B.R. Wells

RICE RESEARCH STUDIES 2008

R.J. Norman, J.-F. Meullenet,
and K.A.K. Moldenhaurer, editors

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RICE
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Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72701

DEDICATED IN MEMORY OF

Bobby R. Wells

Bobby R. Wells was born July 30, 1934, at Wickliffe, Ky. He received his B.S. degree in agriculture from Murray State University in 1959, his M.S. degree in agronomy from the University of Arkansas in 1961, and his Ph.D. in soils from the University of Missouri in 1964. Wells joined the faculty of the University of Arkansas in 1966 after two years as an assistant professor at Murray State University. He spent his first 16 years at the University of Arkansas System Division of Agriculture Rice Research and Extension Center near Stuttgart. In 1982, he moved to the U of A Department of Agronomy in Fayetteville.

Wells was a world-renowned expert on rice production with special emphasis on rice nutrition and soil fertility. He was very active in the Rice Technical Working Group (RTWG), for which he served on several committees, chaired and/or moderated Rice Culture sections at the meetings, and was a past secretary and chairman of the RTWG. He loved being a professor and was an outstanding teacher and a mentor to numerous graduate students. Wells developed an upper-level course in rice production and taught it for many years. He was appointed head of the Department of Agronomy in 1993 and was promoted to the rank of University Professor that year in recognition of his outstanding contributions to research, service, and teaching.

Among the awards Wells received were the Outstanding Faculty Award from the Department of Agronomy (1981), the Distinguished Rice Research and/or Education Award from the Rice Technical Working Group (1988), and the Outstanding Researcher Award from the Arkansas Association of Cooperative Extension Specialists (1992). He was named a Fellow in the American Society of Agronomy (1993) and was awarded, posthumously, the Distinguished Service Award from the RTWG (1998).

Wells edited this series when it was titled *Arkansas Rice Research Studies* from the publication's inception in 1991 until his death in 1996. Because of Wells' contribution to rice research and this publication, it was renamed the *B.R. Wells Rice Research Studies* in his memory starting with the 1996 publication.

FEATURED RICE COLLEAGUE

Dr. Sung Man Lim

Sung Man Lim was born in Suweon, Korea, July 13, 1934 – the oldest son of eight children. During his elementary years, Korea was under Japanese occupation, and during his high school years the Korean War was underway. "Whenever you have war, nothing works right. When you are in war, everything is destroyed," he said. Despite difficult times, he continued his education, earning the B.S. and M.S. degrees in agronomy in 1957 and 1959, respectively, from Seoul National University. From 1959 to 1961 he was a crop protection agronomist for the Korean Ministry of Agriculture and Forestry where he worked on establishing local vegetable production for parts of South Korea. Lim earned the M.S. degree in agronomy - seed technology from Mississippi State University in 1963 and the Ph.D. degree in crop science - plant pathology from Michigan State University in 1966. In 1967, he joined the Department of Plant Pathology, University of Illinois - Urbana, as a research associate. In 1977, he was recruited by the USDA/ARS as a research plant pathologist at the University of Illinois and retained that position as well as his professor position in the Department of Plant Pathology until 1991. Since 1991, he has been professor and head of the Department of Plant Pathology in the University of Arkansas System Division of Agriculture based on the Fayetteville campus until his retirement as emeritus professor in 2008.

Lim's professional achievements in research, teaching, administration, and outreach activities related to plant pathology are very broad. During his first ten years (1967-1977) with the University of Illinois, Lim conducted research on the genetics, physiology, and epidemiology of corn diseases. His research on the host-pathogen relationships between corn and *Helminthosporium maydis,* the causal agent of southern corn leaf blight, was instrumental in minimizing losses caused during the southern corn leaf blight epidemics of 1970 and 1971, which cost the U.S. corn industry more than 2 billion dollars. Lim was co-author of a publication on southern corn leaf blight that was named a Citation Classic in *Current Contents*, as one of the most cited scientific papers in agricultural journals. Lim and his colleagues identified the susceptibility of Texas male-sterile cytoplasm (Cms-T) corn to *H. maydis* race T during the winter before the 1970 epidemic. His bioassay of seed was used by industry to prevent seed lots with a high percentage of Cms-T from being sold. His work on corn also led to the first evidence of a fungal-inhibitory chemical defense mechanism in monocotyledonous plants, and he published the first genetic study of the heterotic effects of plant disease resistance in 1975.

As a research plant pathologist in the USDA/ARS from 1977 to 1991, Lim developed a comprehensive soybean pathology program where he focused on genetic and epidemiological aspects of foliar, pod, and seed diseases. This research led to integrated soybean pest management which helped to define the economic importance of diseases and provide methods for economic management in the Midwest. This model was used to establish the rice disease monitoring program in Arkansas in 1993 and is still in use today. He led the integration of Extension plant pathologists into the department in 2004 and established the Soybean Rust Working Group the same year. His leadership in the department over the years encouraged joint research/extension projects which led to the establishment of the Rice Disease Monitoring Program in 1993, the first molecular pathology effort on rice in the state in 1995, and eventually helped secure the RiceCAP project – a 5 million dollar research effort funded by USDA starting in 2004. He served as a member of the Arkansas Plant Board, and on the Pesticide Seed and Nursery Committees of the Plant Board for many years. He actively participated in the state commodity boards research programs for rice, soybean and wheat.

Lim is recognized both in the U.S. and abroad as a leading authority on corn and soybean pathology, and has received numerous invitations to speak at conferences, symposia, and workshops and to serve as advisor and consultant to various groups. He was elected as a member of the Soybean Germplasm Advisory Committee from 1980-1985 by the Soybean Genetics Committee at the National Soybean Breeders Workshop. In 1981, he was an invited participant in the workshop for the Consortium for IPM by USEPA. He served as chairman and convener of the Plant Protection Session at the China/USA Soybean Symposium in 1982. In 1989, he was invited to organize the special workshop for SDS sponsored by the American Soybean Association. In that same year, he served as Chairman of the Soybean Pathology Session at the National Soybean Breeder/Pathologist Workshop.

Internationally, Lim served as a consultant on a variety of crop research and development projects and was a leader and speaker at many conferences and symposiums. He was a keynote speaker in 1996 at the Korean Phytopathological Society and also delivered another keynote speech at the Korean National Conference on Advancing Technologies for Agriculture in Korea.

Lim has served as associate editor of Plant Disease and as associate and senior editor of Phytopathology. His many awards include the Distinguished Scientist Award from the Korean Ministry of Science and Technology in 1980 and the Soybean Researchers Recognition Award from the American Soybean Association and ICI Americas in 1981. He was named Fellow of the APS in 1988 and named Fellow of the AAAS in 1990. He received the Spitze Land Grant University Faculty award for Excellence from the University of Arkansas in 2006 and the Distinguished Service Award from the Southern Soybean disease Workers in 2008. He has served on the advisory council for the Korean Society of Plant Pathology and editorial board for the Journal of the Korean Phytopathology since 1998.

Lim and his wife, Ah-Ok, have two children. Louis graduated from Northwestern University, Evanston, Ill., in 1991 with a degree in philosophy and from the Law School of the University of Arkansas in 1997. Elizabeth graduated from Wheaton College, Wheaton, Ill., in 1993 with a degree in English. His extracurricular interests include gardening, fishing, and reading western history.

FOREWORD

Research reports contained in this publication may represent preliminary or only a single year of results; therefore, these results should not be used as a basis for long-term recommendations.

Several research reports in this publication will appear in other Arkansas Agricultural Experiment Station publications. This duplication is the result of the overlap in research coverage between disciplines and our effort to inform Arkansas rice producers of all the research being conducted with funds from the rice check-off. This publication also contains research funded by industry, federal, and state agencies.

Use of products and trade names in any of the research reports does not constitute a guarantee or warranty of the products named and does not signify that these products are approved to the exclusion of comparable products.

All authors are either current or former faculty, staff, or students of the University of Arkansas Division of Agriculture, or scientists with the United States Department of Agriculture-Agricultural Research Service. For further information about any author, contact Agricultural Communication Services, (501) 575-5647.

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CONTENTS

OVERVIEW AND VERIFICATION

EMERGING TRENDS

BREEDING, GENETICS, AND PHYSIOLOGY

PEST MANAGEMENT: DISEASES

PEST MANAGEMENT: INSECTS

PEST MANAGEMENT: WEEDS

RICE CULTURE

RICE QUALITY AND PROCESSING

ECONOMICS

OVERVIEW AND VERIFICATION

Trends In Arkansas Rice Production

C.E. Wilson, Jr., S.K. Runsick, and R. Mazzanti

ABSTRACT

Arkansas is the leading rice-producing state in the U.S., representing 45.1% of the total U.S. production and 46.9% of the total acres planted to rice in 2008. Rice cultural practices vary across the state and across the U.S. However, due to changing political, environmental, and economic times, these practices are dynamic. This survey was initiated in 2002 to monitor how the changing times reflect the changes in the way Arkansas rice producers approach their livelihood. The survey was conducted by polling county extension agents in each of the counties in Arkansas that produce rice. Questions included topics such as tillage practices, water sources and irrigation methods, seeding methods, and precision leveling. Information from the University of Arkansas Rice DD50 Program was included to summarize variety acreage distribution across Arkansas. Other data was obtained from the USDA National Agricultural Statistics Service.

INTRODUCTION

Arkansas is the leading rice-producing state in the U.S., representing 45.1% of the total U.S. production and 46.9% of the total acres planted to rice in 2008. Rice cultural practices vary across the state and across the U.S. However, due to changing political, environmental, and economic times, the practices are dynamic. This survey was initiated in 2002 to monitor how the changing times reflect the changes in the way Arkansas rice producers approach their livelihood. It also serves to provide information to researchers and extension personnel about the ever-changing challenges facing Arkansas rice producers.

PROCEDURES

A survey has been conducted annually since 2002, by polling county extension agents in each of the counties in Arkansas that produce rice. Questions were asked concerning topics such as tillage practices, water sources and irrigation methods, seeding methods, and precision leveling. Acreage, yield, and crop progress information was obtained from the USDA National Agricultural Statistics Service (http://www.nass.usda.gov). Rice variety distribution was obtained from summaries generated from the University of Arkansas Rice DD50 program enrollment.

RESULTS AND DISCUSSION

Rice acreage by county is presented in Table 1 with distribution of the most widely produced varieties. 'Wells' was the most widely planted variety in 2008 at 25.1% of the acreage, followed by Rice Tec 'CL XL 729' (14.7%), 'CL 171 AR' (13.8%), 'Francis' (11.8%), and Rice Tec 'CL XL 730' (9.4%). The acreage planted to Wells decreased from 35% in 2007 to 25% in 2008. The biggest changes were the increase in CL 171 AR and the Rice Tec Clearfield hybrid acreage essentially doubled. The adoption of the Clearfield rice system represents a significant factor that plays a significant role in management of red rice. Clearfield rice (all varieties combined) accounted for over 40% of the total rice acreage in 2008, and is up from just over 20% in 2007. Clearfield rice has increased in acreage each after its launch except for 2007. Based on seed supply and other market-related issues, the 2009 Clearfield rice acreage is poised to be as much as 60% or more of the Arkansas rice acreage. This technology provides an opportunity for red rice control that has never been available to rice farmers but is jeopardy in some locations. The stewardship program that was implemented to reduce problems associated outcrossing with red rice have been effective when used. However, in areas where suggested crop rotations have not been followed, imidazolinone-resistant barnyardgrass has been discovered.

Arkansas' planted rice acreage represented 46.8% of the total 2008 U.S. rice crop (Table 2). The state-average yield of 6,660 lb/acre (148 bu/acre) was an 8% reduction in average yield from the record established during 2007 and represented the fourth highest average in the U.S. behind California, Texas, and Mississippi. The reduced yields can be attributed to delayed planting because of spring rainfall (Fig. 2) and substantial damage from Hurricane Gustav and Hurricane Ike. The total rice produced in Arkansas was 92.9 million hundredweight (cwt). This represents 45.6% of the 203.7 million cwt produced in the U.S. during 2008. While Arkansas reduced overall production, all of the other southern states increased overall production compared to 2007. Over the past three years, Arkansas has produced 47.6% of all rice produced in the U.S. The five largest rice-producing counties in 2008 included Poinsett, Arkansas, Lawrence, Jackson, and Cross,representing 37.6% of the state's total rice acreage (Table 1).

Planting began in 2008 much later than the 5-year average due to wet weather during the end of March and beginning of April (Fig. 2). Normally we have approximately

25% of the crop planted by 15 April and yet in 2008 less than 5% had been planted by 15 April. The wet weather resulted in an average of 2 wk delay compared to normal but was as much as 4 wk in some areas. Almost 60% of the crop was planted in May or later compared to the norm of less than 40% planted after 1 May. Because of the planting delays, harvest was also delayed compared to normal (Fig. 3). Because harvest was delayed, more than 90% of the crop was still in the field when the hurricanes moved through the state. Had the crop developed closer to normal, over half of the crop would have been harvested when the hurricanes hit Arkansas.

Approximately 58% of the rice produced in Arkansas was planted using conventional tillage methods in 2008 (Table 3). This usually involves fall tillage when the weather cooperates, followed by spring tillage to prepare the seedbed. This is a slight increase compared to 2006 and 2007. The most common conservation tillage system utilized by Arkansas rice farmers is stale seedbed planting following fall tillage, representing approximately 27% of the state's rice acreage. True no-till rice production is not common but is done in a few select regions of the state. According to the survey, no-till rice production increased slightly compared to previous years and accounted for approximately 16% of the rice acreage in 2008.

The majority of rice is still produced on silt loam soils (Table 3). However, an increasing more important factor is the amount of rice produced on clay or clay loam soils (21% and 21% of the acreage, respectively). This represents unique challenges in rice production issues, such as tillage, seeding rates, fertilizer management, and irrigation. The increase in rice acreage on clay soils has been observed in counties along the Mississippi River, where historically non-irrigated soybeans have dominated. For example, rice production in Mississippi County has more than doubled over the last 20 years increasing from approximately 15,000 acres each in 1984 to about 37,000 in 2008 (Arkansas Agricultural Statistics, 1984; Table 1). Also, the 2008 acreage is down from the high of 49,000 acres in 2005. Other areas where rice production on clay soils have increased during this time frame include Crittenden County, and the eastern half of Poinsett, Cross, and St. Francis counties.

Rice most commonly follows soybean in rotation, accounting for almost 75% of the rice acreage (Table 3). Approximately 22% of the acreage in 2008 was planted following rice, with the remaining 3% made up of rotation with other crops including corn, grain sorghum, cotton, wheat, oats, and fallow. The majority of the rice in Arkansas is produced in a dry-seeded, delayed-flood system with only approximately 2% using a water-seeded system. Approximately three-fourths of all the Arkansas rice acreage is drill-seeded, with an additional 20% broadcast seeded in a delayed-flood system.

