Nitrification Kinetics and Nitrous Oxide Emissions in Long-Term Tillage Systems Following Co-application of Urea-Ammonium-Nitrate and Nitrapyrin

Rex A. Omonode, Cliff Johnston, and Tony J. Vyn

Department of Agronomy, Purdue University

Introduction

Tillage affects the biophysical characteristics of soils (Van Kessel et al., 2013) that subsequently impact nutrient availability or loss. Nitrification inhibitors can delay nitrification of ammoniacal nitrogen (N), reduce N loss, and/or mitigate nitrous oxide (N_2O) emissions. Therefore, understanding the nitrification kinetics of N fertilizers can help to improve N management and use efficiency, and reduce N_2O emissions during crop production. However, the effects of tillage and nitrification inhibitors on nitrification and N_2O emissions are poorly understood, and contrasting effects of these management systems on nitrification and N_2O emissions are often reported. Even less understood are the combined effects of tillage and nitrification inhibitors on nitrification kinetics and N_2O emissions, especially under long-term tillage practices.

Objectives:

Determine effects of tillage and nitrapyrin (Instinct) on:

(1) Nitrification kinetics of urea-ammonium, and

(2) Seasonal N_2O emissions

In long-term no-till (NT), strip-till (ST), chisel (CP) and moldboard (MP) tillage systems for continuous corn.

Materials and Methods

The study was conducted in a Mollisol near West Lafayette, IN, from 2013 to 2014. Urea ammonium nitrate (UAN) was sidedressed at the rate of 220 kg N ha^{-1}, with and without nitrapyrin, to corn plots in a continuous corn system that have been managed under NT, ST, CP, and MP since 1975.

Nitrification Kinetics

Soil samples were taken from treatment plots to the 30-cm soil depth, centered on the zone of UAN application. Samples were taken biweekly for 12 weeks in 2013, and weekly for 6 weeks in 2014, and analyzed for NH_4-N and NO_3-N concentrations. Thereafter, appropriate kinetic models were fitted to the NH_4-N data, and rate constants (*k*) were calculated. The NH_4-N data was best described by the first-order model; therefore *k* was calculated as the slope of ln(C_t) vs. time (*t*) and conversion rate of NH_4^+ to NO_3 was computed using an integrated first-order equation as:

$$\ln C_t = -kt + \ln C_0$$

Half-life ($t_{1/2}$) for NH_4-N in UAN was calculated as: $t_{½} = (\ln 2/ k)$.

Nitrous Oxide Emissions

Soil N2O emissions were measured by the vented chamber procedure (Mosier et al., 2006). Gas samples were taken twice weekly for 8-12 weeks and thereafter, weekly. Nitrous oxide concentrations in samples were determined using a gas chromatograph. From these concentrations, N_2O emissions per unit area and time were calculated, and cumulative seasonal N_2O emissions ($\Sigma_{GS}N_2O$) were then estimated by linearly interpolating N_2O emissions between sampling dates.

