NITROUS OXIDE EMISSIONS IN CLAYPAN SOILS DUE TO FERTILIZER SOURCE AND TILLAGE/FERTILIZER PLACEMENT

P.R. Nash[1], P.P. Motavalli[1], and K.A. Nelson[2]
[1]Dept. of Soil, Environmental and Atmospheric Sciences,
University of Missouri, Columbia, MO 65202,
[2]Div. of Plant Science, Greenley Research Center,
University of Missouri, Novelty, MO 63460

Abstract

Nitrogen fertilization for agricultural production is a major contributor to increased soil nitrous oxide emissions. These emissions may contribute to global warming and ozone depletion. Nitrogen fertilizer source and placement can influence soil nitrous oxide (N_2O) emissions by affecting the concentration of ammonium and nitrate available for nitrification and denitrification throughout the growing season. The objectives of this research were to quantify the effect of tillage / fertilizer placement (no-till, surface broadcast and strip-till, deep banding) and N fertilizer source (non-coated urea, polymer-coated urea, non-treated control) on soil N_2O emissions from agricultural practices in claypan soils located in Northeastern Missouri. Soil N_2O emissions were measured and analyzed using static chambers and gas chromatography, following the USDA protocol (GRACEnet) for field measurements of trace gases. The field experiment planted to corn (*Zea mays* L.) was initiated in 2009 and included six treatments with three replications and two subsamples in a randomized complete block design. No-till, broadcast, and polymer-coated urea management system had the highest average cumulative soil N_2O emissions after fertilization (4.4 lbs N_2O-N $acre^{-1}$), which represented 3.54% N lost from fertilizer as N_2O in 2009. No significant interaction was found between N fertilizer source and tillage/placement ($P < 0.05$). Strip-till management emitted 0.013 lbs N_2O-N per bushel of corn grain produced, which was significantly lower than no-till management that emitted 0.023 lbs N_2O-N Bu^{-1} ($P < 0.10$). Additional results from the 2010 season will be presented.

Background

Nitrous oxide (N_2O) is a greenhouse gas that is 310 times stronger than carbon dioxide (CO_2) and depletes the ozone (Smith et al, 2007). Soil nitrous oxide is naturally produced by nitrification and denitrification processes occurring in soils and emission rates are largely dependent on the amount of soil nitrate-N, soil moisture and temperature. Agricultural practices contribute approximately 58% of the anthropogenic emission of N_2O with 38% of agriculturally produced N_2O emitted from the soil (Smith et al, 2007; USEPA, 2007). Future global N_2O emissions are projected to increase 35-60% by 2030 due largely to the projected increase in global nitrogen (N) fertilizer use and animal production (FAO, 2003).

Agricultural soils with a restrictive subsoil layer. such as a claypan, can potentially have high rates of soil N_2O emissions because these soils typically have poor drainage which can result in a large percentage of the applied N to be lost by denitrification. With current N use efficiency (NUE) typically between 30-50%, significant improvement of NUE in agricultural production on poorly drained soils could make greatest significant impact on reducing agricultural soil N_2O emissions by limiting the total amount of N available for denitrification. Recent advances in management options including enhanced urea fertilizer and minimal tillage systems (strip-till) can potentially be used on a large scale to improve NUE and crop yields while minimizing soil N_2O emissions.

Polymer-coated urea (PCU) reduces potential nitrogen loss by controlling the amount of urea available for soil microbial activity throughout the growing season. Release rates from PCU are related to soil temperature and moisture content; however, more research is needed to fully understand PCU's effect on N availability throughout the growing season. Merchan-Paniagua (2004) observed reduced soil N_2O emissions when comparing non-coated urea (NCU) and PCU plots on claypan soils but did not have the same results in 2005. This could be due to climatic variation since urea's release rate from a prill is directly related to soil temperature and moisture.

