Nitrification's Role in Nitrogen Loss of Urea Applied Preflood in Delayed-Flood Rice Production

UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE

B.R. Golden* (bgolden@uark.edu), N. A. Slaton, R.E. DeLong, and R.J. Norman

University of Arkansas Division of Agriculture, Agricultural Experiment Station, and Cooperative Extension Service

Introduction

The majority (96%) of rice (*Oryza sativa* L.) cultivated in Arkansas is produced utilizing a direct-seeded, delayed-flood production system (Wilson and Runsick, 2008). Nitrogen management in this system is limited to applying an NH_4-forming N source, primarily urea, near the 5-leaf growth stage and incorporating the N immediately with flood water. This N management strategy, if performed correctly, is very efficient with N recovery ranging from 65 to 75% of the applied fertilizer N (Norman et al., 2003). However, if N applications are mistimed, irrigation capacity is inadequate, floodwater management is poor, or dry soil conditions do not exist at application, fertilizer N loss can be substantial. Nitrogen application and management for rice cultivated in the delayed-flood system relies on aerial application, due to the construction of rice levees shortly after planting, which is more costly and less precise than N applied with ground-based equipment.

Nitrogen losses in the delayed-flood system most frequently occur through gaseous emissions of NH_3 and N_2/N_2O. Ammonia volatilization losses prior to flooding are generally regarded as the primary N loss mechanism in this rice production system. The importance of nitrification and denitrification in fertilizer recovery efficiency are less clear, especially when N fertilizer is applied far in advance of flood establishment or irrigation capacity is low resulting in an extended time between N application and flooding. If nitrification could be limited, growers would have greater flexibility in timing fertilizer application, establishing the permanent flood, and performing other management tasks (e.g., weed control).

The primary objectives of this research were to examine i) rice yield response to N sources and application times and ii) the nitrification rate of two eastern Arkansas soils commonly used for rice cultivation. The ultimate goal was to develop alternative N fertilization strategies for rice that result in efficient N uptake and involve different application times and N fertilizer technologies (e,g, nitrification inhibitors and polymer-coated urea fertilizers).

