POTENTIAL USE OF SLOW-RELEASE UREA IN WATER-SEEDED, STALE SEEDBED RICE

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ABSTRACT

Management of fertilizer nitrogen (N) for optimum efficiency with stale seedbed preparation in water-seeded rice can be difficult, especially in a pinpoint flood system of water management. There is no opportunity for preplant incorporation, and all of the N is applied either preplant (PP), postdrain (PD), or postflood (PF) to a wet or saturated soil surface. Efficiency of fertilizer N is usually reduced when N is applied to wet soil surfaces or into the floodwater on young, seedling rice. Slow-release N has the potential to improve N efficiency when applied PD to wet soils or PF on seedling rice. Field experiments were conducted in 1997 and 1999 to compare the effectiveness of Meister urea (a polyolefin-coated urea, PCU), sulfur-coated urea (SCU) (1997 only), and urea in conventional tillage and stale seedbed systems. Cypress rice was cultured in a water-seeded, pinpoint flood system. An application of 135 lb N/A was made PP, PD, and PF with each N source in 1997. In 1999, PCU and urea were applied as single applications at each timing and at variable rates of 90, 120, 150, and 180 lb N/A. Days to 50% heading, plant height, grain yield adjusted to 12% moisture, and total N in the grain and straw (1997 only) were determined. Various significant interactions between tillage and N source, N rate, and N timing occurred for days to 50% heading both years. These differences represented little biological significance (1 to 2 days). Significant interactions also occurred for plant height between tillage and N timing in 1997, and N source and N timing in 1998. Plant height differences reflected differential response to N timing and these differences were not consistent with tillage in 1997 or N source in 1999. Grain yields were higher with conventional tillage in 1997 but similar for both tillage systems in 1999. Both slow-release N sources produced significantly higher yields than urea in 1997, and yields were also higher with PF and PD N timings. There was a significant interaction for grain N content between N source and N timing. Grain N was lowest for both N sources when applied PF, but was highest with PP and PD timings for PCU and SCU, respectively. Grain N content was not affected by timing with urea. Straw N content was highest with conventional tillage and with slow-release N sources, and N timing had no effect on straw N. In 1999, yields with PCU were similar with PP and PD N timings but significantly reduced with a PF timing. Highest yield with urea occurred when N was applied PP, and yields were significantly reduced with PD and PF timings. Approximately 150 lb N/A were required to optimize grain yield with both PCU and urea. Both PCU and SCU increased grain yields in the stale seedbed, indicating that slow-release N products can be successfully used in both conventional and stale seedbed systems. Cost of slow-release N products is currently prohibitive, and higher grain yields at lower N application rates must be consistently realized to offset the additional expense of these products.

INTRODUCTION

Nitrogen is the most important nutrient required for maximizing rice production, but in terms of its efficiency, fertilizer N loss can be as high as 60% (De Datta et al., 1989, Freney et al., 1990). Management of N in flooded rice culture is difficult because of the various loss mechanisms that reduce N uptake and efficiency. Denitrification and ammonia volatilization result in large losses of fertilizer N when N is applied to the surface of wet soils and when N is applied into the floodwater on seedling rice. In Louisiana, severe problems with red rice, a noxious rice biotype, requires water seeding and pinpoint flooding to take advantage of red rice suppression through cultural management offered by this cultural system. Many rice fields in southwest Louisiana are prepared in standing water and N cannot be incorporated. When soils are prepared dry, N can be preplant incorporated and fields are flooded within 5 to 10 days. Delays in flood establishment result in the conversion of urea N to nitrate, and the N is subject to loss by denitrification. Adoption of stale seedbed planting practices significantly reduces soil erosion, but with this system, N has to be applied to the soil surface rather than incorporated.

A slow-release N product has the potential to improve N efficiency in stale seedbed systems in which N is applied to dry and wet soil surfaces. A slow-release urea product sold under the trade name of Meister was developed by Chisso-Asahi Fertilizer Co., LTD, of Japan and is marketed in the United States through Helena Chemical Co. Meister slow-release urea is currently used in commercial rice production in Japan. Limited research in the United States indicates this material can be successfully used preplant in conventional tillage, drill-seeded rice (Wells et al., 1994; Bollich et al., 1994; Bollich et al., 1998). Sulfur-coated urea has also been evaluated in Louisiana for use in water-seeded, conventional tillage rice systems (Brandon et al., 1985; Bollich et al., 1986). The objective of this study was to compare the slow-release urea products with urea at varying rates and N application timings in a water-seeded, pinpoint flood culture using conventional and stale seedbed tillage systems.