Tillage operations in agricultural practices have a strong effect on NUE and fertilizer release rates since the fertilizer placement options are affected by the tillage system used. No-till (NT) practices allow for minimal soil disturbance and have been shown to increase carbon sequestration and sustain or increase soil fertility. However, NT practices typically require fertilizers to be broadcast on the surface. Broadcasting urea-based fertilizers on the soil surface greatly increases the potential for ammonia volatilization, immobilization of N in surface residues, and higher rates of denitrification. Many studies have suggested that NT operations will increase soil N_2O emissions due to lower oxygen levels in soil pores, increased bulk density and higher soil water content (Lipps, 2010). Increased soil N_2O emissions from NT could potentially offset the higher rates of soil carbon sequestration which generally result from this form of conservation tillage.

Strip-till (ST) operations cause less soil disturbance than conventional tillage (CT) practices and allow the placement of fertilizers banded at depth in the soil profile. Incorporation of urea-based fertilizers in bands within the soil profile can minimize volatilization and lower rates of denitrification. Lower soil bulk density and improved drainage should increase soil oxygen levels and reduce soil water content. These properties in theory would reduce N_2O emissions, however, many studies comparing differences in soil N_2O emissions between CT and NT systems have had mixed results. Higher N_2O emissions have been reported in NT operation compared to CT (Mackenzie et al., 1997; Ball et al., 1999; Baggs et al., 2003; Six et al., 2004). While other studies have found lower or similar soil N_2O emissions in NT compared to CT (Robertson et al., 2000; Elmi et al., 2003; Grandy et al., 2006). The variation in the results between these studies is thought to be a product of differences in soil type and climatic conditions. Expanded research on the impact of tillage operations on N_2O emissions for specific soil types and climates will be required to make better estimates of how tillage practices affect N_2O emissions for specific locations.

Research Objectives

- To evaluate differences in soil N_2O emissions due to N fertilizer source, fertilizer application method, and tillage practice, including no-till and strip-till management.

- To determine the effects of variability in soil temperature, soil water content and the time period after fertilizer application on soil N_2O emissions.
- To improve the methodology for measuring soil N_2O emission in claypan soils.

Experimental Design

A field trial was initiated in 2009 at the Greenley Memorial Research Center in Northeast Missouri on corn plots containing soybean residue from the previous season. The N_2O field study is part of a larger experiment examining the production differences between fertilizer source (i.e., PCU, NCU, Anhydrous Ammonia, and Anhydrous Ammonia with N-serve), tillage (urea fertilizer only), and N application timing (i.e., Fall, Early Preplant, Preplant). Treatments were arranged in a randomized complete block design with three replications. In both 2009 and 2010, soil N_2O was sampled only in the preplant N applications which were applied in April at a rate of 125 lbs N/acre. Treatments consisted of NT/broadcast NCU, NT/broadcast PCU, ST/banded NCU, ST/banded PCU, NT/no fertilizer applied, and ST/no fertilizer applied. Gas samples were taken by replication and two N_2O subsamples for each treatment in a replicate. Samples were taken approximately every other day, but sampling increased directly after rainfall events. For each gas sample, soil temperatures were recorded and soil samples were taken for determining soil moisture and nitrate content in order to correlate soil temperature, nitrate concentration, and moisture with soil N_2O flux.

2009 Results

Significant N_2O emissions did not occur until three weeks after the April 23rd fertilizer application (Figure 1). Significant differences in N_2O emissions between treatments occurred on individual sample dates, however; over the entire growing season there was no significant difference in cumulative N_2O emissions between treatments. This was presumably due to differences in N fertilizer release rates as a result of fertilizer source (i.e., PCU, NCU) combined with ST (banded at depth) or NT (surface broadcasted). The highest percentage of N fertilizer loss as N_2O-N was 3.54% (PCU/NT) and the lowest was 1.85% (NCU/ST). Although there was no significant difference in cumulative N_2O emissions between treatments, both ST treatments had significantly higher corn grain yields than the NCU/NT treatment (Figure 2). When combining the cumulative N_2O emissions and corn grain yields for each preplant treatment we obtained a value that represents the amount of N_2O-N emitted per bushel of grain produced. Strip-till treatments (banded at depth) averaged 0.0139 lbs N_2O-N/bu, which at an alpha value of 0.10 was significantly lower than NT treatments (surface broadcasted) which emitted 0.0234 lbs N_2O-N/bu (Figure 3). It is important to note that these results could be high related to the total rainfall and distribution throughout the growing season and will require multiple seasons to confirm these results.

