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Rice Grain Yield Response to Nitrogen Fertilization for Newly Released Cultivars and Hybrids

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Introduction

In midsouthern USA rice production, the amount of nitrogen (N) and the incidence of application are greater than any other nutrient (Norman et al. 2003). Unlike nutrients such as phosphorus (P), potassium (K), and zinc (Zn), no suitable soil test method has been established and implemented for determining the N-supplying capacity for soils used to produce rice (Dobermann and Fairhurst 2000). Instead, numerous N-rate and application timing studies are conducted on experiment stations and farms to determine N recommendations for the various cultivars that are grown in the rice-producing states. Most of the rice in Mississippi is produced in a dry-seeded, delayed flood cultural system in which the permanent flood is not established until the rice is 6 to 8 inches tall. 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), with the remaining N applied within the interval beginning with internode elongation (IE) to 10 days after IE of 0.5 inches (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 cultivars produce yields that are comparable, and sometimes greater, when a single PF application is made as opposed to a two- or three-way split of the total applied N (Norman et al. 2000).

Rate and timing of N are critical for optimum rice grain yield. Nitrogen increases plant height, panicle number, leaf size, spikelet number, and number of filled spikelets (Dobermann and Fairhurst 2000), ultimately determining the yield potential of a rice plant. Panicle number is influenced by the number of tillers that develop during the vegetative stage, while spikelet number and number of filled spikelets are determined in the reproductive stage (DeDatta 1981).

Though hybrid rice is grown on large hectarage in Asia (Longping 2004; FAO 2004), its cultivation in the USA is in its infancy. Data collected in Asia (Surekha et al. 1999; Balasubramanian 2002) as well as preliminary data collected by RiceTec, Inc., (Federico Cuevas, personal communication) indicate that hybrid rice may respond in both grain yield and milling quality by applying N at the early heading (HD) growth stage.

The specific objectives of this study were to determine the rice grain yield response for recently released commercial cultivars and hybrids on both fine and coarse textured soils in Mississippi, as well as to determine the effects of HD N applications on the whole milled rice percentage for the rice hybrids.

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Materials and Methods

Separate experiments were conducted to determine the rough rice yield response to N fertilization for three newly released cultivars — Cheniere, Cybonnet, and Pace — as well as three new commercially available hybrids — CLXL8, XL723, and XP710. Cheniere, Cybonnet, Pace, and XL723 were evaluated in 2004 and 2005. CLXL8 was evaluated at three silt loam locations and at one clay location in 2004. XP710 was evaluated at a clay location in 2003 and 2004 and at two silt loam locations in 2004. The Delta Research and Extension Center (DREC) was the location for all of the clay soil experiments. Sharkey (very-fine, smectitic, thermic Chromic Epiaquerts) clay was present at DREC. The silt loam experiments were conducted on various on-farm locations where Dundee (fine-silty, mixed, active, thermic Typic Endoaqualfs) or Forestdale (fine, smectitic, thermic Typic Endoaqualfs) were present. Table 1 gives a description for each of the locations where the experiments were conducted as well as the year in which they were used for experimentation.

All plots consisted of eight rows that measured 16 feet in length, spaced 8 inches apart, and were drill seeded with either a modified Great Plains 1520 drill or a custom manufactured cone drill with Sunflower double disk openers at a depth of approximately 0.75 inch. Seeding rates of 40 seeds and 14 seeds per square foot were used for the cultivars and hybrids, respectively. Pest control measures were conducted in a manner similar to those outlined by Miller and Street (2000).