Irrigation water is one of the most precious resources for rice farmers of Arkansas. Reports of diminishing supplies have prompted many producers to develop reservoir and/or tailwater recovery systems to reduce the "waste" by collecting all available water and re-using. Simultaneously, producers have tried to implement other conservation techniques to preserve the resource vital to continued production. Approximately 80% of the rice acreage in Arkansas is irrigated with groundwater, with the remaining 20% irrigated with surfacewater obtained from reservoirs or streams and bayous (Table 3).

During the mid 1990's, the University of Arkansas began educating producers on the use of poly-tubing as a means of irrigating rice to conserve water and labor. As of 2008, rice farmers have adopted this practice on more than 36% of the rice acreage. The adoption of multiple-inlet irrigation using poly-tubing has more than doubled from 17% in 2002 (Fig. 4). Approximately 72% of the rice is still irrigated with conventional levee and gate systems. A small percentage of rice acreage is conducted in more upland conditions utilizing furrow irrigation. A number of producers have increased the amount of rice produced using a furrow-irrigated system where they have found it to be particularly efficient in fields that have steep slopes and often contain more area in levees than in paddies if flood irrigated. This has increased from less than 1,000 acres in 2002 to more than 40,000 acres in 2008.

An additional means of conserving water for rice irrigation is through precision leveling. This results in more efficient water management and typically less total water usage. Approximately 45% of the 2008 rice acreage in Arkansas has been precision leveled, with more than 10% utilizing zero-graded fields (Table 3). Approximately 55% of the rice still utilizes contour levees. Stubble management is important for preparing the fields for the next crop, particularly in rice following rice systems. Several approaches are utilized to manage the rice straw for the next crop, including tillage, burning, rolling, and winter flooding. Approximately 26% of the acreage was burned, 26% tilled, 40% rolled, and 23% winter flooded. Combinations of these systems are used in many cases. For example, a significant amount of the acreage that is flooded during the winter for waterfowl will also be rolled. Some practices are inhibited by fall weather. For example, heavy rainfall in the fall may reduce the amount of stubble that can be burned and will also affect the amount of tillage that can be done.

SIGNIFICANCE OF FINDINGS

During the past 20 years, the state average yields in Arkansas have increased approximately 1,780 lb/acre (about 40 bu/acre) or 2 bu/acre/year. This increase can be attributed to improved varieties and improved management, including such things as better herbicides, fungicides, and insecticides, improved water management through precision leveling and multiple inlet poly-pipe irrigation, improved fertilizer efficiency, and increased understanding of other practices such as seeding dates and tillage practices. Collecting this kind of information regarding rice production practices in Arkansas is important for researchers to understand the adoption of certain practices as well as to understand the challenges and limitations faced by producers in field situations.

ACKNOWLEDGMENTS

The author would like to extend thanks to all of the county extension agents who participated in this study.

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Table 1. Arkansas harvested

County/ Parish	Harvested acreage[z] 2007	Harvested acreage[z] 2008	Medium-grain Bengal	Medium-grain Jupiter	Medium-grain Others[y]	CL161
Arkansas	105,961	102,747	413	2,745	0	1,541
Ashley	11,200	12,713	0	0	0	4,055
Chicot	25,091	31,961	0	0	17	1,023
Clay	73,440	75,255	288	5,822	0	452
Craighead	78,155	78,477	1,470	9,281	0	3,059
Crittenden	36,761	36,935	2,053	0	0	0
Cross	85,053	79,819	80	2,421	41	7,503
Desha	27,572	26,660	0	1,245	0	1,394
Drew	10,233	12,441	0	0	0	3,160
Faulkner	2,316	2,839	0	0	0	0
Greene	67,557	77,459	620	1,239	0	5,150
Independence	10,381	10,177	0	0	0	0
Jackson	91,806	95,396	602	14,675	35	10,449
Jefferson	58,132	67,424	0	514	0	14,429
Lafayette	1,974	1,869	0	0	0	0
Lawrence	98,390	102,405	0	7,805	0	2,255
Lee	17,877	22,840	0	291	0	0
Lincoln	26,547	29,337	0	0	0	0
Lonoke	73,650	75,138	2,545	2,166	75	301
Miller	541	1,665	0	0	0	0
Mississippi	37,405	36,715	0	0	0	0
Monroe	46,619	52,358	585	642	0	3,613
Phillips	19,889	35,395	0	0	0	5,522
Poinsett	117,414	116,371	3,087	20,783	0	5,004
Prairie	59,838	60,594	1,990	8,035	40	3,211
Pulaski	3,384	3,246	0	5	0	13
Randolph	32,561	33,033	153	737	0	330
St. Francis	34,212	38,492	425	4,678	0	0
White	12,406	13,943	0	1,217	0	140
Woodruff	56,489	54,990	0	2,345	0	10
Others	4,255	5,159	0	0	0	1,678
Unaccounted[w]	10,497	0				
2008 Total		1,393,854	14,311	86,646	208	74,292
2008 Percent		100.00%	1.03%	6.22%	0.01%	5.33%
2007 Total	1,327,106		99,298	44,527	2,267	135,536
2007 Percent	100.00%		7.48%	3.36%	0.17%	10.21%

[z] Harvested acreage. Source: Arkansas Agricultural Statistics and FSA

[y] Other varieties: AB647, Banks, Cheniere, CL 131, Cybonnet , Cypress, Della, Dellrose, Gulfmont, Jackson, Jasmine 85, Koshihikari, Nortai, Pirogue, Rice Tec CL XL8, Rice Tec CL XP 745, Rice Tec XL 723, Rice Tec XP 744, Skybonnet, Spring, and Trenasse .

[x] Other counties: Clark, Conway, Franklin, Hot Spring, Little River, Perry, and Pope.

[w] Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA. Source: Arkansas Argicultural Statistics and FSA.

rice acreage 2008 summary.

Long-grain						
CL171AR	CLXL729	CLXL730	Cocodrie	Francis	Wells	Others[x]
15,720	6,986	5,753	4,108	30,206	21,011	14,264
521	2,288	839	1,780	0	3,229	0
7,319	5,465	4,187	7,000	160	4,560	2,231
11,442	12,486	12,411	828	5,117	18,665	7,745
14,109	7,648	11,217	4,759	3,993	14,956	7,985
1,145	5,429	480	222	0	24,373	3,233
28,907	8,461	4,230	319	11,095	16,442	319
3,841	3,815	790	3,263	2,920	8,498	894
4,442	1,319	2,475	0	0	759	287
738	741	295	0	0	1,065	0
6,197	23,990	23,425	1,596	3,325	9,407	2,510
0	6,921	0	0	0	0	3,257
13,060	12,950	14,900	271	7,399	13,353	7,702
7,417	7,079	2,225	0	7,200	28,560	0
0	0	0	1,869	0	0	0
28,359	22,643	8,500	6,616	1,503	18,975	5,749
3,926	0	868	2,535	5,870	9,350	0
2,876	9,545	7,550	0	8,390	440	536
10,091	6,387	6,161	301	11,045	23,593	12,473
508	0	0	711	0	446	0
776	3,988	2,519	330	0	28,858	244
3,707	4,608	1,990	8,273	7,644	15,204	6,094
248	248	248	17,273	8,636	2,973	248
8,714	12,568	4,538	0	20,132	32,933	8,611
4,423	7,340	3,757	4,242	8,544	12,019	6,994
766	276	266	13	477	1,079	351
2,859	13,841	4,493	1,817	363	2,534	5,907
500	476	0	1,694	7,506	22,335	879
3,312	3,661	990	1,374	1,458	1,440	351
5,216	12,878	5,239	955	11,187	12,879	4,281
801	481	514	170	537	499	479
						0
191,940	204,517	130,860	72,317	164,708	350,434	103,622
13.77%	14.67%	9.39%	5.19%	11.82%	25.14%	7.43%
13,181	68,502	53,762	85,688	145,361	470,339	208,645
0.99%	5.16%	4.05%	6.46%	10.95%	35.44%	15.72%

Table 2. Acreage, grain yield, and production of rice in the United States from 2006 to 2008[z].

	Area planted			Area harvested			Yield			Production		
State	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
	(1,000 acres)						(lb/acre)			(1,000 cwt[y])		
AR	1,406	1,331	1,401	1,400	1,325	1,395	6,900	7,230	6,660	95,565	95,814	92,938
CA	526	534	519	523	533	517	7,660	8,200	8,320	40,040	43,684	43,030
LA	350	380	470	345	378	464	5,880	6,140	5,830	20,294	23,222	27,037
MS	190	190	230	189	189	229	7,000	7,350	6,850	13,230	13,892	15,687
MO	216	180	200	214	178	199	6,400	6,900	6,620	13,696	12,279	13,173
TX	150	146	175	150	145	172	7,170	6,550	6,900	10,760	9,497	11,868
US	2,838	2,761	2,995	2,821	2,748	2,976	6,898	7,219	6,846	194,585	198,388	203,733

[z] Source: USDA-NASS, 2007.
[y] cwt = hundredweight.

Table 3. Acreage distribution of selected cultural practices for Arkansas rice production.

	2006		2007		2008	
Cultural practice	Acreage	% of total	Acreage	% of total	Acreage	% of total
Arkansas rice acreage	1,400,000	100.00	1,327,106	100.00	1,393,000	100.00
Soil texture						
Clay	309,871	22.1	309,150	22.9	287,612	20.6
Clay loam	231,958	16.6	225,450	16.7	285,532	20.5
Silt loam	734,525	52.5	713,350	52.1	760,351	54.6
Sandy loam	79,915	5.7	70,200	5.2	51,523	3.7
Sand	43,730	3.1	41,850	3.1	7,865	0.6
Tillage practices						
Conventional	782,071	55.9	742.500	55.0	802,478	57.6
Stale seedbed	491,924	35.1	484.650	35.9	372,150	26.7
No-till	126,001	9.0	122.850	9.1	218,372	15.7
Crop rotations						
Soybean	1,116,486	79.7	1,061,100	78.6	1,027,192	73.7
Rice	200,866	14.3	193,860	14.4	308,748	22.2

continued

Table 3. Continued.

Cultural practice	2006 Acreage	2006 % of total	2007 Acreage	2007 % of total	2008 Acreage	2008 % of total
Crop rotations - continued						
Cotton	18,765	1.3	14,850	1.1	9,014	0.6
Corn	27,911	2.0	31,050	2.3	32,885	2.4
Grain sorghum	6,908	0.5	10,800	0.8	8,869	0.6
Wheat	3,700	0.3	21,600	1.2	1,819	0.1
Fallow	25,223	1.8	21,600	1.6	4,459	0.3
Oats	140	<0.1	157	<0.1	0	0.0
Seeding methods						
Drill seeded	1,057,600	75.5	1,031,400	76.4	1,085670	77..9
Broadcast seeded	278,344	19.9	261,900	19.4	276.585	19.8
Water seeded	64,056	4.6	56,700	4.2	31,088	2.2
Irrigation water sources						
Groundwater	1,121,786	80.1	1,084,050	80.3	1.093.675	78.5
Stream, rivers, etc.	128,327	9.9	128,250	9.5	120.585	8.7
Reservoirs	139,887	10.0	137,700	10.2	178.610	12.8
Irrigation methods						
Flood, levees	1,014,984	72.5	928,800	68.8	842,609	60.5
Flood, multiple inlet	378,396	27.0	413,100	30.6	506,864	36.4
Furrow	6,619	0.5	8,100	0.6	43,512	3.1
Sprinkler	0	0.0	0	0.0	0	0.0
Precision leveled soils						
Contour levees	758,240	54.2	738,450	54.7	761,240	54.6
Precision leveled	641,760	45.8	611,550	45.3	631,760	45.1
Zero grade	69,149	4.9	74,250	5.5	134,132	9.6
Stubble management						
Burned	340,400	24.3	313,875	23.3	363,820	26.1
Tilled	375,898	26.8	404,325	30.0	358,348	25.7
Rolled	453,900	32.5	409,725	30.4	551,154	39.6
Winter flooded	300,455	21.5	281,475	20.9	316,776	22.7

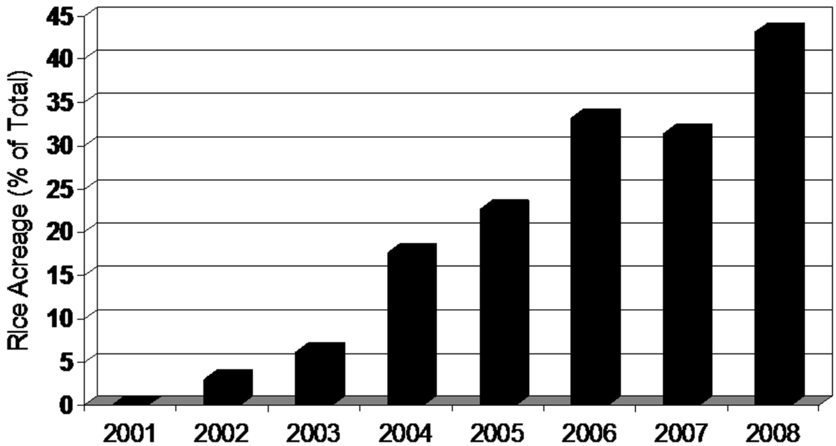

Fig. 1. Percentage of rice planted in Arkansas to Clearfield rice varieties between 2001 and 2008.

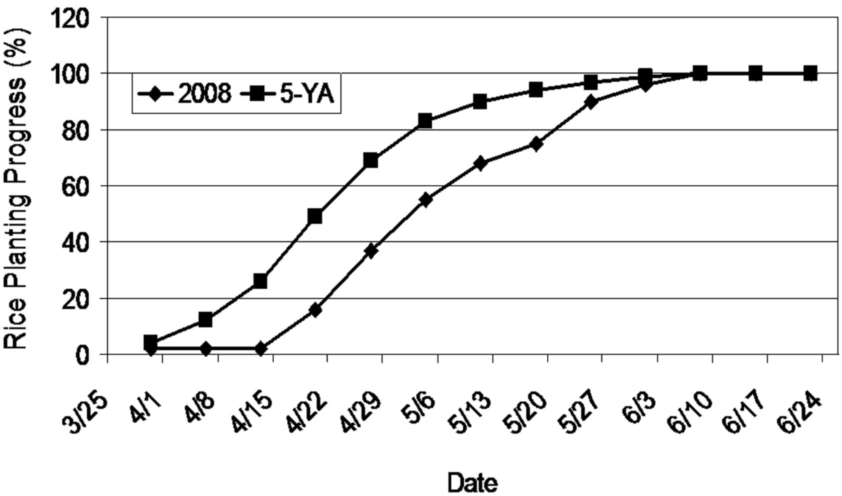

Fig. 2. Arkansas rice planting progress during 2008 compared to the five-year average. (Data obtained from NASS, 2008).