MATERIALS AND METHODS

Field experiments were conducted in 1997 and 1999 at the Rice Research Station in Crowley, LA, on a Crowley silt loam (fine, montmorillonitic, thermic Typic Albaqualf). A randomized complete block design with four replications was used, with a 2 x 3 x 3 factorial arrangement of tillage, N source, and N timing in 1997, and a 2 x 2 x 3 x 4 factorial arrangement of tillage, N source, N timing, and N rate in 1999. Tillage treatments consisted of conventional tillage and a stale seedbed. Both tillage treatments included plowing, mulching, and incorporation of phosphorus and potassium (0-45-45) during October and November. To complete stale seedbed preparation, glyphosate (1.0 lb ai/A) and 2,4-D (0.75 lb ai/A) were applied 4 weeks prior to planting, and paraquat (0.66 lb ai/A) was applied approximately 1 week prior to planting. To complete conventional seedbed preparation, required plowing and mulching were performed 3 days prior to planting. In 1997, polyolefin-coated urea (PCU), sulfur-coated (SCU) urea, and urea were applied at a rate of 135 lb N/A. In 1999, PCU and urea were applied at rates of 90, 120, 150, and 180 lb N/A. Each year, N was applied preplant (PP), postdrain (PD), and postflood (PF). Preplant N was applied to the soil surface and the experiment was flooded within 48 hours. Postdrain N was applied to a saturated soil surface 3 to 4 days after the initial drain and just prior to reflooding. Postflood N was applied into the floodwater 21 and 18 days after emergence in 1997 and 1999, respectively.

The experiment was planted with the variety Cypress at a rate of 100 lb/A into 7 by 25-ft plots. In 1997, seed was presprouted before planting, while in 1999, seed was planted dry. The experiment was drained 3 to 4 days after seeding. The permanent flood was established after 4 to 5 days of drainage. Nitrogen treatments were applied as described above. In-season pest control (weeds, insects, disease) was practiced as required and according to current recommendations. Days to 50% heading (calculated from date of rice emergence), plant height, grain yield adjusted to 12% moisture (ratoon and total grain yields determined in 1999), and N content of the grain and straw (1997 only) by combustion were determined. Data were statistically analyzed using ANOVA procedures and Fisher's Protected LSD for mean separation.

RESULTS

Results from 1997 are shown in Table 1. Significant treatment interactions occurred and treatment means involved in the interactions are shown in Table 2.

Days to 50% heading was affected differentially by tillage depending on N timing. With conventional tillage, days to 50% heading was delayed **1** day with N applied PD compared with PP and PD N timings. With the stale seedbed, heading was delayed 2 days by the PF timing compared with the PP and PD N timings. There was also an interaction between N source and N timing. With PCU, 50% heading was 1 day earlier with the PP and PD timings compared with the PF timing. With SCU, 50% heading was 1 day later with the PF N timing compared with the PP and PD N timings. With standard urea, 50% heading was 2 and 3 days later with the PF timing compared with the PP and PD timings, respectively.

Plant height was significantly increased by PCU and SCU, and an interaction occurred between tillage and N timing. On average, plant heights were 98, 95, and 91 cm with PCU, SCU, and urea, respectively. With conventional tillage, plant height declined as N was delayed. Plant heights were 98, 96, and 93 cm for the PP, PD, and PF timings, respectively. With the stale seedbed, plant height was relatively constant and ranged between 93 and 95 cm for the three N timings.

Grain yield was significantly influenced by tillage, N source, and N timing. On average, grain yield was higher with conventional tillage compared with the stale seedbed. Slow-release N sources yielded higher than standard urea, and the earlier N timings (PP and PD) had higher yields than the PF timing. Grain and straw N contents were significantly higher with conventional tillage compared with the stale seedbed, and straw N was higher with the slow-release formulations compared with urea. The response of grain N to N source was dependent on N timing. With PCU, grain N content increased as N was delayed while timing of SCU and urea had little effect on grain N. In general, grain N was higher with the slow-release formulations compared with urea.