The experimental design for all site years was a randomized complete block with four replications. The treatment structure for each cultivar each year was a factorial that consisted of four preflood (PF) N rates (90, 120, 150 and 180 pounds of N per acre) and four internode elongation (IE) rates (0, 30, 60 and 90 pounds of N per acre). For the hybrids, a 2X3 factorial that consisted of two PF N rates (90 and 120 pounds of N per acre) and three heading (HD) rates (0, 30, and 60 pounds of N per acre) was the treatment structure. Preflood N treatments were weighed individually and applied to dry soil with a custom-manufactured, self-propelled fertilizer distributor equipped with a Hege belted-cone delivery system (Wintersteiger, Inc., Salt Lake City, Utah) and a zero-max adjustable drive (Zero-Max®, Inc., Plymouth, Minnesota). These treatments were applied to rice when it reached 6 to 8 inches tall and flooded within 3 days after application to minimize volatilization losses (Table 2). Internode elongation N applications were weighed and broadcasted by hand into the flood when the uppermost node had elongated 0.25 to 0.5 inch. Urea (46% N) was the N-source for all applications.

Rice plots were harvested with a small-plot combine, and rough rice yields were adjusted to 12% moisture content. Rough rice yield and milling quality data (Adair 1972) were combined for analysis of variance (ANOVA) and tested for main effects and interactions using a mixed model approach (SAS 2003). Preflood N and IE rates were considered fixed effects. Year, replications, and any interactions between these factors were considered random effects. Each cultivar was analyzed separately. A significance level of 0.05 was used for the statistical tests.

Table 1. Site description for experiment locations in 2003-2005.

Location	Cooperator	Soil type	Year[1]			pH	CEC	OM
			2003	2004	2005		meq/100 g	%
Cleveland	Aguzzi	Forestdale sil			x	6.7	15	1.1
Cleveland	Boone	Forestdale sil	x			7.4	13	0.9
Drew	Boone	Dundee sil		x		6.0	17	0.5
Shaw	Satterfield	Dundee sil		x		6.3	17	0.8
Stoneville	DREC	Sharkey c	x	x	x	8.0	35	2.0
Tunica	Berry	Forestdale sil		x		6.8	20	1.5

[1]Indicates the year in which an N rate experiment was conducted at the specified location.

Table 2. Year, location, and agronomic dates (day-month) for Cheniere, Cybonnet, Pace, CLXL8, XL723, and XP710.

Cultivar	Year	Location	Planted	Emerged	PF N	Flooded	IE N	HD N	Harvested
Cheniere	2004	DREC	16-April	26-April	25-May	27-May	22-June	—	14-Sept.
	2004	Shaw	19-April	26-April	24-May	27-May	19-June	—	8-Sept.
	2004	Tunica	5-April	28-April	20-May	22-May	14-June	—	1-Sept.
	2005	DREC	4-May	12-May	6-June	8-June	27-June	—	13-Sept.
	2005	Cleveland	18-April	1-May	23-May	26-May	24-June	—	4-Sept.
Cybonnet	2004	DREC	7-April	23-April	25-May	27-May	22-June	—	14-Sept.
	2004	Shaw	19-April	26-April	24-May	27-May	19-June	—	8-Sept.
	2005	DREC	4-May	12-May	6-June	8-June	27-June	—	13-Sept.
	2005	Cleveland	18-April	1-May	23-May	26-May	24-June	—	4-Sept.
Pace	2004	DREC	16-April	27-April	25-May	27-May	22-June	—	14-Sept.
	2004	Shaw	19-April	26-April	24-May	27-May	19-June	—	2-Sept.
	2005	DREC	4-May	12-May	6-June	8-June	27-June	—	13-Sept.
	2005	Cleveland	18-April	1-May	23-May	26-May	24-June	—	4-Sept.
CLXL8	2004	DREC	7-April	22-April	25-May	27-May	—	14-July	19-Aug.
	2004	Drew	7-April	22-April	24-May	25-May	—	7-July	26-Aug.
	2004	Shaw	19-April	26-April	24-May	27-May	—	10-July	2-Sept.
	2004	Tunica	5-April	5-April	20-May	22-May	—	7-July	1-Sept.
XL723	2004	DREC	7-April	22-April	25-May	27-May	—	14-July	12-Aug.
	2005	DREC	15-April	29-April	24-May	26-May	—	18-July	19-Aug.
	2005	Cleveland	16-April	27-April	23-May	27-May	—	14-July	22-Aug.
XP710	2003	DREC	8-May	17-May	23-June	24-June	—	8-Aug.	16-Sept.
	2004	DREC	7-April	22-April	25-May	27-May	—	14-July	24-Aug.
	2004	Drew	7-April	22-April	24-May	25-May	—	7-July	26-Aug.
	2004	Tunica	5-April	5-April	20-May	22-May	—	7-July	1-Sept.