Results and Discussion

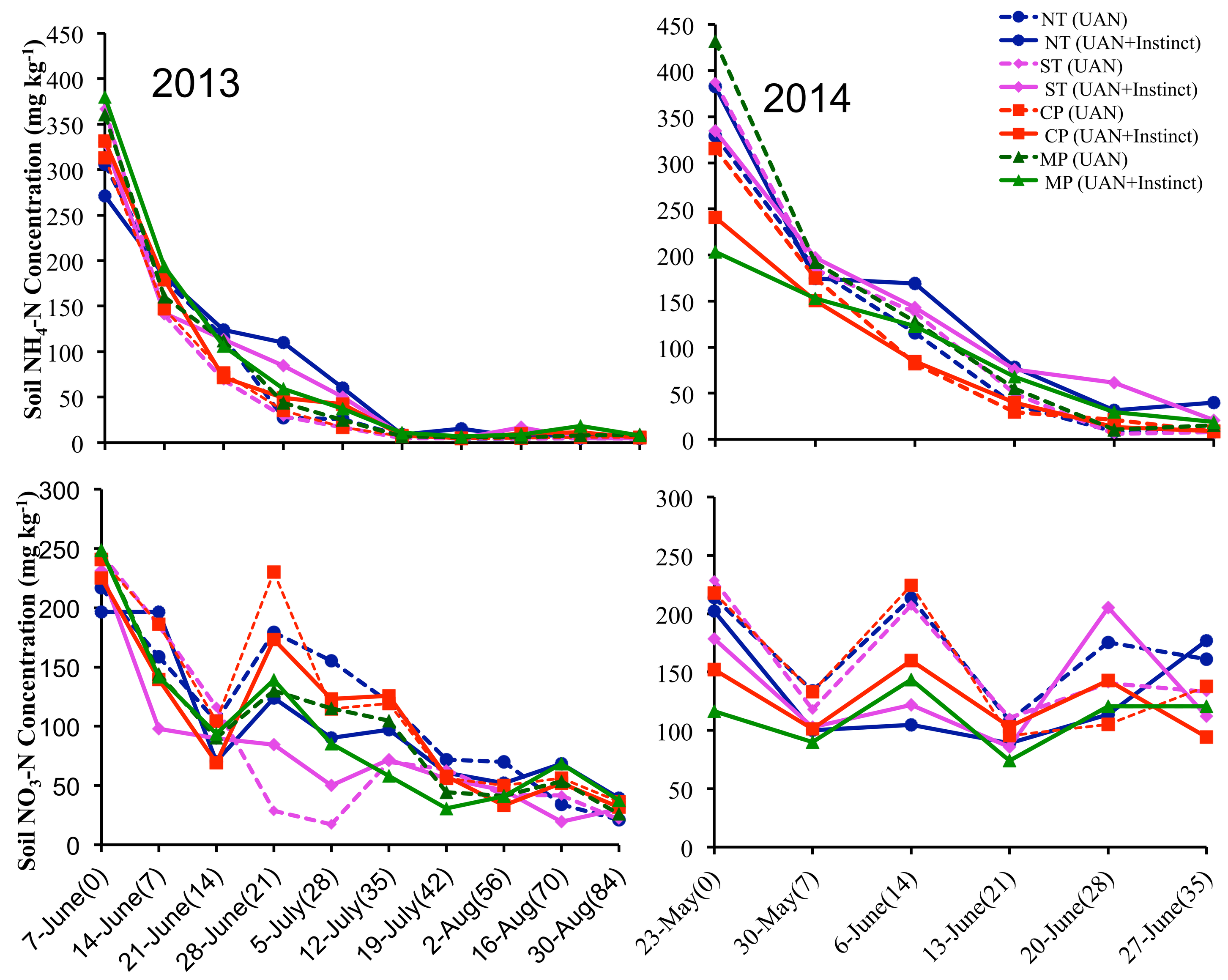

Fig. 1. Soil NH_4-N and (b) NO_3-N Concentrations with Time Following UAN Application With and without Instinct in 2013 and 2014.

Table 1. First-order nitrification rate constant (k), coefficient of regression (r^2) between soil NH_4^+ concentration (ln[NH_4–N]t) and time (t), and UAN half-life ($t_{1/2}$), with and without Nitrapyrin.

Year	Tillage	UAN			UAN + Instinct		
		k (d^{-1})	r^2	$t_{1/2}$ (d)	*k* (d^{-1})	r^2	$t_{1/2}$ (d)
2013	NT	0.098	0.958	7.08	0.067	0.927	10.24
	ST	0.118	0.989	5.85	0.087	0.951	8.69
	CP	0.107	0.998	6.45	0.095	0.987	8.00
	MP	0.106	0.977	6.99	0.079	0.979	7.30
2014	NT	0.107	0.987	6.48	0.072	0.697	9.56
	ST	0.111	0.980	6.27	0.073	0.962	9.46
	CP	0.103	0.989	6.71	0.099	0.982	6.95
	MP	0.126	0.966	5.52	0.071	0.958	9.78