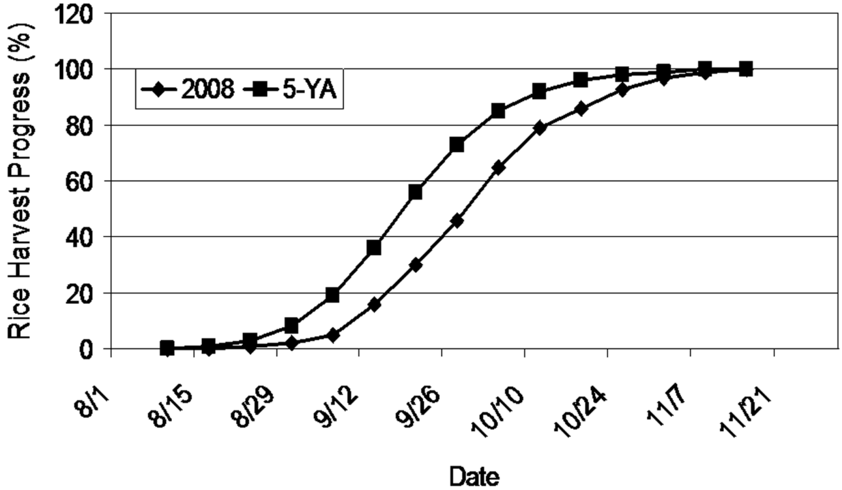

Fig. 3. Rice harvest progress during 2008 compared to the five-year average. (Data obtained from NASS, 2008).

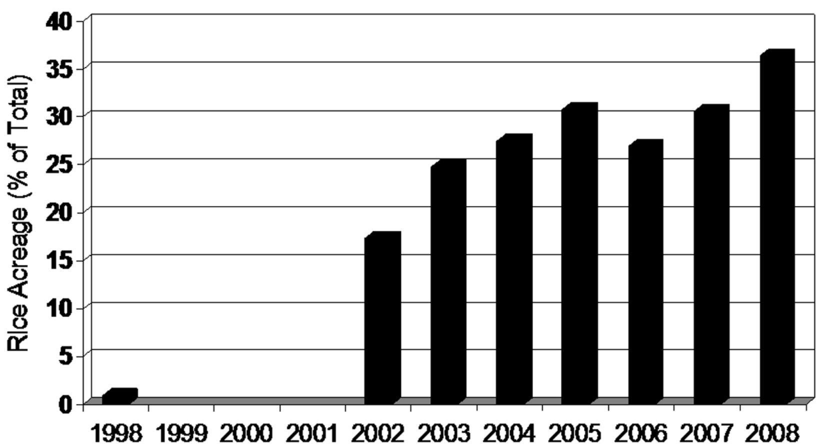

Fig. 4. Adoption of multiple-inlet rice irrigation using poly tubing in Arkansas since 1998.

OVERVIEW AND VERIFICATION

2008 Rice Research Verification Program

S.K. Runsick, R. Mazzanti, C.E. Wilson Jr., J.A. Hignight, and K.B Watkins

ABSTRACT

The 2008 Rice Research Verification Program (RRVP) was conducted on twenty-two commercial rice fields across the state. Counties participating in the program included Arkansas (2 fields), Ashley, Clark, Clay, Craighead, Crittenden, Drew, Jefferson, Lawrence, Lee, Lincoln, Lonoke (2 fields), Mississippi, Poinsett, Pope, Prairie (2 fields), Randolph, St. Francis, and Woodruff for a total of 1,496 acres. Grain yield in the 2008 RRVP averaged 171 bu/acre ranging from 135 to 218 bu/acre. The 2008 RRVP average yield was 23 bu/acre greater than the estimated Arkansas state average of 148 bu/acre. The highest yielding field was in Craighead County with a grain yield of 218 bu/acre. The lowest yielding field was in Mississippi County and produced 135 bu/acre. Milling quality in the RRVP was comparable with milling from the Arkansas Rice Performance Trials and averaged 57/69 (i.e., head rice/total white rice).

INTRODUCTION

In 1983, the Cooperative Extension Service of the University of Arkansas System's Division of Agriculture established an interdisciplinary rice educational program that stresses management intensity and integrated pest management to maximize returns. The purpose of the Rice Research Verification Program (RRVP) was to verify the profitability of Division of Agriculture recommendations in fields with less than optimum yields or returns.

The goals of the RRVP are to: 1) educate producers on the benefits of utilizing University of Arkansas recommendations to improve yields and/or net returns, 2) conduct on-farm field trials to verify research based recommendations, 3) aid researchers in identifying areas of production that require further study, 4) improve or refine existing recommendations which contribute to more profitable production, and 5) incorporate data from RRVP into Extension educational programs at the county and state level. Since 1983, the RRVP has been conducted on 297 commercial rice fields in 33 rice-producing counties in Arkansas. The program has typically averaged about 20 bu/acre better than the state average. This increase in yield over the state average can mainly be attributed to University of Arkansas recommendations which stress intensive cultural management and integrated pest management.

PROCEDURES

The RRVP fields and cooperators were selected prior to the beginning of the growing season. Cooperators agree to pay production expenses, provide expense data, and implement university recommendations in a timely manner from planting to harvest. A designated county agent from each county assists the RRVP coordinator in collecting data, scouting the field, and maintaining regular contact with the producer. Weekly visits by the coordinator and county agents were made to monitor the growth and development of the crop, determine what cultural practices needed to be implemented, and to monitor type and level of weed, disease and insect infestation for possible pesticide applications.

An advisory committee consisting of extension specialists and university researchers with rice responsibility assists in decision-making, development of recommendations, and program direction. Field inspections by committee members were utilized to assist in fine tuning recommendations.

Counties participating in the program during 2008 included Arkansas (2 fields), Ashley, Clark, Clay, Craighead, Crittenden, Drew, Jefferson, Lawrence, Lee, Lincoln, Lonoke (2 fields), Mississippi, Poinsett, Pope, Prairie (2 fields), Randolph, St. Francis and Woodruff. The 22 rice fields enrolled in the program totaled 1,496 acres. Eight varieties were seeded ('Francis', 'Wells', 'CL XL 729', 'CL XL 730' , 'L 723', 'Cocodrie', 'Cybonnet', and 'CL 171') in the 22 fields and University of Arkansas recommendations were used to manage the RRVP fields. Agronomic and pest management decisions were based on field history, soil test results, variety, and data collected from individual fields during the growing season. An integrated pest-management philosophy is utilized based on University of Arkansas recommendations. Data collected included components such as stand density, weed populations, disease infestation levels, insect populations, pesticides applied, temperature, rainfall, irrigation amounts, fertilization utilized, dates for specific growth stages, grain yield, milling yield, and grain quality.

RESULTS

Yield

The average RRVP yield was 171 bu/acre with a range of 135 to 218 bu/acre (Table 1). The RRVP average yield was 23 bu/acre more than the estimated state average yield of 148 bu/acre. This difference has been observed many times since the program began, and can be attributed in part to intensive management practices and utilization of University of Arkansas recommendations. The 2008 RRVP average yield was 20 bu/acre less than the programs highest average yield of 191 bu/acre that was set in 2007. The highest yielding field acheived 218 bu/acre, was seeded with Wells variety, and was located in Craighead County. One additional field, in Drew County, exceeded 200 bu/acre and five fields exceeded 190 bu/acre. The lowest yielding field was the latest planted field, yielded 135 bu/acre, and was seeded with Wells in Mississippi County.

Milling data was recorded on all of the RRVP fields. The average milling yield for the 22 fields was 57/69 (head rice/total white rice) with the highest milling yield of 64/71 measured in Prairie 1 (Table 1). The milling yield of 55/70 is considered the standard used by the rice milling industry. The lowest milling yield was 47/66 and occurred in both the Crittenden and St. Francis county fields of Wells.

Planting and Emergence

Planting began with Lee County on 27 March and ended with Mississippi County planted 22 May (Table 2). The majority of the verification fields were planted in mid to late April. An average of 80 lb/acre was seeded in the RRVP fields. Seeding rates were determined with the Cooperative Extension Service RICESEED program for all fields. An average of 11 days was required for emergence. Stand density ranged from 5 to 35 plants/ft^2, with an average of 20 plants/ft^2. The seeding rates in several fields were higher than average due to planting method and soil texture. Broadcast seeding and clay soils require an elevated seeding rate.

Irrigation

Well water was used to irrigate 18 of the 22 fields in the 2008 RRVP (Table 2). Arkansas 1, Lonoke 2, Pope, and Prairie 2 were irrigated with surface water. Six fields were leveled to zero grade (Craighead, Jefferson, Lawrence, Lonoke 2, Pope, and St. Francis). Ten fields (Arkansas 1, Arkansas 2, Ashley, Clark, Clay, Lee, Lincoln, Lonoke 1, Prairie 2, and Randolph) used multiple inlet (MI) irrigation either by utilizing irrigation tubing or by having multiple risers or water sources. The Clay, Lee, and Randolph fields had 2 wells and 3 risers each. The Lincoln County field had one well with 2 risers. Flow meters were used in 10 of the fields to record water usage throughout the growing season. In fields where flow meters were not utilized, the average of 25 acre-inches for all fields was used.

An average of 25 acre-inches of water was used across all irrigation methods (Table 2). The zero grade fields used the least amount of water for irrigation averaging 22 acre-inches. The field with MI irrigation averaged 25 acre-inches of water, however, many of those fields did not have flow meters and the average was used. Difference in water used was due in part to rainfall amounts which ranged from 4 to 28 inches. Typically, a 25 % reduction in water used has been measured with MI irrigation.

Fertilization

Nitrogen recommendations were based on a combination of factors including soil texture, previous crop, and variety requirements (Table 3). Nitrogen rates can appear high, in some fields where rice was the previous crop and the soil texture was a clay soil texture. These factors increase the nitrogen requirements significantly compared to a silt loam soil where soybean was the previous crop.

Ammonium sulfate (21-0-24) was applied in some fields at the 2- to 3-leaf stage as a management tool to speed height development and shorten the time required to get the rice to flood stage (Table 3). Ammonium sulfate was applied at a rate of 100 lb/acre in Arkansas 1, Clark, Jefferson, and Prairie 2 and at a rate of 50 lb/acre in Lincoln, Lonoke 2, and Woodruff. Ammonium sulfate was blended with the pre-flood urea in Crittenden and Pope counties.

Phosphorus, potassium, and zinc were applied based on soil test results (Table 3). Phosphorus and/or potassium and zinc were applied pre-plant in most of the fields. Phosphorus was applied to Jefferson, Lincoln, Lonoke 2, Pope, St. Francis, and Woodruff in the form of Diammonium phosphate (DAP; 18-46-0). The DAP was blended with pre-flood urea in Pope County and applied during the 2- to 3-leaf stage in the other counties listed. Zinc was applied as a seed treatment in fields with hybrid rice varieties at a rate of one half pound of zinc per sixty pounds of seed. The average cost of fertilizer across all fields was $203.48 (Table 4) which was appreciably more than the $85.10 spent in 2007.

Weed Control

In 2008, the average herbicide cost was $83.14/acre (Table 4). Command was utilized in 16 of the 22 fields for early-season grass control (Table 5). Command was applied early post-emergence as a tank mix with a post-emergence herbicide in Prairie 1 County and provided season long grass weed control. Facet was applied in four fields (Clay, Craighead, Crittenden, and Pope) pre-emergence and in Lee County early post-emergence and provided excellent grass weed control. Facet was used in these fields instead of Command because of either recent land leveling or to aid in the control of hemp sesbania and/or indigo. Three fields (Jefferson, Lonoke 1, and Poinsett) did not utilize a herbicide for pre-emergence weed control. Nine fields, (Arkansas 2, Clark, Drew, Jefferson, Lawrence, Lincoln, Lonoke 1, Poinsett, and Woodruff) were seeded in Clearfield varieties and Newpath was applied for red rice and control of other weeds. The Craighead County field was the only field that did not require a post-emergence herbicide application for grass weed control resulting in the least expensive herbicide program at $37.75/acre. Ashley County had the most expensive weed control program at $161.82/acre (Table 4).

Disease Control

Fungicides were applied to six of the fields in 2008 for control of sheath blight and/or blast (Table 6). The average cost for fungicide was $10.23/acre (Table 4). Disease pressure was mild in the RRVP fields in 2008. Leaf blast lesions were present in the St. Francis County field, however, the producer was able to maintain a deep flood and damage from the disease was very minor. Kernel smut was observed in the Prairie 1 field. Quadris, Quilt, or Stratego were used to control sheath blight and blast and rates were determined based on variety, growth stage, climate, disease incidence/severity, and disease history (Table 6).

Insect Control

The Lee County field required treatment for rice water weevil (Table 6). Ten fields (Clark, Craighead, Lee, Lincoln, Lonoke 1, Pope, Prairie 1, Prairie 2, Randolph, and Woodruff) were treated for rice stink bug. The Craighead County field required two applications of insecticide for control. Rice stink bug levels were well above treatment threshold in the first fields to head. The numbers diminished later in the season. The average cost for insecticides was $7.48/acre compared to $0.62/acre in 2007 (Table 4).

Economic Analysis

This section provides information on the development of estimated production costs for the 2008 RRVP. Records of operations on each field provided the basis for estimating these costs. The field records were compiled by participating county extension faculty, the coordinator of the RRVP, and the producers for each field. Presented in this analysis are specified variable costs, specified ownership costs and total costs for each of the fields. Break-even prices for the various cost components and returns above specified variable expenses at the average 2008 harvest price and adjusted for milling yield are also presented.

Specified variable costs are those expenditures that would generally require annual cash outlays and would be included on an annual operating loan application (Table 4). Actual quantities of all operating inputs were used in this analysis along with input prices collected for use in the Arkansas Cooperative Extension Service 2008 Rice Budgets with updated urea, potash, phosphate, and diesel prices to match spring 2008 input prices.

The producers' actual field operations were used as a basis for calculations and actual equipment sizes and types were matched as closely as possible. Fuel and repair costs were calculated by extension models based on the size or horsepower of the equipment. A diesel price of $4.25/gal was used for 2008 ($2.22 was used for 2007). Therefore, the producers' actual machinery costs may vary from the machinery cost estimates that are presented in this report. Specified variable costs for the 2008 RRVP fields averaged $231/acre more than the 2007 average and ranged from $579/acre for Mississippi County to $818/acre for Woodruff County with an overall acre weighted average of $673/acre (Table 7).