Results from 1999 are shown in Table **3,** and significant treatment interactions are shown in Table 4. For days to 50% heading, tillage, N source, and N timing were highly interactive. The influence of N timing on 50% heading was independently affected by N source, tillage, and N rate. With PCU, the PF timing delayed heading by **1** day compared with the earlier applications. With urea, heading was unaffected by N timing. In general, heading was earlier with urea. A tillage by timing interaction indicated that heading was unaffected by N timing with conventional seedbed preparation and was delayed by 1 day by the PF timing compared with the earlier timings in the stale seedbed system. The N timing by N rate interaction indicated that 50% heading was delayed slightly as N rate increased with PP and PD N timings, but with a PF N timing, rate had no effect. While all of these interactions for days to 50% heading were significant, the differences were 2 days or less and were not thought to be biologically significant.

Numerous interactions also occurred for plant height. With PCU, plant height was similar across N timings. With urea, plant height decreased as N application was delayed. In general, plant heights were taller with PCU. The interaction between tillage and N timing was the result of reductions in plant height at later N timings. With conventional tillage, plant height was reduced only by the PF N timing, while with stale seedbed tillage, plant height was decreased by the PD and PF N timings. The interaction between N source and N rate occurred because of the difference in rate of increase in plant height in response to N rate. Plant height was more responsive to increasing rates of N with PCU than with urea. In general, plant height and grain yield were both higher with the stale seedbed. Main crop and total grain yields increased significantly as N rate increased to 150 lb/A, with little difference between the 150 and 180 lb/A rates of N. Ratoon crop yield was not influenced by main crop N rate. An interaction between N source and N timing occurred in the main crop and was carried over into total grain yield. With PCU, main and total grain yields were similar with the PP and PD N timings and comparatively reduced with the PF N timing. With urea, main and total grain yields declined as N was delayed.

DISCUSSION

Field experiments conducted in Louisiana indicate that slow-release urea products are effective for use in water-seeded, stale seedbed systems. Increased plant heights and higher grain yields resulted from the use of the slow-release N products both years of this study. Efficiency of urea N is significantly affected by its application timing and placement in relation to water management, especially when water seeding. With stale seedbed preparation, there is no opportunity to PP incorporate fertilizer N, resulting in surface placement on either dry seedbeds, wet seedbeds, or in an established flood on seedling rice. Due to the various loss mechanisms that affect N stability in rice, application of urea N to either wet soils or into the floodwater on seedling rice usually results in lower grain yields (Mengel and Wilson, 1988). Both PCU and SCU applied PD to wet soil produced grain yields comparable with those produced from PP applications. With PF applications of the slow-release N products, grain yields were decreased slightly, but were significantly higher than yields produced from urea-N applications into the floodwater. The greater utility provided by slow-release urea products in situations where wet soil applications or applications into the floodwater are unavoidable would certainly be advantageous to the rice producer. Cost is a concern, and at this time, it is questionable whether commercial use of these products is economically feasible. Future research should include evaluation of these materials in fertility programs where either PCU or SCU is used to provide only part of the required N. Such an approach would possibly result in realizing the advantages of slow-release N products but at a more economical cost.

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Table 1. Influence of tillage, N source, and N timing on agronomic performance of water-seeded Cypress rice. Rice Research Station, South Unit. Crowley, LA. 1997.

Tillage	N source[1]	N time[2]	Days to 50% heading	Plant Height	Grain yield at 12% moisture	N content Grain	N content Straw
				(cm)	(lb/A)	-----(%)------	
Conventional	Pcu	PP	79	100	8272	1.27	0.82
Conventional	Pcu	PD	79	101	8466	1.34	0.85
Conventional	Pcu	PF	76	96	8768	1.36	0.79
Conventional	SCU	PP	77	99	8700	1.31	0.75
Conventional	SCU	PD	78	97	8734	1.26	0.73
Conventional	SCU	PF	77	93	8438	1.28	0.76
Conventional	Urea	PP	77	94	7878	1.14	0.64
Conventional	Urea	PD	77	91	7673	1.12	0.55
Conventional	Urea	PF	77	90	7310	1.14	0.57
Stale	Pcu	PP	79	97	7984	1.22	0.71
Stale	Pcu	PD	80	99	7913	1.26	0.74
Stale	Pcu	PF	80	96	7408	1.37	0.84
Stale	SCU	PP	79	95	7881	1.18	0.65
Stale	SCU	PD	79	95	8310	1.18	0.63
Stale	SCU	PF	80	93	7405	1.25	0.77
Stale	urea	PP	78	91	6865	1.10	0.56
Stale	Urea	PD	78	93	7272	1.11	0.52
Stale	Urea	PF	82	90	6604	1.08	0.51
C.V., %			1.22	2.30	5.64	4.08	10.86
					Main effects		
Tillage:							
Conventional			78	96	8249	1.25	0.72
Stale			79	94	7516	1.19	0.66
LSD (0.05)			1	1	210	0.02	0.04
N source:							
Pcu			79	98	8135	1.30	0.79
SCU			78	95	8245	1-24	0.71
Urea			78	91	7267	1.11	0.56
LSD (0.05)			ns	1	258	0.03	0.04
N timing:							
PP			78	96	7930	1.20	0.69
PD			78	96	8061	1.21	0.67
PF			79	93	7656	1.25	0.71
LSD (0.05)			ns	1	258	0.03	ns
Interactions:							
Tillage x N source			ns	ns	ns	ns	ns
Tillage x N timing			•	•	ns	ns	ns
N source x N timing			•	ns	ns	•	ns
Tillage x N source x N timing			no	ns	ns	ns	ns