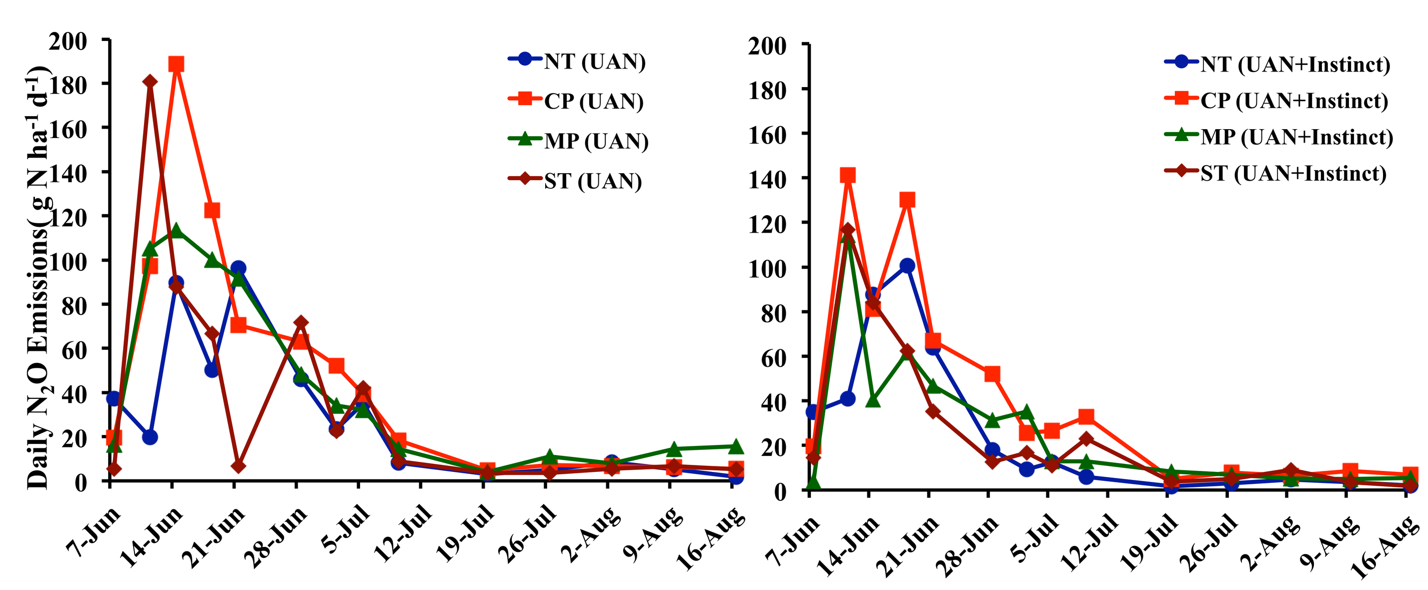

Fig. 2. Daily Nitrous Oxide Emissions Following UAN Application (a) Without Instinct and (b) With Instinct in Different Tillage Systems in 2013.

