N emission levels no different than those from UAN+AgortainPlus, which had the lowest emissions among the N sources, and the check had the lowest level of emissions per unit of yield. These studies show that the enhanced efficiency fertilizers have potential to reduce N_2O-N emissions per unit of grain production in this semiarid, irrigated corn production area of the Central

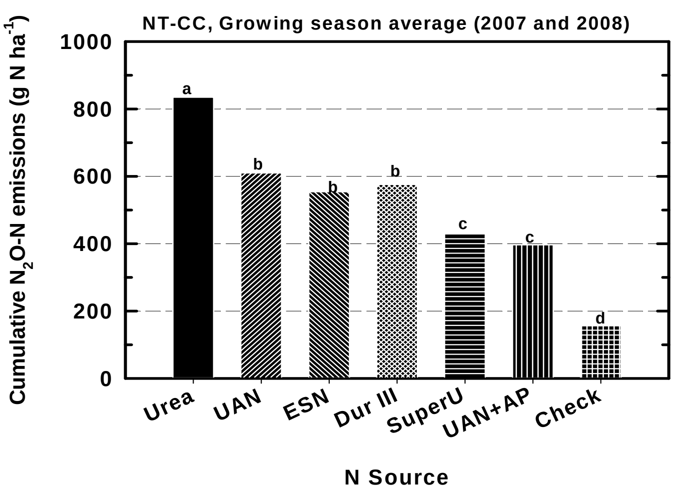

Fig. 5. Average growing season N_2O-N emissions from several N fertilizer sources (Halvorson et al., 2010b).

Great Plains (Halvorson et al., 2010b).

Nitrogen source evaluation studies were continued in 2009 and 2010 under strip-till (ST) continuous corn with the addition of an ESN subsurface band (ESNssb) treatment and UAN+20% Nfusion (22% N) treatment (UAN+Nf). The Nfusion added to UAN was a slow release liquid N made up of slowly available urea polymers in form of methylene urea plus triazone and is produced by Georgia Pacific Chemicals, LLC. The differences between N treatments at the end of the growing season in 2009 are shown in Fig. 6. Dry granular urea had the highest level of N_2O emissions for the growing season and was significantly greater than all other sources. The ESNssb, UAN, ESN, and SuperU, had similar levels of N_2O emissions for the growing season, with UAN+AgrotainPlus and UAN+Nf having lower emissions than UAN. The blank and check treatments (no N applied) were not significantly different. This would indicate increased N_2O-N emissions occurred only when a new supply of N fertilizer was added. Thus, even though there was a slightly higher residual soil N level in the upper 30 cm of soil in the blank plots previously receiving fertilizer N than in the check plots, N_2O-N emissions of the blank treatment were not greater than in the check treatment. The 2010 data (Halvorson et al., 2011) confirmed the 2009 observations that there was no difference between the blank and check treatments in N_2O-N emissions.

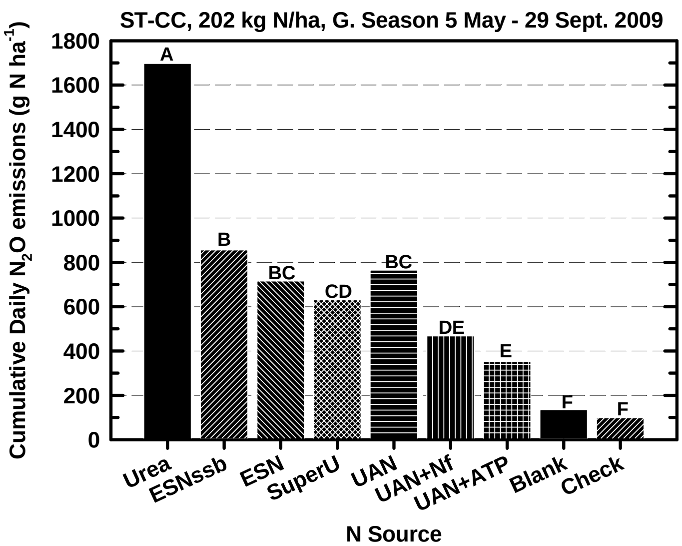

Fig. 6. Growing season N_2O-N emissions for several N sources in 2009 (Halvorson and Del Grosso, 2010).

Carbon dioxide (CO_2) and methane (CH_4) greenhouse gases were also measured during the growing seasons, with the results reported by Mosier et al. (2006), Halvorson et al. (2008, 2010a, 2010b), and Alluvione et al. (2009). In general, net cumulative growing season CH_4 emissions were near zero in all studies. The CO_2 cumulative emissions increased throughout the entire growing season, with greater emissions from the CT-CC system than the NT-CC system, and little differences between N rates or N sources.

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