Land costs incurred by producers participating in the RRVP would likely vary from land ownership, cash rent, or some form of crop share arrangement. Therefore, a comparison of these divergent cost structures would contribute little to this analysis. For this reason, a 20% crop share rent was assumed to provide a consistent standard for comparison. This is not meant to imply that this arrangement is normal or that it should be used in place of existing arrangements. It is simply a consistent measure to be used across all RRVP fields. The average break-even price needed to cover specified variable costs including the assumed 20% crop share rent was $4.89/bu, which is $2.17/bu more than the $2.71 price required in 2007. Furthermore, break-even prices to cover variable costs ranged from $3.76/bu in Craighead County up to $6.76/bu in Arkansas 2 (Table 7).

Table 7 includes estimated net returns above specified variable costs and total costs. Net land costs and impacts of milling yields on gross returns are also included. Estimated landowner returns or net land costs were calculated assuming the landowner pays 20% of the drying expenses and all irrigation system fixed costs at $25.22/acre for a typical well or $24.69/acre for a re-lift system. Arkansas 1, Lonoke 2, Pope, and Prairie 2 used a re-lift irrigation system. Costs for risk, overhead, and management were not included.

Crop price was estimated based on a harvest season average price of $7.50/bu, which was a reported total November futures price average minus an estimated basis of $0.90/bu under for the period of 1 September 2008 to 10 October 2008. A premium or discount was given to each farm based upon the milling yield. A standard milling of 55/70 would generate $7.50/bu. Broken rice is assumed to have 70% of whole price value. If milling yield is higher than the standard, a premium is made while a discount will be given for milling less than standard. The 2008 average premium per acre was less than the 2007 premium by $14.15/acre. Estimated prices adjusted for milling yield varied from $6.71/bu in Ashley County to $7.89/bu in Prairie 1, with an average of $7.51/bu.

Returns above variable costs ranged from $84/acre in Arkansas 2 to $687/acre profit in Craighead County. Rice harvest price helped offset the increase in production costs and the decrease in yields when compared to last year. Irrigation costs and land topography were two main factors that increased profitability. The top five fields with the highest returns above variable cost were Craighead, Lonoke 2, Arkansas 1, Pope, and Randolph. Out of the five fields, three were zero grade, one straight levee, and one contour levee. Three of these five fields also had surface irrigation.

DISCUSSION

Field Summaries

The Arkansas 1 field located near Stuttgart, was a 78-acre field with a silt loam soil. The field was planted 15 April with 80 lb/acre of Francis. This was the second RRVP field planted. The seed treatments used were Dermacor, Trilex, Release, and Allegiance. Even with cool temperatures, this field grew quickly with vigor and to a uniform stand that averaged 28 plants/ft^2. The major weed problems included sprangletop, broadleaf signalgrass, eclipta, and yellow nutsedge. Command was applied early then followed by 3 qt/acre of Duet, 1oz/acre of Aim, and 0.25 oz/acre of Permit. The post emergence herbicides did a good job killing any escaped weeds. Red rice was scattered across the field. Sheath blight showed up late but never reached treatment level. The field yielded an impressive 193 bu/acre.

It's always disheartening to see a field look so good yet produce a low yield. The Arkansas 2 field was located near Dewitt. The field was a 140-acre silty clay loam seeded on 5 May with 90 lb/acre of CL 171. Chicken litter was applied at a rate of 1.5 tons/acre. Three hundred pounds of 0-18-36 was applied according to soil test recommendations. Dermacor was used as a seed treatment with a 30 foot strip through the field left untreated. The field had a history of grape colaspis, yet, it grew exceptionally well with great vigor and was uniform. The herbicides, Command and Riceshot, did a good job early but dayflower was a persistent weed problem. The two applications of Newpath and Permit two weeks apart resulted in good weed control. Blazer was applied mid-season for coffeebean. Pre-flood urea was applied at 225 lb/acre followed by 80 lb/acre at mid-season. The field looked absolutely great. Sheath blight reached treatment level and Quadris was applied at 12.5 oz/acre. The 30-foot untreated check of Dermacor showed no difference when compared to the treated area of the field. The field yielded a disappointing 140 bu/acre which can be contributed to late planting of the variety CL 171.

The field in Ashley County was located in the Overflow National Wildlife Refuge. The field of heavy clay soil was seeded in Cocodrie at a rate of 105 lb/acre. Stand counts indicated a plant population of 22 plants/ft^2. The levees were seeded late and were a challenge to keep weed-free. Command was applied followed by Propanil and Aim. Barnyardgrass persisted so RiceStar was applied at a rate of 22 oz/acre. The producer had trouble keeping a flood on the field and grass weed control was difficult. Clincher was applied at 15 oz/acre but did not provide good control. Barnyardgrass and nutsedge were prevalent at the end of the season. Hurricane Gustav and Ike caused considerable lodging in the field. The field yielded 141 bu/acre.

The Clark County field was seeded 5 June with CL 171 AR at 70 lb/acre. There was a thin stand around the south edge and west side of field. The planting date along with the thin stand was a concern all year. Glyphosate and Command were applied early followed by two sequential post applications of Newpath. Stratego and Karate were applied for sheath blight and stink bugs, respectively. The 142 bu/acre yield can be contributed to the late planting of CL 171.

Clay County was a 120 acre field of Francis. In 2007, half of the field was planted in corn, the other half was soybeans. The field was seeded with 85 lb/acre on 30 April. Command and Facet was applied preemergence and provided excellent grass weed control. You may notice the total nitrogen applied to this field was 191 lb/acre which is more than normally is recommended. The producer has been applying 100 lb of urea/acre at the 2- to 3-leaf stage ahead of a rain or a flush and feels like this helps to increase yield. There are benefits to applying nitrogen at this stage. However, in research, a yield response is not observed. I asked the producer to split the field and apply urea to half and leave the other half untreated. When the application was made, the entire field was fertilized by mistake. The field made a respectable 191 bu/acre and I would argue that the same yield would have been achieved without the early nitrogen application.

The Craighead County field was the second field planted on 7 April and was the highest yielding field in the program with 218 bu/acre. The field was broadcast seeded with Wells, with a plane, at a rate of 150 lb seed/acre. The field came up to a very uniform stand with 28 plants/ft^2 on 20 April. The stand was much more uniform than the field seeded last year with a truck. This field was ahead of the DD50 all season due to excellent growing conditions and above normal temperatures early. This field was recently leveled to zero grade and this was its first rice crop. Facet and Prowl was applied pre-emerge and provided excellent grass weed control. No additional herbicides were needed. The field was the first rice field to head in this area and reached treatment threshold for rice stink bug early. After treatment, the stink bug level exceeded the threshold again, so another application of insecticide was applied. This field was also the most profitable field in the program as the expenses were low.

Crittenden County was one of the lowest yielding fields in the program this year. The field had been recently leveled. Part of this field was sandy and had been in cotton production in past years. Sulfur deficiency symptoms were present in this sandy area of the field. The other part was a clay soil texture and produced the better rice. The cut and fill areas were easily distinguishable as the crop progressed. The seeding rate was too high in this field and it looked like every seed came up; the stand was 35 plants/ft^2. Facet injury was observed in some areas, but was not severe. The hurricanes caused considerable loss from shattering and lodging. Ammonium sulfate was applied twice at a rate of 50 lb/acre blended with the pre-flood and mid-season urea. Potassium and zinc fertilizer was applied according to the soil test recommendations. The producer did an excellent job of managing the flood. The field was free of weeds and disease. The crop appeared to have average yield potential and produced 138 bu/acre. With a little luck, it should be much better next year. The first crop after a field is leveled is usually the worst.

Drew County was seeded with CL XL 729 at a rate of 53 lb/acre on 13 April. Glyphosate, Command, and Permit were applied after planting. Newpath and Strata were applied at the 3- to 5-leaf stage for barnyardgrass and coffeebean control. Aim and Blazer were applied for broadleaves on the levees and for escaped coffeebean in the patties. Due to the limited availability of the herbicides Newpath and Beyond, the second application was not made. The rice was past 0.5-inch internode elongation before the product became available. No red rice was observed in the field. Fertilizer, 100 lb/acre of 0-15-30, was applied according to soil test recommendations. Two hundred pounds per acre of urea was applied preflood followed by 70 lb/acre at the late boot stage. This field looked good all year. Pumping costs were relatively low as rainfall amounts totaled 18 inches. The field was harvested prior to the hurricanes. This was one of the reasons it was the highest yielding field in the program in south Arkansas. The field yielded 215 bu/acre.

The Jefferson County field was a zero grade, 59-acre field that never dried up due to frequent spring rains and flooding. The field was water-seeded on 24 April with 30 lb/acre of CL XL 730. After peg down the field was treated like a drilled-seeded field. The first application of Newpath was applied and the field turned completely brown. Stand counts went from 7 to 9 plants/ft^2 to 5 to 6 plants/ft^2. The field was allowed to dry up for control of rice water weevil. Ammonia sulfate was flown in at a rate of 100 lb/acre and flushed in. The field greened up and looked good with the exception of a few thin spots. The second application of Newpath and Permit did a good job controlling weeds. Herbicide cost for the field were $36/acre. There was increased pumping due to only 4 inches of rainfall all season. All the fertilizer was applied at the rate specified by soil test recommendations. Hurricane Gustav and Ike came in just before harvest and delayed harvest about 1 week. There were 5 bu/acre on the ground before the combine went through and 12 bu/acre on the ground afterwards. The 59-acre RRVP field yielded a respectable 183 bu/acre and turned out to be the best yielding hybrid field on the 1,700 acre farm with the least expense.

The Lawrence County field stayed wet and was planted late. The field was zero graded, a clay soil type, and rice was the previous crop. It was finally planted, still wet, on 12 May. The drill rows did not close well and it took a long time to get a stand. The final stand count was 5 plants/ft^2. There were several holes and thin spots in the field, but by the end of the season it filled in fairly well. It was too late to consider re-planting. The field was seeded in CL XL 729 at 30 lb/acre. Two applications of Newpath were applied and the second application had Grandstand and Propanil for control of Indigo. A few weeds came up late in the thin spots where no rice was in competition, but really did not amount to much. The field yielded 165 bu/acre. This field will be in the program again next year. It has much better yield potential and weather allowing, should be much better next year.

The first field planted was Lee County on 27 March. The field was seeded with Francis at a rate of 120 lb/acre. The field was 135 acres of silty clay loam soil that had deep cuts from leveling through the middle section. Top Choice (pelletized litter) was applied to the cut areas of the field. This field had a history of grape colaspis and water weevil. Mustang Max was applied behind the planter, while later in season Karate was used for water weevil control. Although this field had many levees, it irrigated fined. Glyphosate and Prowl applied preemergence followed by Facet and Command applied early postemergence provided excellent grass weed control. Permit was applied for nutsedge control. The fertility program was 200 lb/acre of 0-24-24 plus 10 lb/acre of zinc followed by 235 lb/acre of urea plus Agrotain at pre-flood, followed by 100 lb/acre of urea at mid season. Even though a high rate of seed was planted, there were thin spots all through the field; mainly in the cut areas. Stratego and Karate were applied for sheath blight and stink bug control, respectively. The field yielded 164 bu/acre.

The Lincoln County field was 140 acres of heavy clay soil. The field was seeded on 22 April with 60 lb/acre of CL XL 729 Blend. Command provided early season grass weed control. The Newpath and Strada went out about 7 days late waiting on the wind to die down. The tank mix did a good job cleaning up grasses, northern jointvetch, and coffeebean. Later an application of Blazer was required for coffeebean. Mustang Max was applied for stink bugs. The fertilizer applied was 100 lb/acre DAP plus 50 lb/acre of ammonium sulfate flushed in. Two hundred pounds per acre of urea was applied pre-flood followed by 70 lb/acre during the late boot stage. The field looked great all year and yielded 177 bu/acre.

Knowing the production history problems of the farm in Lonoke 1 County, this year's yield of 189 bu/acre was excellent. The field was seeded in CL XL 730 which was the major contributing factor to the increased yield. Everything went just as planned with no problems. It was a little dry when the first Newpath application was applied. The larger broadleaf signalgrass was stunted, but did not die. The second application finished it off. The field was sprayed with Karate for rice stink bugs.

This was the second year for the Lonoke County 2 field. The field was a 20-acre, zero-grade field with a clay soil. Francis was the variety of choice seeded at 100 lb/acre. Stand counts averaged 26 plants/ft^2. Glyphosate and Command were applied early for burn down and pre-emergence grass control. The rice struggled to grow because of cool nighttime temperatures so ammonium sulfate and DAP were applied at a rate of 50 lb/acre of each. Urea was applied pre-flood at a rate of 250 lb/acre followed by 100 lb/acre at mid-season. Post applications of Riceshot, Grasp, and Permit were applied to clean up the weeds in the field. Stratego was used for sheath blight control. The field yielded a respectable 190 bu/acre compared to the previous year of 167 bu/acre of CL XL 730.

The Mississippi County field was the last field planted on 22 May. This alone was a major factor for the decreased yield. The other was the pre-flood urea error. In this area, farmers usually wait to pull the levees until just prior to flood so that all the herbicide and fertilizer applications can be made by ground. This year, it rained 1.5 inches after the urea was applied, before the levees were constructed. It took over 2 weeks to get the permanent flood established resulting in a loss of nitrogen. The delayed flood also caused another herbicide application. First Shot was added to the Glyphosate burndown for control of smartweed and provided excellent control. Propanil was applied with the urea application mainly for broadleaf weeds and some small barnyardgrass. Clincher was applied post flood to control the next flush of barnyardgrass. Blazer was applied mid-season for hemp sesbania control. The field never turned yellow, yet, the rice was visibly thin and stunted. The mid-season application of urea was applied early (at green ring). The late planted field yielded 135 bu/acre.

The field in Poinsett County was leveled last fall. It stayed flooded all spring and was finally planted on 18 May. Early in the season, the field stayed clean except for indigo. Grandstand and Propanil was added to the Newpath for control. Red rice was present following the second application of Newpath. The red rice appeared to be stunted but did not die. Amazon sprangletop was also scattered across the field. Raptor was applied post flood because Beyond was not available. The red rice escaped this application as well. The plants were tested for resistance and the results indicated they were resistant to Newpath. Part of the field was rouged; however red rice was present at harvest. The field yielded 155 bu/acre.

