The Evaluation of Fluid Fertilizer as an N Source for Rice

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Abstract

Application costs associated with Nitrogen (N) fertilization in rice represent a significant amount of the production budget. An experiment to evaluate alternative N fertilizer strategies was conducted at the Delta Research and Extension Center near Stoneville, Mississippi, on Sharkey clay (fine, smectitic, thermic Chromic Epiaquerts). Treatments were arranged as a factorial combination of N-fertilizer source {banded fluid urea liquor (22% N) applied at planting and broadcast granular urea (46% N)} applied and incorporated immediately prior to planting, N rate (120, 150 and 180 lb a^{-1}), and panicle differentiation-N rate (0 and 46 lb a^{-1}). In addition, two standard preflood treatments and a zero N control were included to allow broader comparisons. These comparison treatments consisted of; (1) 120 lb N a^{-1} as urea applied preflood followed by 46 lb N a^{-1} top-dressed at midseason; and (2) 150 lb N a^{-1} as urea applied preflood. Within the factorial combination of treatments, an interaction among N source and N rate affected rice grain yield. Rice grain yield and biomass at panicle emergence were greatest when 180 lb N a^{-1} was applied as a banded fluid. Averaged across sources and N rates, yields were greater when a panicle differentiation-N application of 46 lb N a^{-1} was applied. Nitrogen concentration in rice biomass measured at panicle differentiation was greatest when 180 lb N a^{-1} was applied. Nitrogen concentration in rice biomass was greater at panicle differentiation and panicle emergence when the fluid source was used at the preplant timing. The fluid source was superior to preplant granular urea; however, both were inferior to standard preflood treatments. Correlation analyses suggested that N concentration at PD was not sufficient to produce yields equal to or greater than standard preflood N treatments.

Introduction

In the USA, rice is produced in either water-seeded or delayed-flood, dry-seeded cultural systems (Street and Bollich 2003). For rice produced in the midsouthern USA, dry-seeding is the predominant seeding method (Street and Bollich 2003). In this system, rice is typically drill-seeded into soil and grown as an upland crop until the rice reaches the four- to five-leaf stage. Upon reaching this growth stage, a flood is established and maintained until approximately two weeks prior to harvest. The flooded environment has advantages and disadvantages for rice production. Benefits include increased P, K, Ca, Si, and Fe availability and weed control (De Datta 1981; Patrick et al. 1985). One disadvantage is that N management is complicated because of N-loss mechanisms that accompany the flooded soil environment. Published data indicate that the efficiency of N fertilizers applied to rice can be as low as 20% or as high as 70% depending on the environmental conditions present during application (Vlek and Byrnes 1986; Wilson et al. 1989). In the midsouthern USA, optimum N fertilizer use efficiency has been achieved by applying at least 50% of the total N immediately prior to permanent flood establishment (PF), and the remaining N during the interval between panicle initiation and a week after panicle differentiation (PD) (Brandon et al. 1982; Mengel and Wilson 1988; Wilson et al. 1989; Wilson et al. 1998). However, recent work in Arkansas has shown that some new rice cultivars produce yields that are comparable, and sometimes greater, following a single PF application opposed to a two- or three-way split of the total applied N (Norman et al. 2000). Regardless of which system is used, growers in the midsouthern USA annually pay $20 to $30 per acre in fertilizer application costs above the cost of the fertilizer material.

