NITROUS OXIDE EMISSIONS FROM CLAYPAN SOILS DUE TO NITROGEN FERTILIZER SOURCE AND TILLAGE/FERTILIZER PLACEMENT PRACTICES

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Background

Agricultural practices on poorly drained claypan soils can have high amounts of applied N lost through denitrification which can be a major contributor to soil nitrous oxide (N_2O) gas emissions. Increasing levels of N_2O in our atmosphere can have significant environmental consequences because atmospheric N_2O has a residency time of a decade up to centuries, global warming potential 297 times that of CO_2, and is a precursor gas to ozone depletion (Venterea et al., 2005; Smith et al., 2007). Mitigating soil N_2O emissions from agricultural practices in this region while maintaining high yield production through adoption of alternative management will become increasingly important in the future (Bailey, 2005). Selecting management that can optimize N recovery and plant uptake of applied N fertilizers could potentially minimize soil N_2O emissions from agricultural practices while still insuring high agricultural yields.

Global increases in the application of N fertilizers are the main reason soil N_2O emissions from agricultural practices have dramatically risen over the past 30 years (Smith et al., 2007). Enhanced efficiency urea fertilizer products may potentially lower soil N_2O emissions from application of urea fertilizer. Polymer-coated urea (e.g., ESN from Agrium, Inc, Calgary, Canada) is a enhanced efficiency fertilizer product which encases urea within a polymer coat and once urea dissolves within the prill it will diffuse out at a rate dependant on soil temperature (Fujinuma et al., 2009). Addition of the polymer coat should slow or delay the amount of N susceptible to denitrification throughout the growing season. Although research is limited, results have already demonstrated PCU's potential to minimize soil N_2O emissions compared to traditional urea fertilizer (Halvorson et al., 2008).

Inter-related to N fertilizer source, N fertilizer application can significantly impact N losses including soil N_2O emissions. The fertilizer application methods include how (e.g., broadcast or banded) and where (e.g., surface-applied and shallow or deep placement) the fertilizer is applied. No-till (NT) management typically restricts N placement of dry N fertilizers (i.e., urea) to surface broadcasting and banding. Broadcasting N fertilizers results in a more uniform spreading of N fertilizer over the soil surface potentially causing greater soil contact with the fertilizer granule and higher rates of several N processes including ammonia volatilization, nitrification and denitrification. In contrast, banding of N fertilizers may minimize N fertilizer granule contact with soil microbes which presumably reduces the rate of ammonia volatilization and soil N_2O and N_2 emissions (Grant et al., 2010).

Soil tillage expands N placement options of dry N fertilizers to allow for broadcasting and banding at depths ranging from shallow (≈0.8 in) to deep (≈6 in), respectively. Deep placement of N fertilizers will typically place fertilizer at soil depths which have relatively lower soil temperature and total organic carbon levels compared to the soil surface and shallow depths. Resulting from these conditions at deeper soil depths, deep placement of N fertilizers may expose fertilizer to reduced soil microbial activity and lower soil N_2O emissions. A recent study found cumulative soil N_2O emissions from urea decreased with application depth (i.e., 1, 2, and 3 in depth), with placement at 2 and 3 in depth having a 35 and 77% reduction in emissions, respectively, compared to shallow placement of N (Khalil et al., 2009). However, a study in 2006 averaged over three tillage practices (NT, minimal tillage, conventional tillage) and multiple growing seasons found deep placement (3.9 in) increased cumulative soil N_2O emissions by 26% over shallow placement (0.8 in) of N (Drury et al., 2006).

Recent advancements in tillage technology now allow for minimal tillage practices which maintain the stipulations set forth for conservation tillage but do include some degree of tillage. Strip-tillage (ST) is an example of minimal tillage, which tills only the seed row, leaving majority of the soil area non-disturbed. Therefore, ST can potentially to retain most of the soil conservation benefits associated with NT practice and reduce soil N_2O emissions by allowing deep placement of dry N fertilizers (i.e., urea) into soil conditions less conducive for denitrification. However, researchers examining ST have not evaluated whether placement of N in the tilled rows is an effective alternative to NT in terms of reducing soil N_2O emissions. Improved seedbed conditions with ST in poorly drained soils may increase grain yields over NT by promoting higher plant populations which can reduce the amount of N_2O lost through higher overall plant uptake of applied N.