This year's Pope County RRVP field was in the same field as last year with the same variety (i.e., XL723). The main difference was the field was planted a month later than last year and had to be re-planted due to a poor stand. The zero grade clay field stayed wet. This area of the state received more than 28 inches of rainfall during the season. The weather made things difficult this year. Command and Facet was applied pre-emergence. Command was added for sprangletop control. The preemergence herbicide lost control before the permanent flood was established. The flood was delayed waiting on the field to dry out enough to apply the urea. RiceStar was used for grass control followed by Grandstand and Permit for control of hemp sesbania and nutsedge. The field also had some red rice. Despite all the problems from the weather, the field still made a respectable 198 bu/acre.

The post emergence application of Propanil and Command worked well again this year in Prairie 1 County. An application of 2, 4-D with Aim was made to the entire field at mid-season for control of cutleaf ground cherry on the levees. Nothing out of the ordinary occurred here and everything went as planned. No fungicide was needed even though Cybonnet is usually very susceptible to sheath blight. The yield was 163 bu/acre, which is good for this variety. Cybonnet was chosen here because of its blast resistance and excellent milling quality. This was the best milling variety in the program this year and added $63.00/acre premium.

The Prairie 2 field was 86 acres and was seeded 4 April with 95 lb/acre of Cocodrie. Stand counts taken indicated a stand of 26 plants/ft^2. The field grew well until grape colaspis started to slow progression and thin the stand in some areas. The decision was made to apply ammonium sulfate and urea at a rate of 50 lb/acre and that seemed to help growth. Duet and Permit were applied and did a good job controlling grasses and broadleaves. Super Wham and Facet were sprayed on about 20 acres on the west side of the field to control some escaped grass. Red rice came on strong in spots and was scattered throughout the field. A Quilt and Quadris tank mix was applied for sheath blight and Karate was added to control stink bugs. This field cut an impressive 185 bu/acre.

Streaking from the pre-flood nitrogen application in the Randolph County field resulted in at least a 10 bu/acre yield decrease. An equipment problem with the spreader truck resulted in a poor distribution of the urea. Once the problem was noticed, an additional 100 lb urea/acre was applied post flood. It is difficult to make up the difference once the field has been flooded but there was not much of an option. Duet and Permit were used for post-emergence weed control. The field was relatively weed-free following the Command application. The main weed problem was yellow nutsedge with some scattered broadleaf signalgrass. The field did reach treatment level for rice stink bug and was treated with an insecticide. The yield was still very good with 189 bu/acre.

The St. Francis County field also stayed wet all spring and was planted late. This field is the same zero grade field as last year. Wells was broadcast-seeded with an airplane on 6 May. The rice came up to a good stand with 23 plants/ft^2. Glyphosate and Command were applied early followed by Propanil and Permit just prior to flood. Some leaf blast was present. A deep flood was maintained and very little damage from the disease occurred. No fungicide was applied as the field never reached treatment level for sheath blight. The field yielded 164 bu/acre. Some lodging did occur from wind, but was not severe. Late planting and environmental conditions were the main reasons for the decrease in yield from last year.

The Woodruff County field was seeded with CL XL 729. It was planted early and harvested before the hurricanes. It made an excellent yield (190 bu/acre). Everything went as planned in this field. Two applications of Newpath were applied. Duet was added to aid in control of broadleaf weeds. This field also had to be treated with an insecticide for stink bugs.

On-Farm Research

Research was conducted in four of the verification fields in 2008. Disease monitoring tests were planted in Lincoln, Pope, and Randolph Counties. A Dermacor Seed Treatment test for control of grape colaspis was established in Arkansas 2 County. The field has a history of grape colaspis. However no damage was observed this year in either the treated or untreated areas of the field.

SIGNIFICANCE OF FINDINGS

Data collected from the 2008 RRVP reflect the general trend of increasing rice yields and above average returns in the 2008 growing season. Analysis of this data showed that the average yield was higher in the RRVP compared to the state average and the cost of production was equal to or less than the Cooperative Extension Service-estimated rice production costs.

ACKNOWLEDGMENTS

We appreciate the cooperation of all participating rice producers and thank all Arkansas rice growers for financial support through the rice check-off funds administered by the Arkansas Rice Research and Promotion Board. We appreciate the cooperation of all participating county extension agents. We also thank the professors, specialists and program associates of the Agriculture Experiment Station and Cooperative Extension Service and the district administration for their support.

Table 1. Variety, soil series, previous crop, acreage, grain yield, milling yield, and harvest moisture for the 2007 Rice Research Verification Program by county.

County	Variety	Soil series	Previous crop	Acres	Grain yield	Milling yield[z]	Harvest moisture
					(bu/acre)		(%)
Arkansas 1	Francis	Stuttgart Silt Loam	Soybean	78	193	59/68	13.8
Arkansas 2	CL 171	Dewitt Silt Loam	Soybean	139	140	60/68	20.8
Ashley	Cocodrie	Perry Clay	Soybean	50	140	53/61	17.5
Clark	CL 171	Gurdon Silt Loam	Soybean	59	142	55/69	19.6
Craighead	Wells	Roellen Clay Loam	Fallow	12	218	61/70	20.5
Crittenden	Wells	Dundee Silt Loam	Fallow	88	138	47/66	18.0
Drew	CL XL 729	Portland Clay	Soybean	42	215	50/66	19.8
Jefferson	CL XL 730	Perry Clay	Rice	59	183	52/69	18.0
Lawrence	CL XL 729	Calloway Silt Loam	Rice	25	165	52/66	20.0
Lee	Francis	Loring Silt Loam	Soybean	135	164	63/71	19.0
Lincoln	CL XL 729	Perry Clay	Soybean	138	177	63/71	19.6
Lonoke 1	CL XL 730	Calloway Silt Loam	Soybean	34	189	61/71	17.0
Lonoke 2	Francis	Herbert Silt Loam	Rice	20	190	61/70	17.0
Mississippi	Wells	Sharkey Silty Clay	Soybean	36	135	53/67	20.8
Poinsett	CL XL 729	Sharkey Clay	Soybean	77	155	53/69	21.4
Pope	XL 723	Roellen Clay	Rice	40	198	51/70	17.5
Prairie 1	Cybonnet	Calloway Silt Loam	Soybean	54	163	64/71	17.6
Prairie 2	Cocodrie	Calhoun Silt Loam	Soybean	86	185	63/70	17.0
Randolph	XL 723	Dundee Silt Loam	Soybean	146	189	60/71	15.0
St. Francis	Wells	Dundee Silt Loam	Rice	28	164	47/66	20.0
Woodruff	CL XL 729	Grubbs Silt Loam	Soybean	30	190	55/69	21.0
Average				68	171	57/69	18.7

[z] Head rice / total white rice.

Table 2. Stand density, irrigation, seeding rate, and important dates in the 2008 Rice Research Verification Program season by county.

County	Stand density	Rainfall	Irrigation[z]	Rainfall + Irrigation	Seeding rate	Planting date	Emergence date	Harvest date
	(plants/ft^2)	(inches)	(acre in.)	(inches)	(lb/acre)			
Arkansas 1	28	12	25	37	80	15 Apr	26 Apr	8 Sep
Arkansas 2	34	12	25	37	90	5 May	19 May	18 Sep
Ashley	22	14	25	39	105	25 Apr	5 May	9 Sep
Clark	22	22	25	47	70	6 May	22 May	9 Sep
Clay	22	10	25	35	85	30 Apr	11 May	23 Sep
Craighead	28	11	24	35	150	7 Apr	20 Apr	1 Sep
Crittenden	35	12	25	37	120	17 Apr	27 Apr	17 Sep
Drew	24	18	25	43	53	13 Apr	23 Apr	5 Sep
Jefferson	8	4	22	26	30	24 Apr	9 May	5 Sep
Lawrence	5	12	22	34	30	12 May	22 May	4 Oct
Lee	26	21	25	46	120	27 Mar	10 Apr	11 Sep
Lincoln	20	9	19	28	60	22 Apr	3 May	8 Sep
Lonoke 1	12	22	29	51	30	29 Apr	9 May	19 Sep
Lonoke 2	26	19	21	40	100	21 Apr	2 May	12 Sep
Mississippi	28	10	25	35	115	22 May	27 May	26 Sep
Poinsett	7	10	16	26	28	18 May	24 May	24 Sep
Pope	7	28	10	38	58	20 May	25 May	8 Oct
Prairie 1	23	12	30	42	90	14 Apr	24 Apr	30 Aug
Prairie 2	26	8	25	33	90	23 Apr	4 May	16 Sep
Randolph	7	14	31	45	38	13 May	18 May	1 Oct
St. Francis	23	10	34	44	180	6 May	15 May	23 Sep
Woodruff	7	11	35	46	28	14 Apr	28 Apr	31 Aug
Average	20	14	25	37	80			

[z] The average of 25 acre-inches was used for fields not utilizing flow meters.

Table 3. Soil test results from 2007 Rice Research Verification Program fields and fertility recommendations.

County	pH	Soil test[z] P	K	Zn	Split application rates of urea (45%)[y]	Total-N rate	Preplant fertility N-P-K-Zn[x]
		(lb/acre)					
Arkansas 1	5.8	29	170	11.9	200-100-0	156	21-53-60-0-24[w]
Arkansas 2	5.5	34	136	6.3	225-80-0	137	0-54-108-0
Ashley	5.8	58	1000	9.8	275-100-0	169	0-0-0-0
Clark	5.7	29	122	2.8	200-111-0	161	21-0-0-0-24[w]
Clay	7.2	55	146	13.8	225-100-0	191	45-50-90-0
Craighead	6.0	96	438	14.4	250-100-0	158	0-60-120-0
Crittenden	5.3	72	185	3.5	248-123-0	167	0-0-60-1
Drew	5.2	34	787	5.4	200-0-70	122	0-15-30-.44
Jefferson	7.0	55	606	8.0	250-0-75	185	39-46-0-.25-24[w]
Lawrence	6.1	38	210	16.0	275-0-70	155	0-40-80-.25
Lee	7.1	68	200	6.7	235-100-0	151	0-48-48-10
Lincoln	6.9	47	575	5.9	200-0-70	150	28-46-0-..23-12[w]
Lonoke 1	5.6	30	186	4.0	200-0-70	122	0-50-60-.25
Lonoke 2	6.8	73	588	5.0	250-100-0	177	19-23-0-0-12[w]
Mississippi	7.0	104	697	15.7	300-100-0	180	0-0-0-0
Poinsett	7.4	60	247	13.4	225-0-100	146	0-50-60-1.23
Pope	5.5	54	542	8.0	272-0-70	154	0-46-0-10.48
Prairie 1	6.2	59	164	12.7	230-100-0	149	0-40-90-0
Prairie 2	6.8	22	103	20.9	125-150-0	168	44-60-120-0-24[w]
Randolph	5.8	62	159	9.0	200-100-0	135	0-0-0-0
St. Francis	5.6	61	312	8.6	250-100-0	175	18-46-0-0
Woodruff	6.4	60	462	4.2	225-0-70	153	19-23-90-.23-12[w]

[z] P= phosphorus, K=potassium, and Zn=zinc.

[y] Preflood-midseason-boot.

[x] N-P_2O_5-K_2O-Zn includes seed treatments.

[w] Ammonium sulfate was applied to 2- to 3-leaf rice and the field flush-irrigated.

Table 4. Selected variable input expenses from 2007 Rice Research Verification Program fields by county.[z]

County	Variety	Seed[y]	Fertilizer[x]	Herbicides[x]	Fungicides[x]	Insecticides[x]	Fuel[w]	Irrigation[v]
		[Input cost ($)/acre]						
Arkansas 1	Francis	48.69	215.94	47.52	0.00	0.00	44.09	71.24
Arkansas 2	CL171	74.47	243.75	105.32	31.63	0.00	41.88	125.27
Ashley	Cocodrie	22.05	137.81	161.82	0.00	0.00	25.90	124.52
Clark	CL171	41.87	150.03	83.19	24.46	11.71	35.42	124.52
Clay	Francis	19.74	259.41	50.10	19.69	11.16	36.22	114.12
Craighead	Wells	56.63	252.97	37.75	0.00	23.42	19.67	108.84
Crittenden	Wells	27.09	205.95	91.30	0.00	0.00	34.57	114.12
Drew	CLXL729	99.14	164.11	121.33	0.00	0.00	34.33	114.12
Jefferson	CLXL730	104.03	199.41	52.22	0.00	0.00	15.04	99.77
Lawrence	C XL729	112.00	316.41	59.12	0.00	0.00	21.70	99.77
Lee	Francis	27.09	181.31	118.85	27.78	29.31	41.89	114.87
Lincoln	CLXL729	113.68	166.00	102.66	0.00	11.16	34.33	86.91
Lonoke 1	CLXL730	107.00	183.26	55.28	0.00	11.16	41.38	141.14
Lonoke 2	Francis	47.40	167.10	117.05	24.46	0.00	19.24	60.25
Mississippi	Wells	24.15	147.00	114.79	0.00	0.00	44.03	114.87
Poinsett	CLXL729	109.53	244.80	84.79	0.00	0.00	25.68	74.67
Pope	XL723	150.80	192.71	79.87	0.00	0.00	33.77	40.29
Prairie 1	Cybonnet	33.86	212.72	56.92	0.00	12.06	43.99	135.28
Prairie 2	Cocodrie	21.84	266.10	55.01	33.34	4.41	44.72	70.49
Randolph	XL723	98.80	170.75	54.32	0.00	11.16	28.87	139.07
St. Francis	Wells	51.06	181.18	69.50	0.00	0.00	25.71	156.90
Woodruff	XL729	113.41	196.61	96.79	0.00	11.18	49.34	163.84
Weighted Average 2008[u]		65.83	203.48	83.14	10.23	7.48	35.34	108.78
Weighted Average 2007[t]		48.20	85.10	58.38	8.45	0.62	19.96	69.72
Change[s]		17.63	118.38	24.75	1.79	6.85	15.38	39.07

[z] Does not include all variable costs, such as drying, hauling, equipment repair, etc.
[y] Includes seed cost and treatments.
[x] Includes the cost of material and application for each input.
[w] Fuel for tractors, combines, and self-propelled equipment ($4.25/gal).
[v] Includes irrigation labor, irrigation supplies (levee gates & poly-pipe), irrigation repair and maintenance, and diesel fuel ($4.25/gal).
[u] Weighted by acres.
[t] Average costs from 2007 RRVP Fields using 2007 costs of production.
[s] Change in average costs from 2007 to 2008.