Materials and Methods

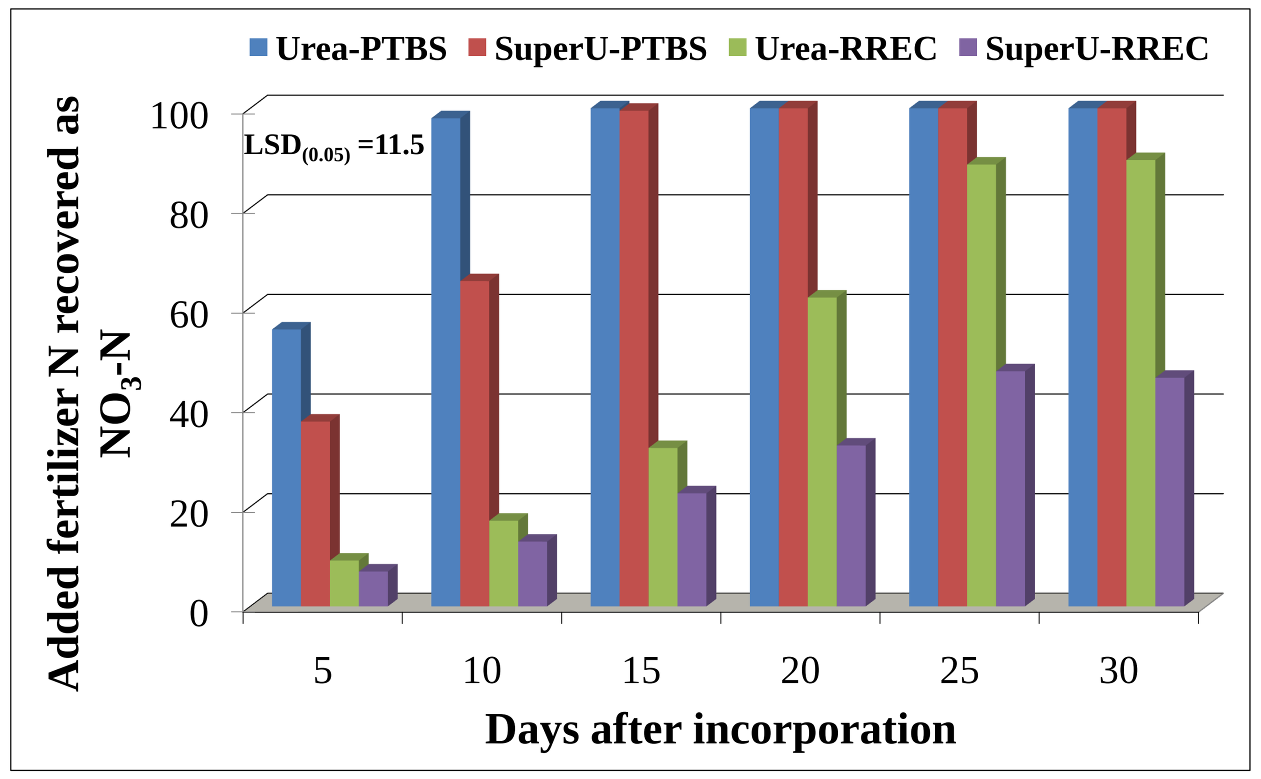
- Four Field Experiments (2008 & 2009):
  - Pine Tree Branch Station (PTBS), Calhoun silt loam
  - Rice Research Extension Center (RREC), Dewitt silt loam
- 'Francis' rice seeded in 2008 and 'Wells' rice seeded in 2009
- Two N-fertilizer sources:
  - Urea (46% N)
  - SuperU (Agrotain, Int. 46% N; urea+NBPT+DCD)
- Two N rates applied at different rice growth stages
  - N rates = 68 & 134 kg N ha^{-1}
  - Application times = 2-lf or preflood
  - Four replications at each siteyear
  - Grain yields adjusted to 12% moisture
- Locations were analyzed separately using PROC GLM in SAS 9.1
- Lab Incubations:
  - Calhoun silt loam (PTBS) & Dewitt silt loam (RREC).
  - Incubated at 25ºC and -85 kPa water potential (~21% g/g).
- N sources incorporated 2.5 cm beneath soil surface
  - ~100 mg N kg^{-1} added to the soil
  - 2 *M* KCl extracts every 5 d after incorporation (DAI) until 30 d.
- Replicate data was analyzed using PROC GLM in SAS 9.1.

Table 1. ANOVA p-values for percentage of fertilizer-N added recovered as NO_3-N as affected by soil, N source, sample time and their interactions for lab incubations conducted in silt-loam soils.

Source†	df	*p*-value
Soil	1	<0.0001
N Source	1	<0.0001
DAI	5	< 0.0001
Soil N source	1	0.0004
Soil DAI	5	<0.0001
N Source DAI	5	0.0418
Soil N Source DAI	5	<0.0001

†DAI = Days after incorporation

Fig 1. Percentage of fertilizer N recovered as NO_3-N as affected by the significant soil x N source x sample time interaction for two silt loams incubated at 25 C and -85 kPa water potential.



Results

Laboratory Incubations – Nitrification of added N

- Total recovery of added fertilizer N ranged from 73 to 98% depending on soil series, N source and sample time (data not shown).
- Fertilizer N recovery in each soil, averaged across products and sample times, was 84% for the RREC and 83% for the PTBS.
- The soil N source sample time interaction was significant for percent of added fertilizer recovered as NO_3-N (Table 1).
- Within each sample time, the percentage of added N recovered as NO_3-N was greatest for the PTBS soil and lowest for the RREC soil (Table 2).
- For the PTBS soil, nitrification was limited for 10 d by addition of SuperU, compared with urea, suggesting that DCD contained in SuperU only slightly inhibited nitrification.
- Nitrification of the added fertilizer N was essentially complete (>95%) by 10 and 15 DAI for urea and SuperU, respectively, in the PTBS soil.
- For the RREC soil, nitrification was similar between urea and SuperU until 20 DAI. Thereafter, SuperU limited nitrification for the duration of the experiment.
- By 30 DAI, nitrification of urea-N in the RREC soil was nearly complete (~90%), whereas only 50% of the SuperU-N was present as NO_3-N.