Limited research has been conducted for the practice of banding plant nutrients in drill-seeded, delayed-flood rice culture. Turner et al. (2006) have shown promising results from pre-plant (PP) banding N on a clay soil in TX. Peterson and Wilson (1975) reported that maximum rice yields were achieved in Louisiana with less N and P fertilizer when granular products were banded 2 inches below and 2 inches to the side of drill-seeded rice. The most commonly used N-application strategies in Mississippi consist of three to five applications per season. Ammonium sulfate (AMS) is typically applied to one- to three-leaf rice at a rate of 20 to 30 lb N a^{-1}. Urea or a blend of urea and AMS (41-0-0-4S) is applied at a rate to supply 90 to 135 lb N a^{-1} when rice is tall enough to establish a permanent flood (4- to 6-leaf). Once rice reaches internode elongation, N is top-dressed either in one or two applications to supply 45 to 90 lb N a^{-1}. Most of the fertilizer is applied with an airplane. The cost of fertilizer application with an airplane is approximately $5.25 cwt^{-1} of material. Research has shown that to obtain optimum N efficiency, the PF urea application should be made to dry soil and the field flooded within 5 to 7 days (Norman et al. 2004). Weather conditions often dictate the timeliness of this PF application and some fields take longer than 7 days to establish a permanent flood; therefore, N is lost via volatilization. In addition, if growers wait to apply fertilizer on dry soil, residual herbicides often break, requiring an additional herbicide application, which can be costly. Furthermore, the delay in fertilizer and flood can cause an N deficiency, which can decrease yields. Mississippi State University Extension Service economists indicate that banding fluid fertilizer can potentially reduce application costs five-fold. Banding fluid fertilizer could potentially provide growers a more economical option to produce rice yields that are equal to or greater than the standard method of application with less environmental risks. These factors deem this potential practice worth investigating. The objective of this experiment was to evaluate an alternative N source and application methods with a standard N application source and methods.

Materials and Methods

Grain Yield. An experiment was conducted at the Delta Research and Extension Center near Stoneville, Mississippi, on a Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts) to determine the rice grain yield response to alternative N fertilizer strategies. The experiment consisted of a 3 x 2 x 2 factorial arranged in a RCB design, and treatments were replicated four times. Factors consisted of three N rates (120, 150 and 180 lb N a^{-1}), two urea sources {fluid (22% N) and granular (46% N)}, and two levels of panicle differentiation (PD) N (0 and 46 lb N a^{-1}). In addition to these treatment combinations, three additional treatments were included to allow for broader comparisons. These treatments consisted of (1) 120 lb N a^{-1} applied PF as a granular followed by 46 lb N a^{-1} applied at PD; (2) 150 lb N a^{-1} applied PF as a granular; and (3) a zero N control. A Great Plains small-plot drill was modified with knives and a piston pump so that the fluid N treatments were applied approximately four inches below the soil surface between every other drill row at planting. The granular treatments were applied broadcast to the soil surface with a custom-made fertilizer distributor equipped with a belt cone and a zero-max and then incorporated with a rotary tiller immediately prior to planting. Panicle differentiation-N treatments were broadcast by hand into the flood. 'Cocodrie' rice was drill-seeded on 3 May 2007 and emerged 9 May 2007. A permanent flood was established on 4 June 2007. Standard agronomic and pest management practices were conducted to provide an environment conducive for high yields and to minimize variability due to pest pressure. The plots remained flooded until approximately two weeks prior to harvest. At harvest maturity, the center four rows of each plot were harvested with a small plot combine and the grain yields were adjusted to 12% moisture content.

Total Dry Matter and Nitrogen Concentration. Total above ground rice biomass was collected from three linear feet of row at PD and again when approximately 5% of the panicles had emerged from the sheath (PE). Prior to weighing, total dry matter samples were dried at 60 degrees C for 72 hours in a forced air dryer. Samples were then processed in a Wiley mill and analyzed for total N by combustion.

Statistics. Analysis of variance procedures were conducted to determine treatment effects on rice grain yield and total dry matter and nitrogen concentration. Treatment means were separated using Fisher's Protected LSD at the 0.05 level of significance.

Results and Discussion

Grain Yield. For the factorial combination of treatments, grain yield was affected by an interaction among N rate and source ($P<0.0159$) and the main effect of PD-N rate ($P<0.0001$). Averaged across PD-N rate, rice grain yield was greatest when the fluid N source was banded at planting at a rate of 180 lb N a^{-1}. Regardless of N rate, the fluid source produced greater yields compared to the dry source. Though grain yields increased with increasing N rate for both sources, the magnitude of yield increase per increase in N rate was greater for the fluid source **(Table 1)**. When averaged across at-planting N rates and sources, grain yields were increased when a PD-N application of 46 lb a^{-1} was applied **(Table 2)**.