Table 5. Herbicide rates and timings for 2008 Rice Research Verification Program fields by county.[z]

Arkansas 1	**PRE[y]:** Command (12.8 oz) **POST[x]:** Duet (3 qt), Aim (1 oz), Permit (0.25 oz)
Arkansas 2	**PRE:** Command (12.8 oz) **POST:** Propanil (2 qt) fb Newpath (4 oz) Permit (0.5 oz) Aim (0.5 oz) fb Newpath (4 oz) Permit (0.5 oz)
Ashley	**PRE:** Command (25.6 oz) **POST:** Propanil (4 qt) Aim (1.0 oz) fb RiceStar (22 oz) Permit (1.0 oz) fb Clincher (15 oz) fb Blazer (10.6 oz)
Clark	**PRE:** Glyphosate (2 pt) Command (12.8 oz) **POST:** Newpath (4 oz) Aim (1.0 oz) fb Newpath (4 oz)
Clay	**PRE:** Quinstar (0.33 lb) Command (12.8 oz) **POST:** Strada (1.75 oz) Permit (0.25 oz) Propanil (2 qt)
Craighead	**PRE:** Facet (0.5 lb) Prowl (2.0 pt)
Crittenden	**PRE:** Facet (0.5 lb) Prowl (2.4 pt) **POST:** Rice Pro (3 qt) Permit (0.5 oz)
Drew	**PRE:** Glyphosate (2 pt) Permit (0.75 oz) Command (21 oz) **POST:** Newpath (4 oz) Strada (2 oz) fb Blazer (10.6 oz) Aim (0.5 oz)
Jefferson	**POST:** Newpath (4 oz) fb Newpath (4 oz) Permit (0.5 oz)
Lawrence	**PRE:** Glyphosate (2 pt) **POST:** Newpath (4 oz) fb Newpath (4 oz) Grandstand (0.67 pt) Propanil (2 qt)
Lee	**PRE:** Glyphosate (2 pt) Harmony (0.25 oz) fb Glyphosate (1 qt) Prowl (2.4 pt) **POST:** Facet (0.375 lb) Command (12.8 oz) fb Permit (0.5 oz)
Lincoln	**PRE:** Command (25.6 oz) **POST:** Newpath (4 oz) Strada (2 oz) fb Newpath (4 oz) fb Blazer (10.6 oz)
Lonoke 1	**POST:** Newpath (4 oz) fb Newpath (4 oz) fb 2,4-D (1.5 pt)
Lonoke 2	**PRE:** Glyphosate (1 qt) 2,4-D (1 qt) fb Glyphosate (1 qt) Command (16 oz) **POST:** Propanil (4 qt) Permit (0.6 oz) Grasp (2 oz)
Mississippi	**PRE:** Glyphosate (2 qt) First Shot (0.08 oz) Command (24 oz) **POST:** Propanil (4 qt) fb Clincher (15 oz) fb Blazer (0.5 pt)
Poinsett	**POST:** Newpath (4 oz) fb Newpath (4 oz) Grandstand (0.67 pt) Propanil (2 qt) fb Raptor (5 oz)
Pope	**PRE:** Glyphosate (1.5 pt) fb Command (12.8 oz) Quinstar (0.25 lb) **POST:** RiceStar (17 oz) fb Grandstand (0.67 pt) Permit (0.5 oz)
Prairie 1	**PRE:** Glyphosate (1.5 pt) **POST:** Command (12.8 oz) Propanil (3 qt) fb 2,4-D (8 oz) Aim (1 oz)
Prairie 2	**PRE:** Command (12.8 oz) **POST:** Duet (3 qt) Permit (.33 oz) (Super Wham (4 qt) Facet (0.25 lb) on 20 acres)
Randolph	**PRE:** Glyphosate (1 qt) Command (8 oz)) **POST:** Duet (4 qt) Permit (0.25 oz)
St. Francis	**PRE:** Glyphosate (2 pt) Command (16 0z) **POST:** Propanil (4 qt) Permit (0.67 oz)
Woodruff	**PRE:** Command (8 oz) fb Newpath (4 oz) **POST:** Newpath (4 oz) Duet (3 qt) fb Grandstand (0.5 pt) Propanil (2 pt)

[z] All rates are on a per-acre basis.
[y] PRE=pre-emergence.
[x] POST=post-emergence.

Table 6. Fungicide and insecticide applications in 2008 Rice Research Verification Program fields by county.

County	Sheath blight	Blast	Rice water weevil	Rice stink bug
Arkansas 1	-----	------	------	------
Arkansas 2	Quadris (12.5 oz)	------	------	------
Ashley	------	-----	------	------
Clark	Stratego (16 oz)	------	------	Karate (1.8 oz)
Clay	Quadris (6.5 oz)	------	------	------
Craighead	------	------	------	Karate (3.6 oz)
Crittenden	-----	------	------	------
Drew	------	------	------	------
Jefferson	------	------	------	------
Lawrence	------	------	------	------
Lee	Stratego (19 oz)	------	Karate (1.8 oz)	Karate (1.8 oz)
Lincoln	------	------	------	Mustang Max (3.2 oz)
Lonoke 1	-----	-----	-----	Karate (1.6 oz)
Lonoke 2	Stratego (16 oz)	-----	-----	-----
Mississippi	-----	-----	-----	-----
Poinsett	-----	-----	-----	-----
Pope	-----	-----	-----	Karate (1.6 oz)
Prairie 1	-----	-----	-----	Mustang Max (3.2)
Prairie 2	Quilt (14 oz) Quadris (7 oz)	-----	-----	Karate (1.6 oz)
Randolph	-----	-----	-----	Karate (1.6 oz)
St. Francis	-----	-----	-----	-----
Woodruff	-----	-----	-----	Mustang Max (2.6 oz)

Table 7. Economic analysis of fields from 2007 RRVP by county.

County	Yield	Milling yield	Crop price[z]	Specified variable costs[y]	Specified ownership costs[x]	Land costs[w]	Return above variable costs	Return above total costs	BEP[u] to equal variable costs	BEP to equal total costs	Milling yield premium or discount[v]
	(bu/acre)		($/bu)	($/acre)					($/bu)		($/acre)
Arkansas 1	193	59/68	7.48	602	60	247	569	509	3.79	4.20	-4.42
Arkansas 2	140	60/68	7.51	771	55	171	84	30	6.76	7.28	1.61
Ashley	141	53/61	6.71	599	37	150	172	135	5.19	5.55	-111.40
Clark	142	55/69	7.42	603	46	172	254	208	5.18	5.63	-11.38
Clay	191	60/68	7.51	693	50	244	473	423	4.42	4.77	2.19
Craighead	218	61/70	7.71	676	31	291	687	657	3.76	3.96	44.93
Crittenden	138	47/66	6.90	609	47	152	168	121	5.39	5.85	-82.17
Drew	215	50/66	7.01	716	45	257	509	463	4.05	4.34	-105.86
Jefferson	183	52/69	7.32	619	24	226	469	445	4.11	4.30	-33.52
Lawrence	165	52/66	7.08	759	32	193	190	158	5.63	5.91	-69.90
Lee	164	63/71	7.85	697	54	217	349	295	5.19	5.64	58.22
Lincoln	177	63/71	7.85	676	45	237	452	406	4.66	5.01	62.83
Lonoke 1	189	61/71	7.79	715	55	251	480	426	4.61	5.00	54.11
Lonoke 2	190	61/70	7.71	590	31	252	598	567	3.77	3.99	39.16
Mississippi	135	53/67	7.19	579	55	155	211	156	5.24	5.78	-41.73
Poinsett	155	53/69	7.35	684	39	189	241	202	5.41	5.74	-23.07
Pope	198	51/70	7.36	668	50	251	514	464	4.12	4.45	-27.20
Prairie 1	163	64/71	7.89	655	56	216	391	334	4.89	5.36	63.46
Prairie 2	185	63/70	7.77	664	55	246	503	448	4.37	4.77	50.84
Randolph	189	60/71	7.75	678	43	250	513	470	4.36	4.68	47.61
St. Francis	164	47/66	6.90	625	36	184	298	262	4.63	4.95	-97.65
Woodruff	190	55/69	7.42	818	62	238	330	268	5.25	5.69	-15.23
Weighted average 2008	171	57/69	7.51	673	48	216	371	323	4.89	5.27	3.60

continued

Table 7. Continued.

County	Yield	Milling yield	Crop price[z]	Specified variable costs[y]	Specified ownership costs[x]	Land costs[w]	Return above variable costs	Return above total costs	BEP[u] to equal variable costs	BEP to equal total costs	Milling yield premium or discount[v]
	(bu/acre)		($/bu)	----------------	----------------	($/acre)	----------------	----------------	----------($/bu)	---------	($/acre)
Weighted average											
2007	191	58/72	4.66	442	52	161	304	252	2.71	3.07	17.74
Change[u]	-20	---	2.85	231	-5	55	67	72	2.17	2.21	-14.15

[z] Based upon premium or discount above $7.50/bu with a standard milling of 55/70.
[y] Includes all variable expenses for production, drying, hauling, checkoff fee, interest, etc.
[x] Excludes ownership expenses of irrigation well, which are assumed to be paid by the landlord.
[w] BEP = break-even price.
[v] Impact of milling on gross returns. (Gross returns with milling yields – gross returns at standard milling, i.e. 55/70).

EMERGING TRENDS

Overview of the Carbon Credit Trading System and the Potential for Agricultural Soil Carbon Sequestration Associated with Arkansas Rice Production

K.R. Brye

ABSTRACT

Enhanced environmental concern over rising concentrations of greenhouse gases, particularly carbon dioxide (CO_2), in the atmosphere has sparked a nationwide drive to develop a system by which agricultural producers can accumulate carbon (C) credits for the C that they store in the soil of the fields they crop using conservation tillage practices, particularly no-tillage. These accumulated C credits could ultimately be sold on an exchange market known as the Chicago Climate Exchange (CCX), an electronic trading system similar to the NASDAQ stock exchange market, to entities, such as large industries to offset their CO_2 emissions. Though eastern Arkansas soils are grouped together with soils from upper-mid-western states, such as Iowa, northern Missouri, Illinois, and Ohio, for which a uniform, standardized soil C sequestration rate has been applied by the CCX, theoretical and direct evidence exists to suggest that the expected, but still conservative, soil C sequestration rate is greater than the currently assigned standardized rate. Even under the current CCX guidelines, important societal, ecological, and potentially significant economic benefits can be realized.

ISSUE

Over the last century or so, the Earth's atmosphere has been experiencing two critical trends. First, greenhouse gas (GHG) concentrations have been increasing. A GHG, such as carbon dioxide (CO_2), methane (CH_4), ozone (O_3), nitrous oxides (NO_x), and water (H_2O), tends to absorb radiant heat energy and traps it within the Earth's atmosphere before that heat energy escapes into space. Second, as a consequence of increasing GHG concentrations, the Earth's atmosphere has warmed between 0.5 and 1.7°F throughout the past century (USEPA, 2006). Therefore, the composition of the Earth's atmosphere has been changing at an accelerated rate, exacerbating the greenhouse effect and global warming, due, at least in part, to certain human activities, namely the burning of fossil fuels (IPCC, 2001; USEPA, 2006). However, land-use change and cultivated agriculture are two additional mechanisms that are greatly affecting Earth's atmosphere.

EMISSIONS REDUCTION SYSTEM

There is a necessary global effort underway to reduce GHG emissions into the atmosphere. A cap-and-trade system has been conceived and developed for reducing GHG emissions. The recent establishment of climate exchange markets, such as the European Climate Exchange (ECX, 2009), the Montreal Climate Exchange (MCeX, 2009), and the Chicago Climate Exchange (CCX, 2009c), have made it possible to assemble a pool of credits generated by conducting certain practices for a particular length of time that entities that emit large quantities of GHGs can purchase to help offset their emissions and achieve their mandated reductions. In particular, the Chicago Climate Exchange (CCX) is the first, and presently only, trading system that is actively working to reduce emissions of the suite of GHGs (i.e., CO_2, CH_4, O_3, and NO_x; CCX, 2008). The CCX, which began trading in 2003, is a voluntary system, but is also legally binding through contracts established for eligible offset projects (CCX, 2008).

Offset projects for which contracts can be issued include agricultural, coal mine, and landfill methane, agricultural and rangeland soil carbon (C) management, forestry, renewable energy, and ozone-depleting substance destruction (CCX, 2009b). All eligible and enrolled projects are subject to third-party verification to ensure proper determination of enrolled acres and compliance with specified management practices (CCX, 2009b).

General Agricultural Soil Carbon Sequestration

In the case of agricultural soil C, it is known that certain land management practices, particularly conservation tillage (Reicosky, 1997; Brye et al., 2006) and grassland restoration (Potter et al., 1999), will result in a net input of C to the soil over time through reduced CO_2 emissions to the atmosphere that occur from soil respiration, which is the combination of respiration from plant roots and soil microorganisms. Therefore, the CCX offers contracts of a minimum 5-yr duration for agricultural soil C offsets for continuous conservation tillage and grassland plantings (CCX, 2008). As defined by the CCX, conservation tillage includes no-tillage, strip-tillage, or ridge-tillage, all of which must result in a minimum of two-thirds of the soil surface undisturbed and a minimum of two-thirds of the residue remaining on the soil surface (CCX, 2008). Though only infrequently conducted likely due to perceived management challenges, continuous conservation tillage contributes to improved soil and water quality, decreases on-farm fuel consumption and GHG emissions from implements, and will likely improve agricultural producers' ability to withstand climatic fluctuations (CCX, 2007).

To accomplish the minimal required soil surface disturbance and surface residue coverage, there are some necessary implement limitations that project owners must observe. Eligible implements to use to conduct conservation tillage include, but are not limited to, no-till drills, no-till and strip-till planters, and rolling harrows (CCX, 2004). Implements considered to be ineligible to use to conduct conservation tillage include, but are not limited to, field cultivators, tandem disk, offset disk, chisel plow, and moldboard plow (CCX, 2004). If the soil requires a leveling or smoothing following a particular field activity (i.e., smoothing out ruts left from a combine at rice harvest), it would likely result in too much soil surface disturbance and therefore be ineligible as an acceptable conservation tillage practice (CCX, 2004). Fields simply left as fallow for a period of time are also considered ineligible (CCX, 2004). Crop rotations, such as continuous cotton (*Gossypium hirsutum*) and continuos soybean [*Glycine max* (L.) Merrill], are eligible to earn C credits, but only if a winter cover crop is also grown (CCX, 2004). In addition, removing surface residue (i.e., by burning or baling) would also negate any C credits accrued for that year (CCX, 2004).