Results

Field Study- Rice Grain Yield

- Dates of agronomic importance are shown in Table 2.
- At the PTBS, in both 2008 and 2009, the main effects of N rate and time of N application significantly affected grain yield (Table 3).
- At the PTBS (both years), rice grain yield,
  - averaged across N rates and sources, was greatest for N applied preflood (Fig. 2A).
  - averaged across N application times and sources, was greatest for rice fertilized with 134 kg N ha^{-1} (Fig. 2B).
- At the RREC, in 2008, rice grain yield was not significantly affected by N source, N application time, N rate, or their interactions (data not shown).
- At the RREC, in 2009, rice grain yield was significantly affected by only the main effect of N rate (Table 3).
  - grain yield, averaged across N application times and sources, was greatest for rice fertilized with 134 kg N ha^{-1} (Fig. 2B).
- Grain yield was not affected by N source at any site-year suggesting the DCD contained in SuperU had no benefit to rice grain yield (Table 3).

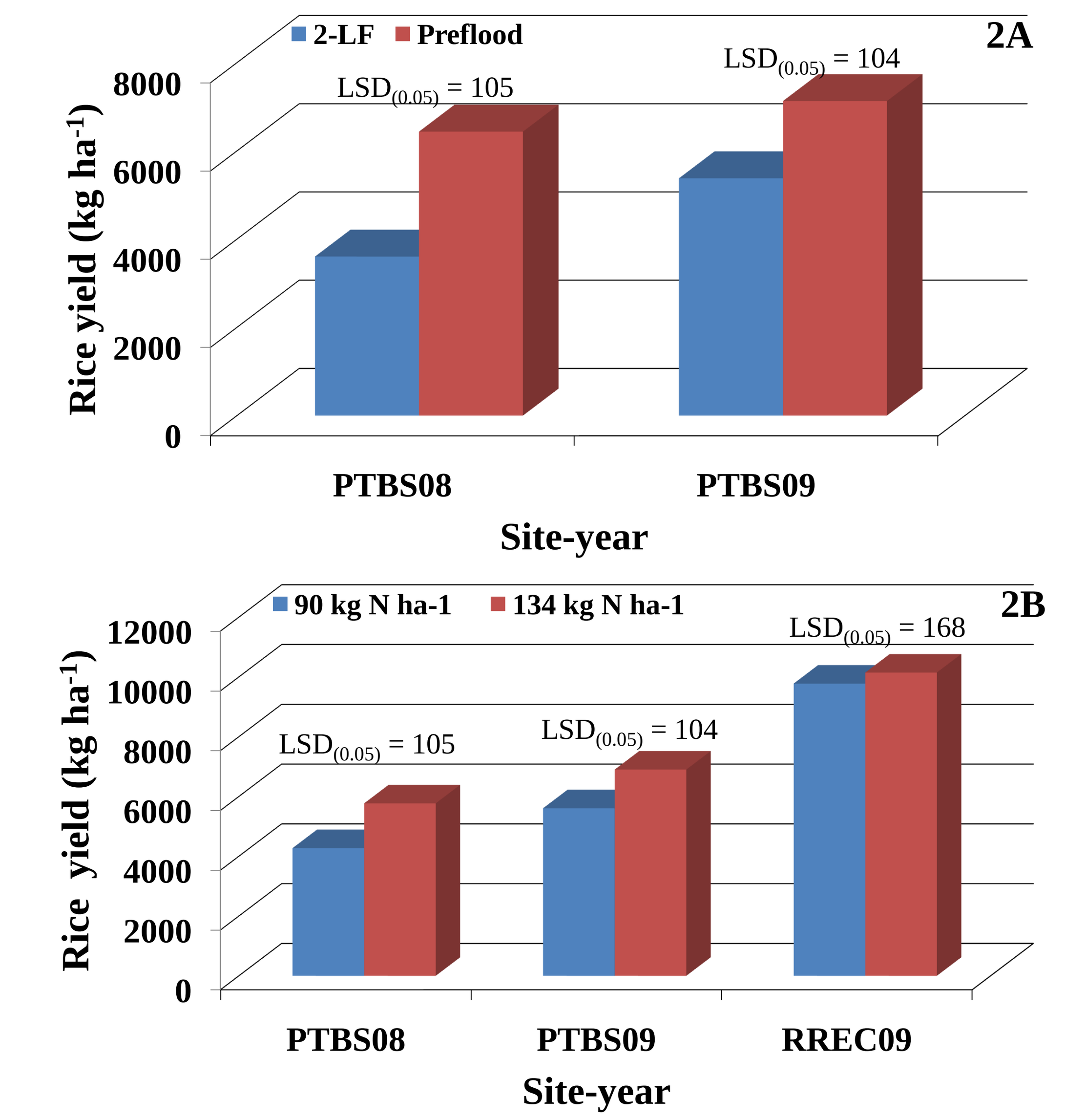
Table 2. Dates of agronomically important events for field research conducted at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC) on silt loam soils in 2008 and 2009.