2010 Preliminary Results

As of July 17th the total rainfall has been similar to the 2009 growing season (Figures 4 and 5) and we have found similar trends in cumulative N_2O- N emissions as of June 6th. Similar to the 2009 growing season, significant N_2O emissions did not occur until three weeks after N application. Also both NT treatments have greater emissions and fluctuations earlier in the season than ST treatments, however; ST treatments will most likely have greater emissions later in the season resulting in similar cumulative emissions between treatments at the end of the growing season (Figure 6). The percentage of N fertilizer loss between treatments should not significantly exceed the 2009 values but completion of the 2010 season will be required to confirm this.

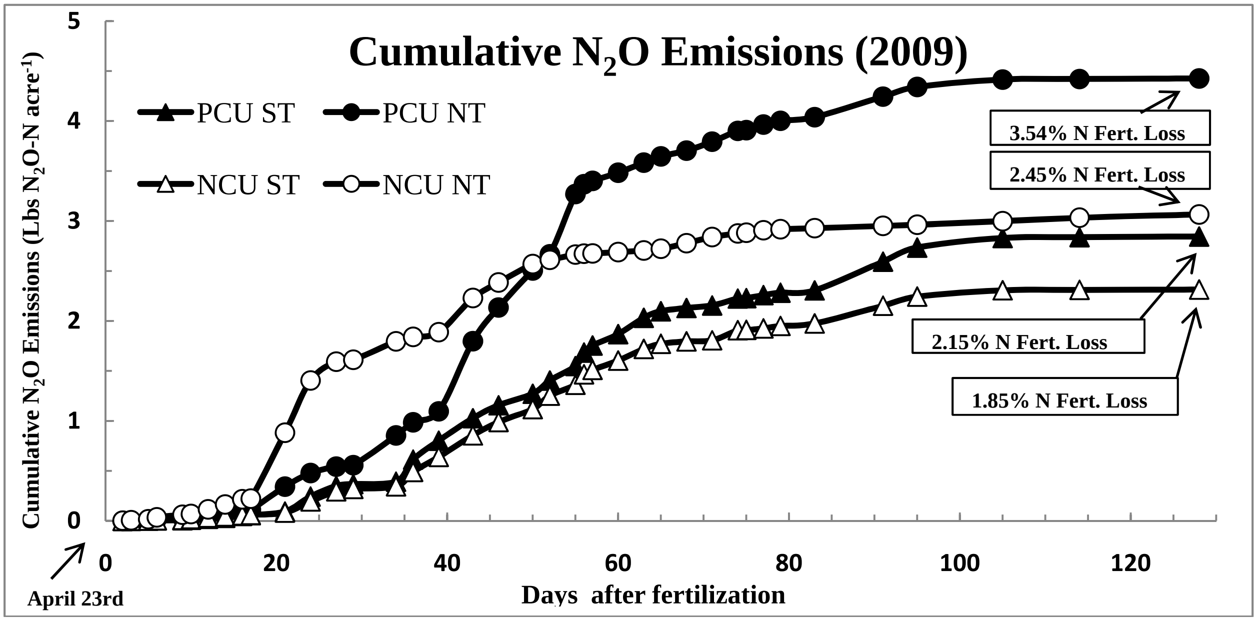

Figure 1. Cumulative N_2O emissions (minus unfertilized control) for preplant applied polymer coated urea (PCU) and non-coated urea (NCU) with strip-till (ST) and no-till (NT) management from 2009.