Results

Cultivars. Cheniere and Pace rice grain yields were significantly affected by PF rate on clay soils, but Cybonnet was not (Table 3). For Cheniere on clay soils, rice grain yields when averaged across IE rates were greatest when 120 pounds of N per acre was applied PF, but it took 150 pounds of N per acre to reach the greatest yields for Pace. Though the difference was not significant, Cybonnet responded similarly to Cheniere for PF N rate. For silt loam soils, and averaged across IE rates, there was no advantage to applying more than 90 pounds of N per acre PF for Cheniere, Cybonnet, and Pace. Averaged across IE rates, when PF rates exceeded 120 pounds of N per acre for Cheniere, rice grain yields decreased. Rice grain yields for Cheniere on silt loam soils were also affected by IE N rate. Averaged across PF rates, the 90-pound N treatment applied at IE reduced yields compared with the lower IE N rates.

Hybrid Grain Yield. Rough rice yields were significantly affected by PF N rate for XL723 and XP710 on clay soils. Both hybrids produced greater grain yields when 120 pounds of N per acre were applied PF (Table 4). Heading N rate did impact CLXL8 rice grain yields on clay soils. Averaged across PF rates, when 30 or 60 pounds of N per acre were applied at HD, grain yields increased. For silt loam soils, grain yields were not affected by PF N rate or HD N rate for any of the hybrids.

Hybrid Whole Milled Rice. Whole milled rice for CLXL8 grown on clay soils was also greater when the higher PF N rate was applied (Table 5). There was a trend for increased whole-grain rice with increased HD N for XL723, but XP710 was not affected by PF or HD N. On silt loam soils, an increase in PF N rate for each of the hybrids produced higher whole milled rice. When the HD rate was increased to 30 pounds of N per acre, a greater percentage of whole milled rice was obtained for CLXL8. Though not significant, a similar trend was present for XL723; however, for XP710, a numerical decline was observed for increasing HD N on silt loam soils.

Table 3. Means of rice grain yield for Cheniere, Cybonnet, and Pace grown on clay and silt loam soils in 2004 and 2005.[1]

PF N rate	IE N rate	Clay			Silt loam		
		Cheniere	Cybonnet	Pace	Cheniere	Cybonnet	Pace
lb N/A	*lb N/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
Individual Treatment Means							
90	0	7460	5576	6275	8141	6277	8392
	30	7697	5814	6370	8259	6351	7869
	60	7904	5889	6547	8458	6247	7930
	90	7998	6262	6711	8248	6803	7875
120	0	8003	6070	6952	8442	6455	8102
	30	8244	5606	6865	8249	6164	7923
	60	8106	6211	6805	8209	6791	8089
	90	8100	6588	6866	7757	6709	8104
150	0	8231	6036	7010	8012	6675	8461
	30	8277	6259	7365	7859	6642	8075
	60	8347	6318	7445	7876	6622	8177
	90	8218	6154	7271	7572	6570	8178
180	0	8096	6060	7232	7997	6614	8272
	30	8405	6007	7377	7863	6184	8167
	60	8244	6311	7162	7718	6413	8258
	90	7936	6181	7117	7440	6444	7892
Pooled Means							
90		7765b	5885	6476c	8277a	6420	8017
120		8113a	6119	6872b	8164a	6530	8055
150		8268a	6192	7273a	7830b	6627	8223
180		8170a	6140	7222a	7755b	6414	8147
	0	7948	5936	6867	8148y	6505	8307
	30	8156	5922	6994	8058y	6335	8009
	60	8150	6182	6990	8065y	6518	8114
	90	8063	6296	6991	7754z	6632	8012
Analysis of Variance							
PFrate		*	NS	*	*	NS	NS
IErate		NS	NS	NS	*	NS	NS
PF*IE		NS	NS	NS	NS	NS	NS

[1]Means within a column followed by different letters are statistically different (P< 0.05).