Research Objectives

The objectives of this research were to quantify the effect of tillage and/fertilizer placement (i.e., no-till/surface broadcast and strip-till/deep banded) and N fertilizer source (i.e., non-coated urea (NCU), polymer-coated urea (PCU), non-treated control) on soil N_2O emissions from agricultural practices in claypan soils.

Experimental Design

Soil N_2O emissions were measured using vented, static chambers, following the USDA GRACEnet protocol for field measurement of trace gases. The field experiment was conducted in corn production (*Zea mays* L.) over the 2009 and 2010 growing season in a claypan soil located in Northeast Missouri at the University of Missouri – Greenley Research Center. The experimental design consisted of six treatments with three replications and two subsamples for gas flux measurements in each plot. Fertilized treatments had N applied directly before planting at 125 lbs-N acre^{-1}.

Results

The interaction between N fertilizer source and tillage/fertilizer placement was not found to significantly impact cumulative growing season soil N_2O-N emissions ($P < 0.05$). Polymer-coated urea did not significantly lower cumulative growing season emissions of N_2O compared the NCU fertilizer (Fig. 1). Averaged over 2009 and 2010, no significant differences were observed in cumulative growing season soil N_2O emissions, due to N fertilizer source which ranged from 4.67 (NCU) to 4.89 (PCU) lbs N_2O-N acre^{-1} (Table 1). These N_2O-N losses represented between 2.8 to 3% of annual fertilizer N applied. Although not statistically different, cumulative soil N_2O emissions from strip-till/deep banded N placement averaged 3.27 lbs N_2O-N acre^{-1} compared to 3.87 lbs N_2O-N acre^{-1} averaged with no-till/surface broadcast treatments. The alternative management options, of PCU and strip-till/deep banding, both produced significantly ($P < 0.05$) higher grain yields than their conventional management counterparts (i.e., NCU and no-till/surface broadcast). Combining cumulative growing season N_2O emission with grain yield revealed strip-till/deep banded N placement emitted significantly less N_2O (0.01 lbs N_2O-N) per bu grain produced compared to no-till/surface broadcasted N.

Conclusions

Strip-till with deep banding of N produced significantly greater corn grain yields than NT/surface broadcasting in moderately wet to very wet growing seasons. Including yield, ST/deep banded N significantly lowered the amount of N_2O emitted per Mg of grain produced compared to NT/surface broadcasting. These findings support our hypothesis that increasing corn yields by improving N management will lower the environmental impacts associated with corn grain production related to N_2O emissions. Nitrous oxide and grain yield data were not obtained in a growing season with lower than average rainfall; however, these results demonstrate that ST with deep banding placement is a promising management practice in poorly drained, claypan soils to produce higher yields with lower environmental impacts that NT/surface broadcasted N systems in moderately wet to very wet growing seasons. Results from this study also demonstrate that evaluation of alternative management practices impact on soil N_2O losses may also need to consider changes in yield production to allow producers to decide which practices are best suited for their production and environmental goals.

Figure 1. Nitrogen fertilizer source and tillage management effects on the cumulative soil N_2O emissions over the 2009 and 2010 growing season, including the % N fertilizer loss and LSD (0.05) for the last sampling date. A) Nitrogen fertilizer source (2009). B) Nitrogen fertilizer source (2010). C) Tillage / N placement (2009). D) Tillage / N placement (2010).