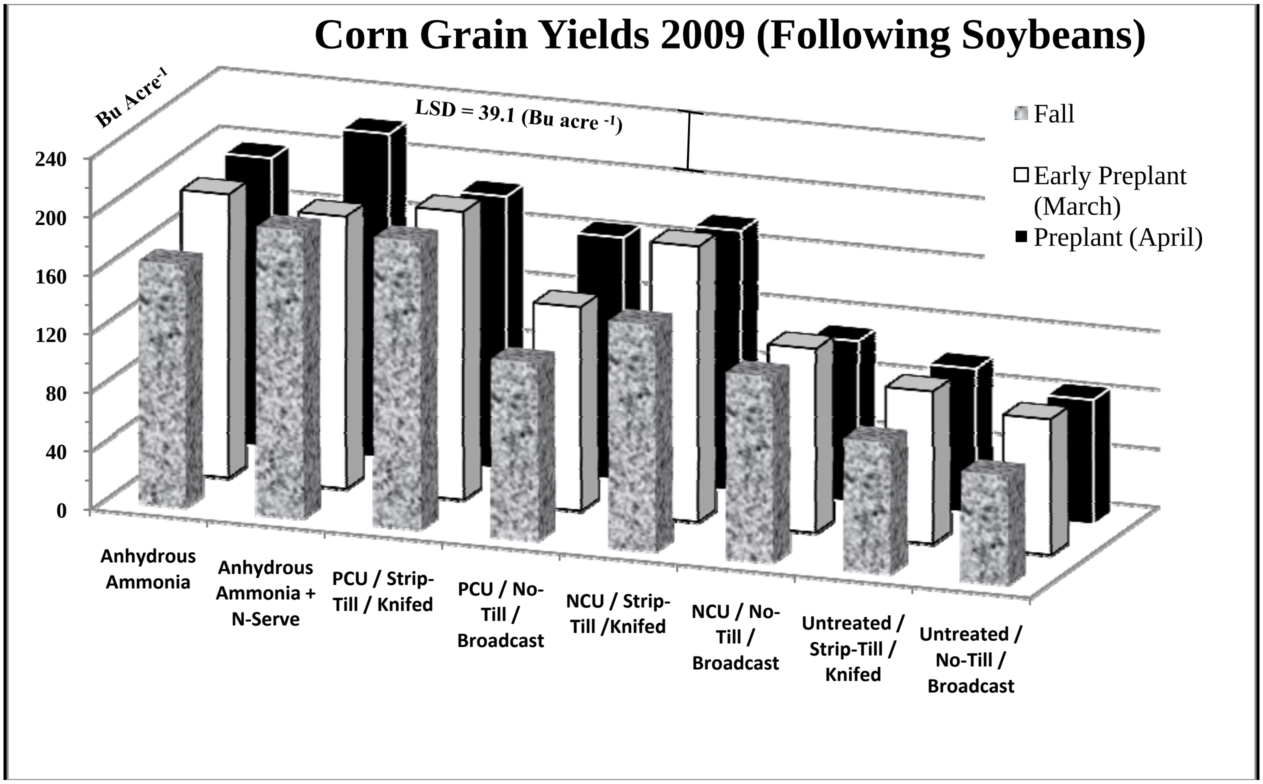

Figure 2. Corn grain yields as affected by time and method of N fertilizer application, the N fertilizer source, and tillage method in 2009.