Table 4. Means of rice grain yield for CLXL8, XL723, and XP710 grown on clay and silt loam soils in 2003-2005.[1]

PF N rate	HD N rate	Clay			Silt loam		
		CLXL8	XL723	XP710	CLXL8	XL723	XP710
lb N/A	*lb N/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*	*lb/A*
Individual Treatment Means							
90	0	7941	6285	8742	10930	8408	12214
	30	8287	6605	9024	10995	8550	12230
	60	8439	6827	9295	10995	9010	12195
120	0	8102	7091	9351	11460	8168	11466
	30	8539	7174	9633	10651	8661	11687
	60	8789	7299	9839	10872	8537	11654
Pooled Means							
90		8222	6573a	9020a	10974	8656	12213
120		8476	7188b	9608b	10994	8455	11602
	0	8021a	6688	9046	11195	8288	11840
	30	8413b	6952	9432	10823	8606	11959
	60	8614b	7001	9464	10934	8774	11924
Analysis of Variance							
PFrate		NS	*	*	NS	NS	NS
HDate		*	NS	NS	NS	NS	NS
PF*HD		NS	NS	NS	NS	NS	NS

[1]Means within a column followed by different letters are statistically different (P< 0.05).

Table 5. Means of whole milled rice percentage for CLXL8, XL723, and XP710 grown on clay and silt loam soils in 2003-2005.[1]

PF N rate	HD N rate	Clay			Silt loam		
		CLXL8	XL723	XP710	CLXL8	XL723	XP710
lb N/A	*lb N/A*	%	%	%	%	%	%
Individual Treatment Means							
90	0	49.5	50.8	62.0	60.0	55.8	60.1
	30	52.1	52.8	62.3	60.6	56.6	60.3
	60	52.5	54.1	62.9	61.5	57.2	59.7
120	0	52.8	51.4	62.4	61.3	57.2	62.1
	30	53.4	53.2	62.7	62.2	57.6	61.1
	60	54.2	54.3	62.5	62.2	58.2	60.5
Pooled Means							
90		51.4a	52.5	62.4	60.7a	56.6a	60.0a
120		53.4b	53.0	62.5	61.9b	57.7b	61.2b
	0	51.1	51.1	62.2	60.6y	56.5	61.1
	30	52.7	53.0	62.5	61.4z	57.1	60.7
	60	53.3	54.2	62.7	61.8z	57.7	60.1
Analysis of Variance							
PFrate		*	NS	NS	*	*	*
HDate		NS	NS	NS	*	NS	NS
PF*HD		NS	NS	NS	NS	NS	NS

[1]Means within a column followed by different letters are statistically different ($P < 0.05$).

Summary

Based on these data, approximately 30 more pounds of N per acre are needed to produce optimum yields on clay soils compared with silt loam soils for the cultivars and hybrids presented. These data also suggest that minimal yield response for cultivars is gained when N is applied at IE unless the plant is deficient at the time of application. For Cheniere, Cybonnet, and Pace, growers should consider applying at least two-thirds of the total N prior to flooding. Furthermore, regardless of the PF N rate, seldom would there be an economic return from applying more than 60 pounds of N per acre at the IE growth stage. For hybrids produced on clay soils, a minimum of 120 pounds of N per acre is needed to achieve optimum grain and milling yields. This can be reduced to 90 pounds of N per acre when hybrids are planted on silt loam soils. A minimum of 30 pounds of N per acre applied at the HD stage has proven to be beneficial in grain yields, milling yields, and lodging reduction for the hybrids reported here.

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