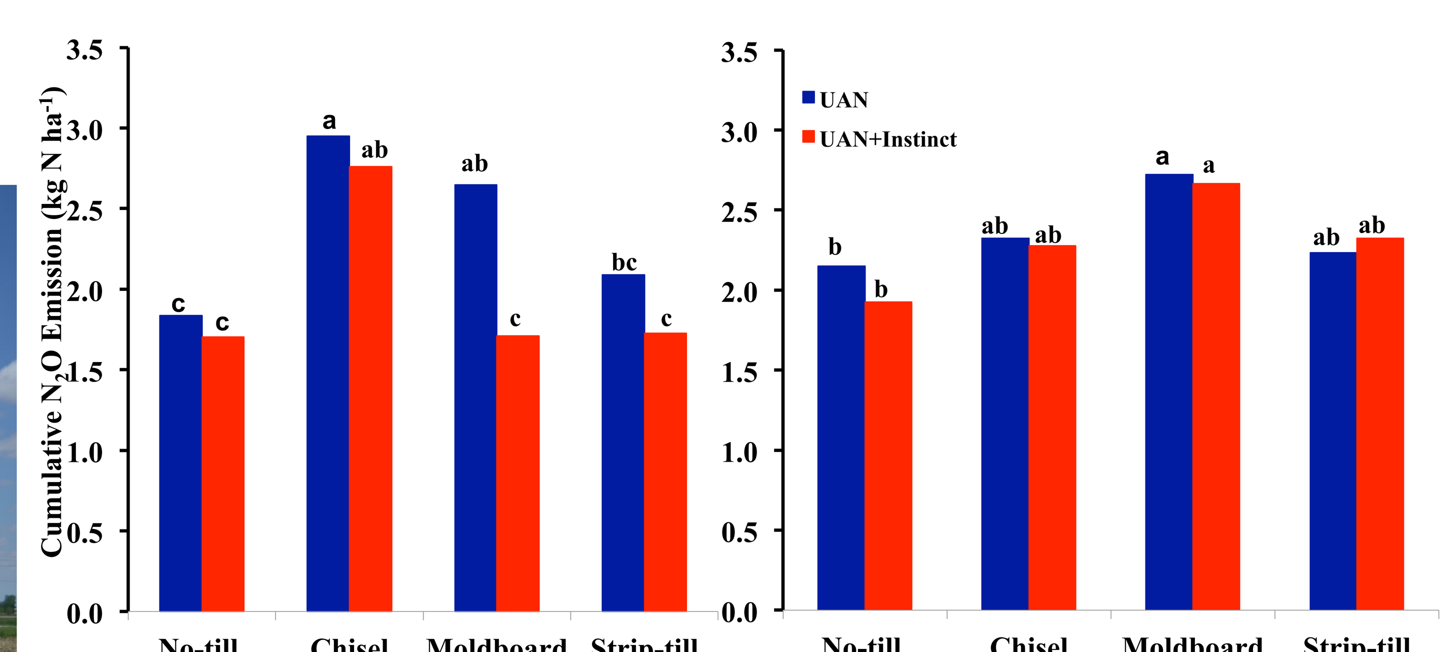

Fig. 3. Cumulative Nitrous Oxide Emissions Due to UAN Application With and Without Instinct In Long-term Tillage Systems in (a) 2013, and (b) 2014

Table 2. Instinct Effect on Cumulative Seasonal Nitrous Oxide Emissions Under Different Tillage Systems in 2013 and 2014.

Tillage	N Source	$\Sigma_{GS}N_2O$ (kg N ha^{-1})		$\Sigma_{GS}N_2O$ Reduction (%)	
		2013	2014	2013	2014
No-till	UAN	1.8c	2.6b	7.1	11.0
	UAN+Instinct	1.7c	2.35b		
Strip-till	UAN	2.1bc	2.7ab	17.2	-11
	UAN+Instinct	1.7c	2.9ab		
Chisel	UAN	2.9a	2.9ab	6.4	0.4
	UAN+Instinct	2.8ab	2.8ab		
Moldboard	UAN	2.7ab	3.3a	35.5	0
	UAN+Instinct	1.7c	3.3a		

Nitrification Kinetics

- NH_4-N nitrification declined rapidly 7-14 d after application as NO_3-N increased; nitrification was complete in ~35 d, regardless of tillage system, with or without Instinct (Fig 1)
- Nitrification followed 1st order kinetics regardless of tillage, or Instinct application. Without Instinct, the nitrification rate constant (k) ranged from 0.098 for NT to 0.126 d^{-1} under MP, and from 0.067 for NT to 0.099 for CP with Instinct application over the 2-year period (Table 1).
- Instinct application increased the UAN half-life ($t_{1/2}$) from about 6 to 10 d for NT and ST, but had little impact on the half-life for CP (Table 1).

Nitrous Oxide Emission

- In 2013, daily N_2O emissions peaked in 7-14 d (14 June) after application across tillage systems (~ 190 g for CP and ST without Instinct, and ~130 g N ha^{-1} d^{-1} for CP with Instinct application), and declined rapidly to baseline levels around 12 July (Fig. 2).
- Cumulative N_2O ranged from 1.84 kg ha^{-1} for NT to ~3.0 kg ha for CP in 2013, and ranged from 2.6 to 3.3 kg N ha^{-1} , respectively, for NT and MP in 2014 (Fig 2)
- Instinct application affected N_2O emissions in 2013, but the only significant reduction occurred in MP system (Fig 3); Instinct application did not reduce N_2O emissions in any tillage system in 2014.

Conclusions

- Nitrification rate and N_2O emissions generally increased with tillage, with or without Instinct application.
- No-till had consistently lowest cumulative N_2O emissions, but the addition of Instinct to UAN did not significantly lower cumulative N_2O emissions with no-till in either year.
- Instinct effects on nitrification rate and N_2O emission appeared to be short-lived in these long-term tillage systems applied to a Mollisol in continuous corn production.
- N fertilizer application closer to time of active N uptake is especially important in MP and CP to reduce N_2O emission.

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