Event	PTBS		RREC	
	2008	2009	2008	2009
	-Month/day-			
Seeding	5/21	4/22	5/7	4/29
Rice emergence	5/29	5/1	5/15	5/10
2-lf N app.	6/11	5/20	6/4	5/30
Preflood N app.	6/16	6/2	6/16	6/9
Flooded	6/18	6/4	6/17	6/11

Table 3. ANOVA p-values for rice grain yield as affected by N source, N rate, N application time, and their interactions for trials conducted at the Pine Tree Branch Station (PTBS) and the Rice Research and Extension Center (RREC) during 2008 (08) and 2009 (09).

Source	df	Siteyear		
		PTBS08	PTBS09	RREC09
		-p-value-		
Rep	2	0.4089	0.6509	0.0008
N Source	1	0.8190	0.7957	0.8827
N Rate	1	0.0003	<0.0001	<0.0001
N Time	1	<0.0001	<0.0001	0.1802
N source N Rate	1	0.1463	0.9516	0.0604
N Source N Time	1	0.9023	0.9031	0.4673
N Time N Rate	1	0.2184	0.4907	0.3843
N Source N Rate N Time	1	0.9699	0.1228	0.3227

Fig 2. Rice grain yield as influenced by N application time (A) and N rate (B) for research at the Pine Tree Branch Station (PTBS) and Rice Research and Extension Center (RREC) on silt loam soils during 2008 (08) and 2009 (09).



Conclusions

- The rate of nitrification of fertilizer N differed for the two silt loam soils. Nitrification of urea-N proceeded slower in the Dewitt soil (RREC) compared to the Calhoun soil from PTBS, regardless of N source. The more rapid nitrification rate for the Calhoun soil may be due to its higher pH (>7.5) compared to the Dewitt soil (~6.0).
- Nitrification in both silt loam soils was slower for SuperU (contains DCD) than urea, but the length of time nitrification was inhibited was greater in the Dewitt soil (RREC).
- Applying N as early as 7 d before flooding could significantly influence rice yield as observed for the Calhoun soil (PTBS) during both years. The observed differences were attributed to rapid nitrification in the Calhoun soil followed by denitrification after flooding rather than N loss via NH_3 volatilization.
- Results suggest urea-N could be applied to the Dewitt soil weeks before flooding without yield loss. However, time of N application and flooding were important for efficient N uptake for the Calhoun soil.

References

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