Continuous conservation tillage and/or maintenance of grassland plantings are assigned a standardized rate of CO_2 storage (i.e., sequestration) per acre per year depending on geographic location (CCX, 2009a). Standardized, regional soil C sequestration rates were set based on solicited input from experts and a Technical Advisory Committee and are meant to represent a conservative, mean sequestration rate that would be expected across a large number of enrolled acres over the 5-yr contract period (CCX, 2007). An offset aggregator serves in an administrative capacity on behalf of project owners to oversee and facilitate registration and selling of offsets (i.e., credits; CCX, 2009d) and is typically used when projects involve < 10,000 metric tons of CO_2 equivalent per year (CCX, 2009b). However, presently, there are no registered offset aggregators in Arkansas for potential project owners to go through to enter the trading system. Prices for C credits have ranged from less than $1 to greater than $5 per metric ton (i.e., one megagram), but prices fluctuate according to market conditions (CCX, 2008). Participation in the voluntary program ceases when a project owner (i.e., individual land owner or land manager) fails to conform to the practices specified in their CCX contract (CCX, 2008). Enrolled participants have no contractual obligation to continue conservation tillage practices after their contract ends, but there is scientific evidence documenting continued soil C sequestration beyond 30 years after the adoption of low- or no-tillage practices (CCX, 2007).

Agricultural Soil Carbon Sequestration in Eastern Arkansas

The rice (*Oryza sativa* L.)-producing counties of eastern Arkansas are grouped into what is referred to as Zone A (CCX, 2004). Zone A states and counties have been assigned the standardized soil C sequestration rate of 0.6 metric tons or megagrams (Mg) of CO_2/acre/year (CCX, 2009a), which is equivalent to 0.18 Mg C/acre/year or 0.445

Mg C/ha/year. Zone A also includes far eastern South Dakota, Kansas, and Nebraska; southern Minnesota; northern Missouri; south-eastern Texas; northern and south-eastern Louisiana; southern Michigan; most of Ohio, Pennsylvania, and New Jersey; northern Florida; and all of Iowa, Illinois, Indiana, Maryland, Delaware, Kentucky, Tennessee, West Virginia, Virginia, North Carolina, South Carolina, Mississippi, Alabama, and Georgia. In other words, there is a substantially large area in the eastern United States that had been assigned a uniform standardized soil C sequestration rate. However, it is known that soil C sequestration varies according to numerous climatic, soil, and agronomic factors, particularly the size of the soil organic carbon (SOC) pool, where low-SOC soils typically have greater soil C sequestration rates than high-SOC soils (VandenBygaart et al., 2003) because there is simply a greater storage capacity with initially low SOC before maximum or equilibrium SOC storage is achieved. Therefore, it is possible that the common soils of the Mississippi River Delta region and other areas throughout the southern United States (i.e., Alfisols and Ultisols) have greater expected soil C sequestration rates than upper-mid-western soils (i.e., Alfisols and Mollisols) due to the generally lower soil organic matter (SOM) and SOC contents from the long history of cultivated agriculture and the relatively warm and wet climate that favors the decomposition and turnover of SOM.

Based on direct observations across a 48-year chronosequence of silty-clay soils cropped to continuous no-tillage rice in east-central Arkansas (see article by Brye "*Soil Carbon Sequestration in a Silty Clay Cropped to Continuous No-Tillage Rice*" in this publication), the soil C sequestration rate is approximately 0.24 ton C/acre/year (0.54 Mg C/ha/year) in the top 8 inches (20 cm) of the soil profile alone compared to the standardized rate of 0.20 ton C/acre/year (0.445 Mg C/ha/year) for the entire soil profile that is uniformly applied to all states and/or counties in Zone A. Considering the rooting depth for rice is much deeper than 20 cm, the true root-zone or whole-profile soil C sequestration rate is likely much greater than the standardized rate that is applied to eastern Arkansas soils, which appears to be too conservative. Aside from the size of the SOC pool and tillage, soil C sequestration also depends on other soil and agronomic factors such as soil texture (Ihori et al., 1995; Brye and Kucharik, 2003), land use or agricultural management system (i.e., crop rotation; West and Post, 2002) and time (i.e., consistent duration of current landuse or agricultural management system; Potter et al., 1999; Brye and Kucharik, 2003; Post et al., 2004).

Furthermore, the extended duration of nearly saturated to saturated soil conditions that accompany rice production during much of the growing season, and, in some instances, for much of the over-winter period, slows soil respiration, hence the oxidation (i.e., decomposition) of SOM is also slowed and soil surface CO_2 emissions to the atmosphere are decreased during periods of nearly saturated to complete soil saturation. Therefore, though little data presently exists, C sequestration in soils cropped with flood-irrigated rice in the rotation may likely be greater than that in soils under non-rice-containing rotations common to eastern Arkansas, such as the wheat (*Triticum aestivum* L.)-soybean double-crop production system among others.

Potential Economic Impact for Rice Producers in Eastern Arkansas

Under the current system guidelines, acceptable offset projects and C credit trading offer numerous social, ecological, and economic benefits, including the direct benefits of a reward for farming sustainably, improved environmental quality, and a new, potentially significant, on-farm income source (CCX, 2008). For example, using the planted rice acreage in Arkansas in 2008 (1.35 million acres; NASS, 2009) and making the following assumptions: i) approximately 10 % of the rice acreage in Arkansas is currently farmed using no-tillage practices (135,000 acres; Wilson and Runsick, 2008); ii) 0.6 metric tons of CO_2/acre/year can be sequestered in the soil using conservation practices such as no-tillage (81,000 metric tons CO_2 or 81,000 C credits; CCX, 2008); and iii) C credits could ultimately be sold through the Chicago Climate Exchange for around $4/credit - it is estimated that rice producers in Arkansas currently farming using no-tillage practices could earn in total approximately $324,000/year, or approximately $2.40/acre/year, by simply selling the C credits for the management practices they are already employing. Over a 5-yr period, the duration of a typical contract, C credits could earn Arkansas rice producers in total approximately $1,620,000 for simply selling the C credits built up from soil/crop management practices they are already employing for their rice production. These estimates of extra income for C credits would increase accordingly if the amount of land area under continuous conservation and/or no-tillage practices for rice production increased or the price per C credit increased. Some economic analysts project that selling C credits may be a way for agricultural producers to earn enough additional income to pay for property taxes.

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Soil Carbon Sequestration in a Silty Clay Cropped to Continuous No-Tillage Rice

K.R. Brye

ABSTRACT

Through the appropriate avenues, carbon (C) credits, generated from the sequestration of agricultural soil C as a result of continuous conservation tillage, can be sold in the United States through the Chicago Climate Exchange (CCX). Selling C credits from agricultural management practices that land owners are already conducting represents a potentially significant extra income source in addition to the ecological and environmental benefits soil C sequestration provides. A study was conducted in a silty-clay soil in east-central Arkansas to ascertain the soil C sequestration rate associate with continuous no-tillage (NT) rice (*Oryza sativa* L.) production. Based on soil samples collected from a chronosequence of four fields that have been managed under continuous NT rice for 1 to 48 years, the soil C sequestration rate for the top 8 in (top 20 cm) of the soil profile was 0.24 tons C/acre/year. This observed soil C sequestration rate for the top 8 in alone is greater than the whole-soil C sequestration rate assigned by the CCX to counties in eastern Arkansas. Soils in the southern and mid-southern United States may likely be able to sequester C in the soil at rates greater than those observed in the upper mid-west due to lower initial soil organic C pools.

INTRODUCTION

With the advent of the Chicago Climate Exchange (CCX; CCX, 2009), carbon (C) credits, which can be accrued by the agricultural community through the use of continuous conservation-tillage practices, can be bought and sold in a stock-exchange-like market to offset carbon dioxide (CO_2) emissions to the atmosphere from large companies and utilities. Thus, C credits can represent an added economic incentive to producers to continue with or convert to more environmentally friendly and sustainable agricultural management practices. However, more scientific data exist for observed soil C sequestration (i.e., the removal of CO_2 from the atmosphere and subsequent storage in the soil) rates in upper-mid-western states, where the climate is generally cool and wet, than exist in southern and mid-southern states, where the climate is generally warm and wet. The regional climatic differences are important because soil organic matter tends to be decomposed and oxidized by soil microorganisms at a greater rate in warm/wet as compared to cool/wet environments. Consequently, soil surface CO_2 fluxes (i.e., CO_2 emissions to the atmosphere) are also generally greater in warm/wet as compared to cool/wet environments, which, when coupled with the long history of cultivation of eastern Arkansas soils for row-crop production, has resulted in many soils with low soil organic matter and soil C contents.

Considering C sequestration potential is generally recognized as being greater for soils with an initially low organic C pool (VandenBygaart et al., 2003), mid-southern soils, particularly those of the Mississippi River Delta region in eastern Arkansas, may have a greater potential for C sequestration than the organic-matter-rich, upper-mid-western soils due to the generally lower soil organic matter and organic C contents present in warm/wet environments. Since a potentially significant economic incentive exists from selling C credits on a climate exchange market, it is essential to ascertain an appropriate range of expected soil C sequestration rates for mid-southern soils, particularly those soils that are cropped with a large biomass-producing crop like rice (*Oryza sativa* L.), so that agricultural producers can maximize economic benefits for employing more-sustainable, conservation-tillage practices. Therefore, the objective of this study was to evaluate soil C sequestration using a chronosequence of silty-clay fields cropped to continuous no-tillage rice in east-central Arkansas. It was hypothesized that soil C sequestration rates in the Mississippi River Delta soils of eastern Arkansas that are cropped with rice using conservation-tillage practices will be greater than the standardized rate assigned to eastern Arkansas by the CCX.

PROCEDURES

Site Description

A series of four fields were targeted for study within a 1.7-mile radius of each other in Lonoke County, north of Humnoke, that have been cropped to continuous no-tillage (NT) rice for 1, 7, 26, and 48 years, respectively, at the time of soil sampling. All four fields are mapped as Perry silty clay (very-fine, smectitic, thermic Chromic Epiaquert; Fielder et al., 1981; USDA-NRCS, 2009). However, all four fields were also substantially disturbed by land leveling to a zero grade prior to initiating continuous NT rice.

Typical annual field management has consisted of direct water-seeding of rice at planting followed by burning of the rice straw, or rolling in some instances, after rice harvest. Each field is also typically flooded over winter for waterfowl. Fields are generally dry (i.e., without a flood) for less than three months per year (i.e., August through mid-October).

Soil Sampling and Analyses

In early September 2007, soil core samples were collected from each of the four fields at 15-m intervals along a 60-m line transect from the 0- to 4- and 4- to 8-in. (0- to 10- and 10- to 20-cm, respectively) depth intervals. Soil samples were collected with a stainless steel core chamber, beveled to the outside to minimize compaction, 1.9 in. (4.8 cm) in diameter using a manually driven slide hammer. Soil samples were subsequently oven-dried at 70°C for 72 hrs, weighed for bulk density determinations, and crushed and sieved through a 0.08-in. (2 mm) mesh screen for total C analysis by high-temperature combustion. Measured total C concentrations were converted to contents using the measured soil bulk density and the 4-in. sampling interval and expressed in tons (T)/acre.

Statistical Analyses

Due to the limited number of fields of varying duration of continuous NT rice that could be included in this study, simple linear regression was used to characterize total soil C content over time (i.e., across the four fields, where each field represented a different duration in continuous NT rice) and to facilitate soil C sequestration rate determinations in the 0- to 4-, 4- to 8-, and the combined 0- to 8-in. depth intervals. Statistical analyses were conducted using Minitab (version 13.31, Minitab Inc., State College, Penn.). Also due to the limited number of fields that could be included in this study, time trends were judged to be significant at $P \leq 0.15$.

RESULTS AND DISCUSSION

As expected, C was sequestered in the soil from continuous NT rice management. Based on soil samples collected from the chronosequence of four silty-clay fields in Lonoke County that have been managed under continuous NT rice for 1 to 48 years, soil C has increased over time (Fig. 1). Soil C has been sequestered at a rate of 0.165 T/acre/year in the top 4 in. (top 10 cm), but at a rate less than half that (0.075 T/acre/year) in the 4- to 8-in. (10- to 20-cm) depth interval (Fig. 1). These results indicate that soil C contents and sequestration rates likely exponentially decrease with depth despite the Perry silty clay being a Vertisol that tends to invert or mix itself over time due to the high percentage of shrink-swell clays that cause the formation of cracks at the soil surface for extended periods of time when dry. When depth intervals are combined, soil C has been sequestered at a rate of 0.24 T/acre/year in the top 8 in. (top 20 cm; Fig. 1). However, much additional data will be required to better ascertain soil C sequestration rates that would be expected in eastern Arkansas among differing soil depths, soil textures, crop rotations that include rice at some frequency, and the various possible conservation tillage practices that could practically be used in rice production.

SIGNIFICANCE OF FINDINGS

Though managing post-harvest rice straw by burning would not be an allowable practice according to a CCX continuous-conservation-tillage contract, the observed soil C sequestration rate of 0.24 T/acre/year (i.e., 0.54 Mg C/ha/year) in the top 8 in. (top 20 cm) of the soil profile alone is 20 % greater than the standardized sequestration rate (0.20 T/acre/year or 0.445 Mg C/ha/year) assigned by the CCX to the entire soil profile for counties in eastern Arkansas (CCX, 2008). If continuous NT is managed properly, including refraining from residue burning, expected whole-soil C sequestration rates for fine-textured Vertisols cropped to rice in the Mississippi River Delta region of eastern Arkansas will likely exceed the standardized sequestration rate assigned for continuous conservation tillage practices in eastern Arkansas. Greater soil C sequestration should translate into greater accrued C credits and ultimately greater economic returns for eastern Arkansas producers selling agricultural soil C offsets through the climate exchange market. However, before this can happen, a registered offset aggregator must be established in Arkansas to assist in the process of enrolling, verifying, and finalizing continuous-conservation-tillage contracts for project owners (i.e., individual land owners or land managers).