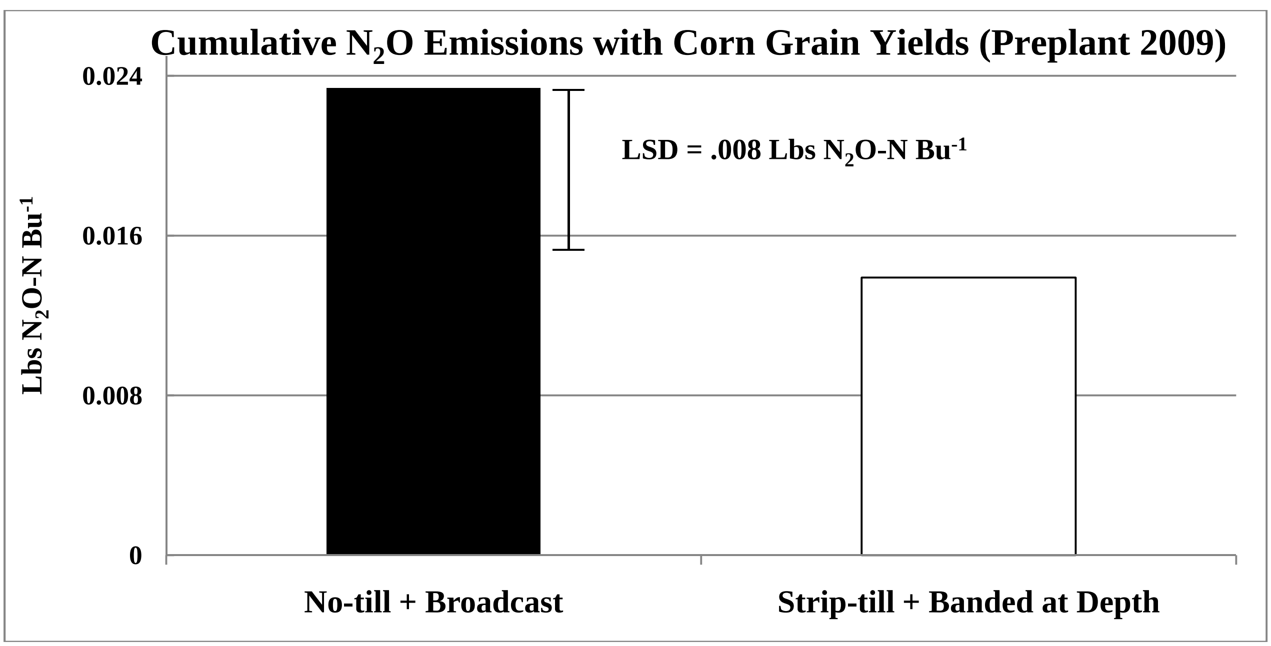

Figure 3. Amount of soil N_2O-N emitted per bushel of corn grain for tillage/N fertilizer placement for the preplant N fertilizer application following soybeans from 2009.

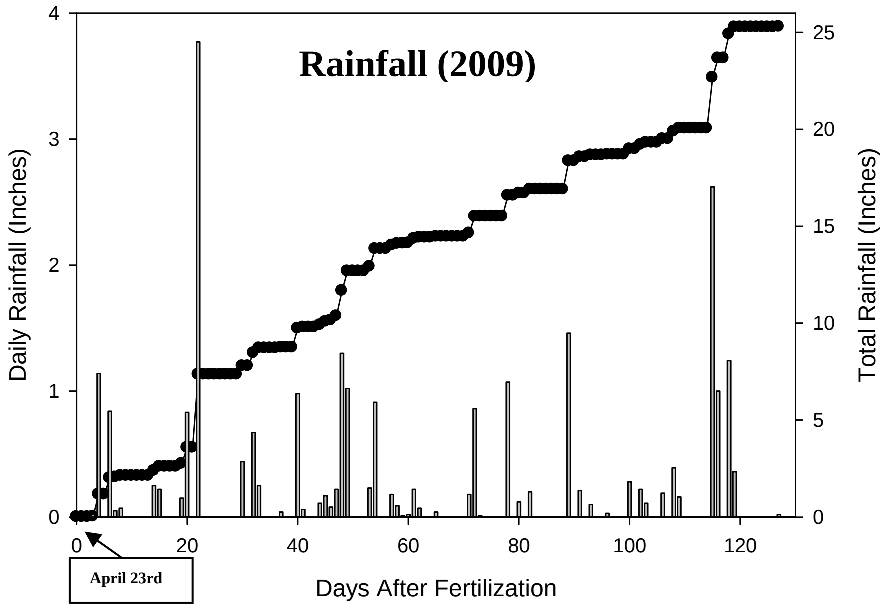

Figure 4. Daily and total rainfall after N fertilizer application for the 2009 growing season.