[1]PCU = mister with 150 day release; SCU = sulfur-coated urea.
[2]PP = preplant; PD = postdrain (surface application during pinpoint drainage); PF = postflood (3 weeks after emergence).

Table 2. Interaction means for selected variables. 1997.

Interaction		Days to 50% heading	Plant height	Grain N content
			(cm)	(%)
Tillage by N timing[1]				
Conventional	PP	78	98	
conventional	PD	78	96	
Conventional	PF	77	93	
Stale	PP	79	94	
Stale	PD	79	95	
Stale	PF	81	93	
N source[2] by N timing				
Pcu	PP	79		1.25
Pcu	PD	79		1.30
Pcu	PF	78		1.36
SCU	PP	78		1.25
SCU	PD	78		1.22
SCU	PF	79		1.26
urea	PP	78		1.12
Urea	PD	77		1.11
Urea	PF	80		1.11

[1]PP = preplant; PD postdrain (surface application during pinpoint drainage); PF = postflood (3 weeks after emergence).
[2]PCU = Meister with 150 day release; SCU = sulfur-coated urea.

Table 3. Influence of N source, tillage, and N rate on agronomic performance of drill-seeded Cypress rice. Rice Research Station, South Unit. Crowley, LA. 1999.

Source [1]	Tillage	N timing[2]	N rate[3]	Days to 50% heading	Plant height	Grain yield at 12% moisture Main	Ratoon	Total
			lb/A		(cm)	----------(lb/A)----------		
PCU	Conventional	PP	90	78	89	7021	2004	9025
PCU	Conventional	PP	120	77	90	7456	1758	9214
PCU	Conventional	PP	150	79	90	7561	2089	9650
PCU	Conventional	PP	180	79	95	7447	2003	9450
PCU	Conventional	PD	90	78	84	7180	1882	9062
PCU	Conventional	PD	120	78	92	7651	2011	9662
PCU	Conventional	PD	150	78	94	76%	1855	9550
PCU	Conventional	PD	180	80	99	7766	1831	9597
PCU	Conventional	PF	90	79	83	6357	1871	8228
PCU	Conventional	PF	120	79	85	6973	1767	8740
PCU	Conventional	PF	150	79	96	7715	2171	9887
PCU	Conventional	PF	180	79	95	7809	2151	9961
PCU	Stale	PP	90	77	84	7055	2244	9299
PCU	Stale	PP	120	77	90	7466	2237	9703
PCU	Stale	PP	150	77	91	7773	1935	9708
PCU	Stale	PP	180	78	93	7863	2104	9966
PCU	Stale	PD	90	77	82	6868	2186	9054
PCU	Stale	PD	120	78	88	7630	2039	9669
PCU	Stale	PD	150	78	90	8022	2098	10120
PCU	Stale	PD	180	79	92	7929	1975	9903
PCU	Stale	PF	90	79	86	6536	2103	8639
PCU	Stale	PF	120	80	87	7277	1709	8986
PCU	Stale	PF	150	80	92	7321	2003	9324
PCU	Stale	PF	180	81	91	7602	2052	9655
Urea	Conventional	PP	90	77	82	5787	1923	7709
Urea	Conventional	PP	120	77	82	6526	2034	8560
Urea	Conventional	PP	150	78	86	6861	1891	8152
Urea	Conventional	PP	180	78	91	7192	1858	9050
Urea	Conventional	PD	90	77	83	5843	2185	8028
Urea	Conventional	PD	120	77	82	5795	1988	7783
Urea	Conventional	PD	150	77	84	6471	2103	8574
Urea	Conventional	PD	180	78	88	6603	2200	8803
Urea	Conventional	PF	90	78	78	4486	1941	6427
Urea	Conventional	PF	120	78	78	4853	1938	6791
Urea	Conventional	PF	150	77	79	5552	2316	7867
Urea	Conventional	PF	180	78	80	5447	2178	7626
Urea	Stale	PP	90	76	79	6069	2232	8301
Urea	Stale	PP	120	76	81	6802	2252	9054
Urea	Stale	PP	150	77	86	6789	2131	8921
Urea	Stale	PP	180	77	89	7166	1919	9085
Urea	Stale	PD	90	76	76	5666	2102	7768
Urea	Stale	PD	120	77	79	5870	2120	7991
Urea	Stale	PD	150	77	83	6824	2194	9018
Urea	Stale	PD	180	76	81	6807	2072	8879
Urea	Stale	PF	90	77	78	4892	2158	7050
Urea	Stale	PF	120	77	79	5066	2192	7258
Urea	Stale	PF	150	77	78	5382	1999	7381
Urea	Stale	PF	180	77	79	5378	2287	7666
C.V., %				1.16	4.44	6.56	12.49	6.46
						Main effects		
Source:								
PCU				78	90	7416	2003	9419
Urea				77	82	6005	2092	8098
LSD (0.05)				1	1	126	73	161