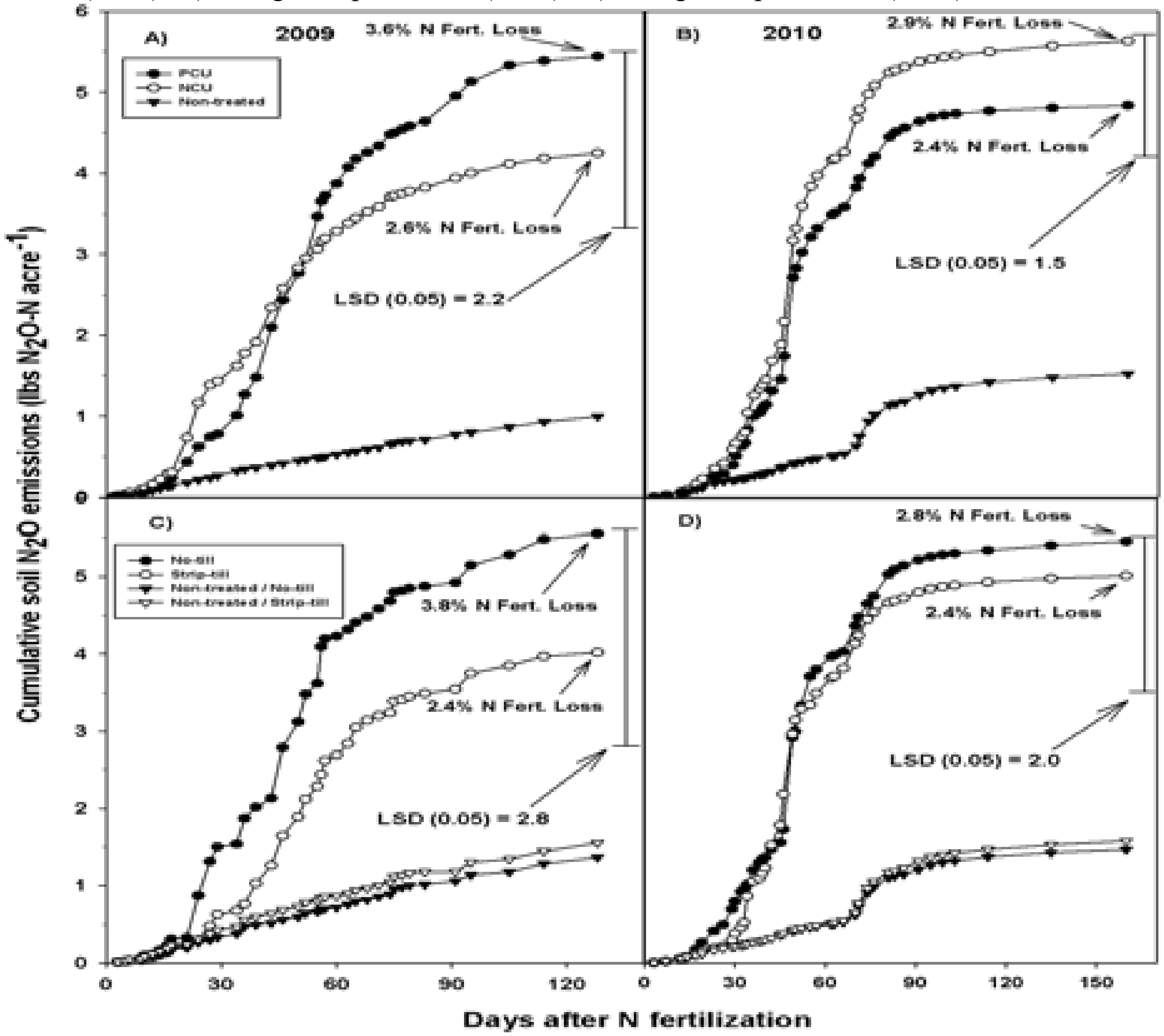

Table 1. Cumulative growing season soil N_2O emissions, corn grain yields, and N_2O-N emitted per yield produced, analyzed by the main effect of N fertilizer source, tillage/placement, and year.

	N Fertilizer Source			Tillage / Placement		Year
				No-till	Strip-till	
Year	PCU	NCU	Non-Treated	Surface Broadcast	Deep Banding	Average
			lbs N_2O-N $acre^{-1}$			
2009	5.46	4.26	1.00	4.06	3.09	4.58a
2010	4.32	5.02	1.37	3.68	3.45	4.57a
Average	4.89a	4.65a	1.18b	3.87a	3.27a	
			bu corn grain $acre^{-1}$			
2009	176	144	92	120	154	137a
2010	95	88	49	69	86	77b
Average	136a	116b	70c	94a	120b	
			lbs N_2O-N bu-corn $grain^{-1}$			
2009	0.031	0.030	0.011	0.034	0.020	0.033b
2010	0.045	0.057	0.028	0.053	0.040	0.059a
Average	0.038a	0.044a	0.020b	0.044a	0.030b	

† Letters following averages of N fertilizer source, tillage / placement, and year for cumulative growing season N_2O emissions, corn grain yield, and N_2O / yield indicate least significant differences $P < 0.05$ among treatments.

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