Nitrogen Concentration and Total Dry Matter. Nitrogen concentration at PD was affected by the main effects of rate ($P = 0.0100$) and source ($P = 0.0038$). When averaged across N source and PD-N rate, N concentration at PD was greatest at the highest N rate **(Table 3)**. When averaged across N rate, N concentration at PD was greater when the fluid source was used **(Table 4)**. Averaged across N rate and PD-N rate, N concentration in rice biomass at PE was greater when the fluid source was used **(Table 4)**. No treatment effects were detected for total dry matter when collected at PD; however, total dry matter measured at HD was affected by an interaction among N rate and source ($P < 0.0001$). Averaged across PD-N rates, greater total dry matter was produced with the fluid source when 120 and 180 lb N a^{-1} was applied; however, when 150 lb N was applied, total dry matter produced by fluid and granular sources were not different **(Table 5)**.

Though the fluid N source was superior to the dry source for yield, N concentration, and total dry matter, grain yields produced from the alternative application methods were inferior to both comparison standards. When the same rate of N was applied (150 lb N a^{-1}), the fluid source applied at planting yielded 81% of the standard single preflood application. The yield gap was narrowed to a 7% advantage in favor of the standard single preflood method (150 lb N a^{-1} PF) when 180 lb N a^{-1} was banded at planting and an additional 46 lb N a^{-1} was applied at PD. To better understand the deficiencies associated with the alternative methods, correlation analysis was employed to determine relationships between the measured parameters already discussed. The greatest correlation ($r=0.85$) existed between grain yield and N concentration measured at PD. Standard treatments resulted in average PD N concentrations of 3.84% and 3.65% for 150 and 120 lb N a^{-1} applied PF, respectively. When equal rates were banded at planting, the average N concentration was 2.36% and 2.59%, respectively. The alternative treatment that yielded the greatest was 180 lb N a^{-1} banded as a fluid at planting followed by 46 lb N a^{-1} applied at PD. The resulting N tissue concentration at PD from the 180 lb N a^{-1} fluid treatment was 3.34%.

Conclusions

Nitrogen application costs represent a significant budget line item in southern USA rice production. Technology which would allow N applications to be made less expensively without reducing net returns would be welcomed by producers. These data suggest that any cost savings realized by reduced application costs would be offset by reduced yield or increased expense in additional N fertilizer that would be needed to narrow the yield gap between the alternative application methods and the standard treatments.

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Tables

Table 1. Mean rice grain yield as affected by an interaction among N rate and source averaged across panicle differentiation N rate.

Rate	Source	Yield bu a^{-1}
120	Fluid	143 c
	Dry	125 e
150	Fluid	160 b
	Dry	132 d
180	Fluid	171 a
	Dry	146 c

Means in the same column followed by a different letter are different (P≤ 0.05).

Table 2. Mean rice grain yield as affected by panicle differentiation N rate averaged across N rate and source

PD-N (lb N a^{-1})	Yield (bu a^{-1})
0	137 b
46	156 a

Means in the same column followed by a different letter are significantly different (P ≤ 0.05).

Table 3. Mean N concentration at panicle differentiation as affected by N rate averaged across N source.

N rate (lb N a^{-1})	%N
120	2.33 b
150	2.35 b
180	2.89 a

Means in the same column followed by a different letter are significantly different (P ≤ 0.05).

Table 4. Whole plant N concentration at panicle differentiation (PD) and panicle emergence (PE) as affected by N source averaged across rate for PD N concentration and rate and PD-N rate for PE-N concentration.

Source	PD	PE
	%N	
Fluid	2.76 a	1.06 a
Dry	2.28 b	0.85 b

Means in the same column followed by a different letter are significantly different ($P \leq 0.05$).

Table 5. Total dry matter at panicle emergence as affected by an interaction among N rate and source averaged across panicle differentiation N rate.

Rate	Source	biomass lb a^{-1}
120	Fluid	7964 b
	Dry	6860 c
150	Fluid	7196 bc
	Dry	7724 bc
180	Fluid	11082 a
	Dry	7580 bc

Means in the same column followed by a different letter are different ($P \leq 0.05$).