Continued.

Table 3 continued.

	Days to 50% heading	Plantheight	Grain yield at 12% moisture		
			Main	Ratoon	Total
		(cm)	(lb/A)		
			Main effects		
Tillage:					
Conventional	78	87	6669	1998	8666
Stale	71	85	6752	2098	8850
LSD (0.05)	1	1	ns	73	161
N timing:					
PP	77	87	7052	2038	9090
PD	77	86	6914	2053	8966
PF	78	84	6166	2052	8218
LSD (0.05)	1	1	154	ns	198
N rate:					
90	77	82	6147	2069	8216
120	78	84	6614	2004	8618
150	78	87	6997	2065	9063
180	78	89	7084	2052	9137
LSD (0.05)	1	2	178	ns	228
Interactions:					
Source x tillage	ns	ns	ns	ns	ns
Source x N timing	*	*	*	ns	*
Tillage x N timing	*	*	ns	ns	ns
Source x tillage x N timing	ns	ns	us	ns	ns
Source x N rate	ns	*	ns	ns	ns
Tillage x N rate	ns	ns	ns	ns	ns
Source x tillage x N rate	ns	ns	ns	ns	ns
N timing x N rate	*	ns	ns	ns	ns
Source x N timing x N rate	ns	*	ns	ns	ns
Tillage x N timing x N rate	ns	ns	ns	ns	us
Source x tillage x N timing x N rate	ns	ns	ns	ns	ns

[1]PCU = Meister with a 15O-day release.
[2]PP = preplant; PD = postdrain (surface application during pinpoint drainage); PF = postflood (18 days after emergence).
[3]All N source treatments applied in single applications at each timing.

Table 4. Interaction means for selected variables. 1999.

Interaction		Days to 50% heading	Plant height	Main crop grain yield	Total grain yield
			(cm)	----------------(lb/A)---------------	
N source[1] by N timing[2]					
PCU	PP	78	90	7455	9502
PCU	PD	78	90	7593	9577
PCU	PF	79	89	7199	9177
Urea	PP	77	85	6649	8679
Urea	PD	77	82	6235	8355
Urea	PF	77	79	5132	7258
Tillage by N timing					
Conventional	PP	78	88		
Conventional	PD	78	88		
Conventional	PF	78	84		
Stale	PP	77	87		
Stale	PD	77	84		
Stale	PF	78	84		
N source by N rate[3]					
PCU	90		85		
PCU	120		88		
PCU	150		92		
PCU	180		94		
Urea	90		79		
Urea	120		80		
Urea	150		83		
Urea	180		85		
N timing by N rate					
PP	90	77			
PP	120	77			
PP	150	78			
PP	180	78			
PD	90	77			
PD	120	77			
PD	150	77			
PD	180	78			
PF	90	78			
PF	120	78			
PF	150	78			
PF	180	78			

[1]PCU = Meister with a 150-day release.
[2]PP = preplant; PD = postdrain (surface application during pinpoint drainage); PF = postflood (18 days after emergence).
[3]All N source treatments applied in single applications at each timing.