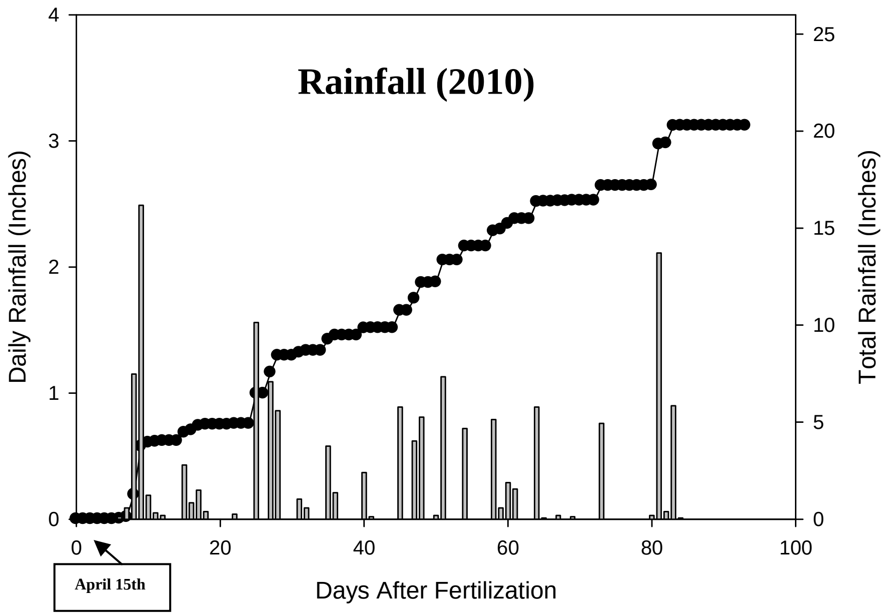

Figure 5. Daily and total rainfall after N fertilizer application for the 2010 growing season.

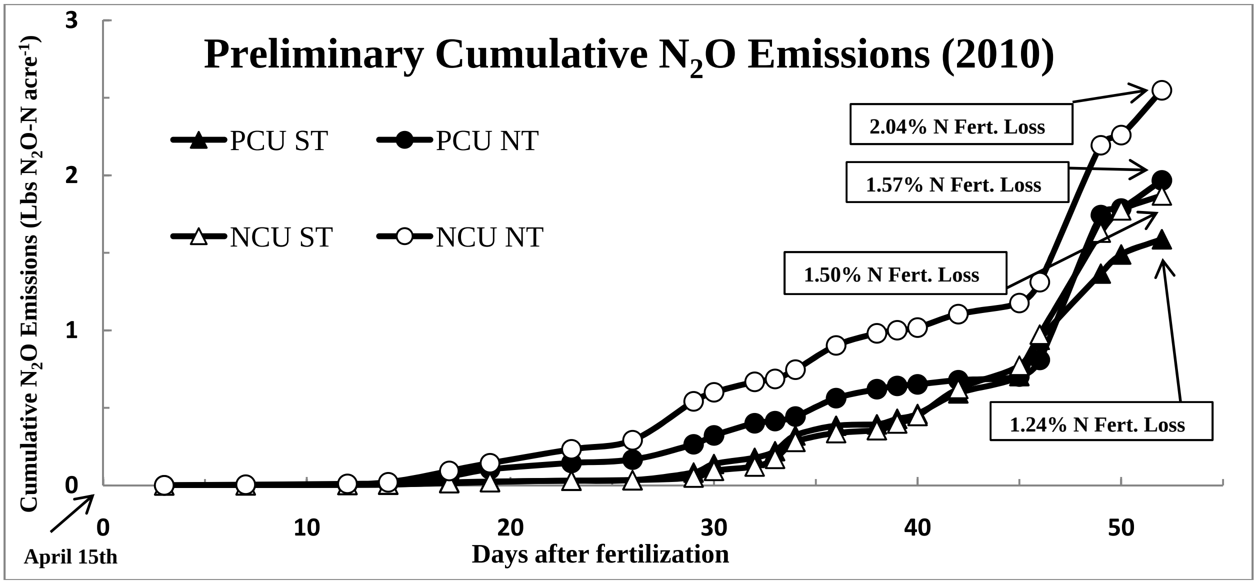

Figure 6. Preliminary cumulative N_2O emissions for preplant applied polymer urea (PCU) and non-coated urea (NCU) with strip-till (ST) and no-till (NT) management during the 2010 growing season.

Preliminary Conclusions

- Significant soil N_2O emissions do not occur until 3 weeks after N application.
- No-till/broadcasted treatments have the largest soil N_2O emissions early after N application while ST/banded at depth treatments have the largest soil N_2O emissions later after N application.
- Significant differences in soil N_2O emissions of treatments occur on individual days but cumulative emissions over an entire growing season are not significantly different.
- Both ST treatments (i.e., NCU, PCU) had significantly greater corn grain yields than NT/NCU treatment.
- Strip-tillage with N fertilizer banded at depth significantly reduces the amount of N_2O-N emitted per bushel of corn grain produced compared to NT/surface broadcasted treatments.
- Improving the method of sampling N_2O emitted from soil in the field will improve the precision and accuracy of soil N_2O flux calculations.

References

Baggs, E.M., M. Stevenson, M. Pihlatie, A. Regar, H. Cook, and G. Cadisch. 2003. Nitrous oxide emissions following application of residues and fertilizer under zero and conventional tillage. Plant Soil 254:361-370.

Ball, B.C., A. Scott, and J.P. Parker. 1999. Field N_2O, CO_2, and CH_4 fluxes in relation to tillage, compaction, and soil quality in Scotland. Soil Tillage Res. 53:29-39.

Elmi, A.A., C. Madramootoo, C. Hamel, and A. Liu. 2003. Denitrification and nitrous oxide to nitrous oxide plus dinitrogen ratios in the soil profile under three tillage systems. Biol. Fertil. Soils 38:340-348.

FAO. 2003. World Agriculture: Towards 2015/2030. An FAO Perspective. FAO, Rome, 97 pp.
Grandy, A., Terrance Loecke, Sara Parr, and G. Robertson. 2006. Long-term trends in nitrous oxide emissions, soil nitrogen, and crop yields of till and no-till cropping systems. J. of Environ. Qual. 35:1487-1495.
Lipps, L., 2010. Examining the role of soils in emissions of the potent greenhouse gas N_2O. CSA News 55:4-9.
MacKenzie, A.F., M.X. Fan, and F. Cadrin. 1997. Nitrous oxide emission as affected by tillage, corn-soybean-alfalfa rotations and nitrogen fertilization. Can. J. of Soil Sci. 77:145-152.
Merchan-Paniagua, S. 2006. Use of slow-release N fertilizer to control nitrogen losses due to spatial and climatic differences in soil moisture conditions and drainage in claypan soils. M.S. thesis, Univ. of Missouri, Columbia, MO
Robertson, G.P., E.A. Paul, and R.R. Harwood. 2000. Greenhouse gases in intensive agriculture: Contributions of individual gases to the radiative forcing of the atmosphere. Science 289:1922-1925.
Six, J., S.M. Ogle, F.J. Breidt, R.T Conant, A.R. Mosier, and K. Paustian. 2004. The potential to mitigate global warming with no-tillage management is only realized when practiced in the long term. Glob. Change Biol. 10:155-160.
Smith, P., D. Martino, Z. Cai, D. Gwary, H. Janzen, P. Kumar, B. McCarl, S. Ogle, F. O'Mara, C. Rice, B. Scholes, and O. Sirotenko. 2007. Agriculture climate change mitigation. Contribution of Working Group III to the fourth assessment report of the Intergovernmental Panel on Climate Change [B. Metz, O. Davidson, P. Bosch, R. Dave, L. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Tilman, D., K. Cassman, P. Matson, and R. Naylor. 2002. Agricultural Sustainability and Intensive Production Practices." Nature 418:671-677.
USEPA. 2007. Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2007: Agriculture.http://Yosemite.epa.gov/oar/globalwarming.nfs/content/EmissionsNational.html. Accessed 07-15-2010.

PROCEEDINGS OF THE

40^{th}

NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 26

November 17-18, 2010
Holiday Inn Airport
Des Moines, IA

Program Chair:

Richard Ferguson
University of Nebraska - Lincoln
Lincoln, NE 68583
(402) 472-1144
rferguson@unl.edu

Published by:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net