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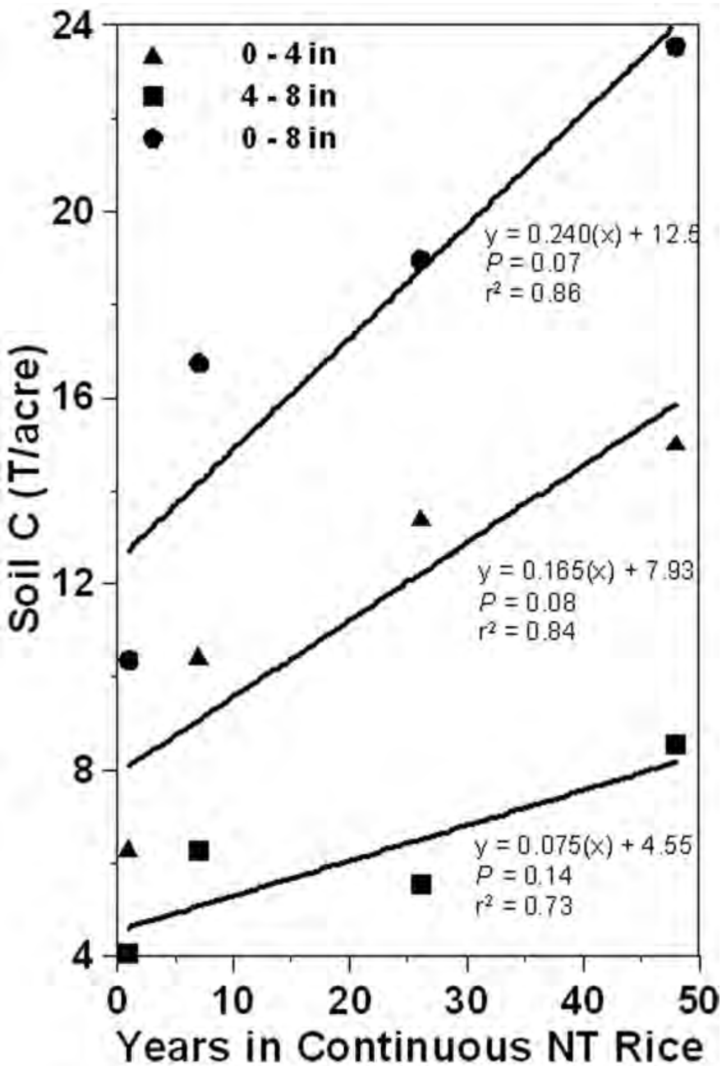

Fig. 1. Relationship between total soil carbon (C) and years in continuous no-tillage (NT) rice for the 0- to 4-, 4- to 8-, and 0- to 8-in. depth intervals using a chronosequence of silty-clay fields in Lonoke County. The slope coefficient in each regression equation represents the soil C sequestration rate in T/acre/year for the respective soil depth interval.

BREEDING, GENETICS, AND PHYSIOLOGY

Challenges of Marker-Assisted Selection of Quantitative Trait Loci Introgression from *O. rufipogon*

V.A. Boyett, J. You, and K.A.K. Moldenhauer

ABSTRACT

Efforts to introgress Quantitative Trait Loci (QTLs) from *Oryza rufipogon* that enhance yield were evaluated using DNA marker technology. A segregating population of 2,700 individuals from an *O. rufipogon*/'Wells' cross was first screened with a marker for red pericarp, then selected progeny were screened with peak markers for yield QTLs *yld1.1*,*yld2.1*, *yld3.2*, *yld6.1*, *yld8.1*, and *yld9.1* on chromosomes 1, 2, 3, 6, 8, and 9, respectively. Selections from that analysis were further screened with flanking markers to the QTL to determine if the entire region of the QTL was introgressed. Progeny that showed potential for containing the yield QTLs were used as breeding material in a backcross scheme and as female parents in crosses with other improved germplasm.

INTRODUCTION

Since modern cultivars that comprise the southern U.S. rice collection have a narrow genetic base and can be traced to only 22 plant introductions (Dilday 1990), there has been significant effort to increase genetic diversity which increases the chances for finding genetic material useful for improving important agronomic traits. This effort includes the use of wild relatives of domesticated rice as a source of genes useful for rice improvement by recapturing desirable traits that were lost during the domestication process (Eizenga et al., 2006).

O. rufipogon is a wild relative of cultivated rice with a red pericarp encoded by the dominant *Rc* gene. It shares the AA genome with cultivated rice and can be hybridized through crossing. It is genetically very close to cultivated rice and gives fertile F_1 offspring when crossed with both *indica* and *japonica* cultivars. It is phenotypically inferior to cultivated rice for many important agronomic traits, however, QTLs derived from *O. rufipogon* can contribute positively to the performance of elite cultivars of domesticated rice (Xiao et al., 1998; McCouch et al., 2007).

The objectives of this study are to use DNA markers linked to yield QTLs derived from *O. rufipogon* to (I) identify the F_2 progeny of *O. rufipogon*/Wells that are homozygous for white pericarp, (ii) identify the resulting selections that have the *O. rufipogon* allele at the yield QTLs, and (iii) identify the selections to use as parents in a marker-assisted backcross program.

PROCEDURES

Greenhouse generated seedling leaf tissue was harvested into manila coin envelopes and stored at -80°C until sampled. Sampling was performed with a single hole-punch, and total genomic DNA was extracted using Sodium hydroxide/Tween 20 and neutralized with 100mM Tris-HCl, 2 mM EDTA (Xin et al., 2003). Each sample was arrayed in a 96-well format and 2 µl of template used for each 25 µl PCR analysis.

F_2 seedlings were screened in three groups of 900 with the INDEL marker RID12 linked to pericarp color. The phenotypic red allele is 166 nt. The white pericarp phenotype is the result of a 14 nt deletion, so the white allele is 152 nt. Since the *Rc* gene that encodes the protein conditioning red pericarp in rice is dominant, only those samples which were homozygous for the 152 nt allele were selected. After the selections, the screening with the RID12 marker was repeated for confirmation.

Selected plants were then screened with the SSR peak markers RM5, RM6165, RM1373, RM3, RM210, and RM215 for QTLs *yld1.1*,*yld2.1*, *yld3.2*, *yld6.1*, *yld8.1*, and *yld9.1*, respectively. Those plants that amplified the *O. rufipogon* allele at those loci were selected and further screened with the flanking markers to the QTLs (Table 1).

PCR was performed with either HEX, FAM, or NED labeled primers by adding template and enough bovine serum albumin and polyvinylpyrrolidone 40 to have final concentrations of 0.1% and 1% respectively (Xin et al., 2003) and cycling the reactions in a Mastercycler Gradient S thermalcycler (Eppendorf North America, Inc., Westbury, N.Y.). Resulting PCR products were grouped according to allele sizes and dye colors and diluted together with a epMotion 5070 liquid handling robot (Eppendorf North America, Inc., Westbury, N.Y.), separated on an Applied Biosystems 3730 DNA Analyzer, and analyzed using GeneMapper Software (Applied Biosystems, Foster City, Calif.).

RESULTS AND DISCUSSION

Although 573 plants were advanced to the QTL peak marker screening, entries were dropped from marker analysis if something adverse happened to the plant, resulting in approximately 370 plants being screened with the peak markers (Tables 1 and 2). Analysis with the yield QTL peak markers was as expected with the exception of RM6165, the peak marker for *yld2.1*. The *O. rufipogon* allele was null and the region containing the peak marker was homologous to the *O. rufipogon* parent, as there was no Wells allele amplified in the population (Table 2). Finding alternative markers in this region of the genome is problematic. Another primer sequence listed for RM6165 (AUT13347) amplified poorly, and the region has many monomorphic markers between Wells and this accession of *O. rufipogon*. In a cross between 9311 X *O. rufipogon*, Liang et al. used markers that are mapped close to the yld2.1 region, RMs 208 and 166, for marker-assisted selection. RM208 is a robust marker, so it was included as a potential peak marker for this population (Liang et al., 2004). Due to the differences in genetic background between 9311 and Wells, and the different accessions of *O. rufipogon*, it is unknown if this marker will be reliable for this population.

Although RM210 has been named the peak marker for *yld8.1* in some genetic backgrounds (Thompson et al., 2003), RM25 was named as the peak marker for *yld8.1* in an *O. rufipogon* test cross population and RM210 was identified instead as the peak marker for *yld8.2* (Xiao et al., 1998), so RM25 was also included as a potential peak marker for *yld8.1* (Table 2).

Since it is currently possible to screen for only five of the yield QTLs in this population, plants were selected on the basis of the data for the five peak markers for *yld1.1*, *yld3.2*, *yld6.1*, *yld8.1*, and *yld9.1*. None of the entries were homozygous for the *O. rufipogon* allele at all five loci, but nine plants were at four loci, 31 plants were at both three and zero loci. The largest group of plants with homozygous *O. rufipogon* alleles was 74 at only one locus, followed closely by 72 plants at two loci (Table 3).

With the goal of introgressing all the QTLs with positive effects on yield , plants were selected to be used in further crossing that had the desired allele at two or more loci and had a robust plant type. *Yld1.1* has been shown to have a negative effect on yield (Marri et al., 2005; Xiao et al., 1998) so those plants with the Wells allele at RM5 were kept, and the plants with the *O. rufipogon* allele at the other loci were kept. Based on this analysis, a core group of 42 plants was advanced to the flanking marker analysis to determine if the entire region of the QTL or only part of it was introgressed. A preliminary screening with the flanking markers, however, revealed several monomorphic markers, necessitating a search for new markers for *yld2.1*, *yld8.1*, and *yld9.1* (Table 4).

SIGNIFICANCE OF FINDINGS

This parental accession of *O. rufipogon* was used because it is very easy to make successful crosses with cultivated rice. It has been extensively characterized on a molecular level using markers spanning the entire genome. The molecular data suggests that this accession of *O. rufipogon* has probably lost a trait common to most accessions of *O. rufipogon*–the ability to readily outcross. This *O. rufipogon* appears to be partially domesticated as it is homozygous at numerous loci, far more so than other "wilder" accessions (Jia, pers. comm.). It is possible that this is the reason why the markers that have been used in other programs in analyzing *O. rufipogon* x cultivated rice crosses are monomorphic and not informative with this *O. rufipogon* x Wells population. Another possibility is that the high-yielding Wells already contains *O. rufipogon* homologous regions, particularly the area of *yld2.1*, and these regions may be contributing to Wells' yield trait.

Informative markers need to be found not only to fill in the regions where currently there is no marker data, but also to characterize other parts of the genome as well. This work will be necessary to determine exactly what regions of the genome are responsible for yields and what molecular markers are associated with the yield trait.

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Table 1. Results from analysis with the RID12 marker for pericarp color on 2,441 F2 individuals, or 90% of the population planted. Only those individuals with the homozygous white genotype were kept for further analysis with QTL markers.

RID12 Marker	Homozygous Wells (White)	Homozygous *O. rufipogon*	Heterozygotes	Total
Group 1	395	427	842	1,664
Group 2	178	164	435	777
Total	573	591	1,277	2,441
	23%	24%	52%	

Table 2. Results from analysis with the peak markers linked to the yield QTLs. With the exception of *yld1.1*, which has been shown to have a negative effect, the plants with the *O. rufipogon* allele were selected for further analysis with the QTL flanking markers.Totals reflect successful amplifications with a given marker. RMs 208 and 25 were not in the original marker list.

QTL	Peak marker	Homozygous Wells alleles	Homozygous *O. rufipogon* alleles	Hetero-zygotes	Total
yld1.1	RM5	67	114	150	331
		20%	34%	45%	
yld2.1	RM6165	0	Null	0	N/A
		0	100%	0	
yld2.1[z]	RM208	47	42	86	175
		27%	24%	49%	
yld3.2	RM1373	82	115	164	361
		23%	32%	45%	
yld6.1	RM3	74	104	183	361
		20%	29%	51%	
yld8.1	RM210	87	91	138	316
		28%	29%	44%	
yld8.1[y]	RM25	57	42	79	178
		32%	24%	44%	
yld9.1	RM215	66	113	173	352
		19%	32%	49%	

[z] RM208 was used as an alternative peak marker for *yld2.1* after the failure of RM6165 (Liang et al., 2005). It is unknown if the marker is reliable for this population.

[y] RM25 was identified as the peak marker for *yld8.1* and RM210 for *yld8.2* (Xiao et al., 1998).

Table 3. Number of individuals with homozygous *O. rufipogon* alleles at multiple loci resulting from analysis with yield QTL peak markers.

5 Loci	4 Loci	3 Loci	2 Loci	1 Locus	0	Total
0	9	31	72	74	31	217
0%	4%	14%	33%	34%	14%	

Table 4. Marker characterization resulting from multiple amplifications. Mono refers to a monomorphic marker.

Yield QTL	Effect	Chromosome	Position	Alleles-bp Marker	Wells/Rufi
			Left Flank	RM1196	184/172
yld1.1	-	1	Peak	RM5	114/106
			Right Flank	RM306	142/172
yld2.1	+	2	Left Flank	RM3284	174/164
			Peak	RM6165	171/Null
			Peak	AUT13347	171/?
			Peak	RM208	164/174
			Right Flank	RM13452	150-Mono
yld3.2	+	3	Left Flank	RM130	80/72
			Peak	RM1373	137/121
			Right Flank	RM85	78/87
yld6.1	+	6	Left Flank	RM3183	139/120
			Peak	RM3	119/125
			Right Flank	RM20071	88/85
yld8.1	+	8	Left Flank	RM6193	N/A
			Peak	RM210	141/145
			Right Flank	RM307	Chrom. 4
			Right Flank	RM6976	116-Mono
			Right Flank	RM8043	N/A
yld9.1	+	9	Left Flank	RM107	297/290
			Peak	RM215	151/144
			Right Flank	RM6643	94-Mono

Development of Semidwarf Long- and Medium-Grain Cultivars

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ABSTRACT

Semidwarf rice cultivars contribute to the continued success of Arkansas rice production. Experimental semidwarf lines are in all stages of development from segregating populations to breeder head rows. New sources of yield, disease, and stress resistance are being used as parents in the breeding program, and new techniques such as molecular aided selection are utilized to efficiently identify disease and quality genes in segregating populations. Lines with diverse genetic origins exhibit high yields, good disease and stress tolerance, and acceptable grain quality under Arkansas growing conditions. Continued exchange and utilization of new germplasm is valuable to Arkansas rice improvement.

INTRODUCTION

Since the release of ‘Lemont’ in the mid 1980’s, semidwarf rice cultivars have been grown in Arkansas. ‘Cocodrie’ and ‘Bengal’ are long- and medium-grain semidwarfs that have occupied a large proportion of the rice area. These cultivars continue to be the base for semidwarf cultivar development in Arkansas. Recently, the first semidwarf long- and medium-grain cultivars ’Cybonnet’ and ‘Medark’ were released by the Arkansas Experiment Station (Gibbons et al., 2006).

Lee et al. (1998) have characterized several recently introduced USDA germplasm accessions as tolerant to both rice sheath blight and blast. Most of these introductions belong to the indica subtribe of cultivated rice. Indicas have been suggested as sources for yield potential and disease resistance for domestic breeding programs (Eizenga, et al., 2006). Our objective is to develop genetically diverse semidwarf long- and medium-grain cultivars that are high yielding with excellent grain, milling and processing quality that tolerate the common stresses and pests found in Arkansas rice fields.

PROCEDURES

Potential parents for the breeding program are evaluated for the desired objectives. Cross combinations are programmed that combine desired characteristics to fulfill the breeding objectives. Use of parents of diverse genetic backgrounds is emphasized. Segregating populations are planted at Stuttgart and the winter nursery at Lajas, Puerto Rico. Selection is based on grain and plant type, spikelet fertility, field and greenhouse disease reaction, and grain quality. Yield evaluations include the preliminary yield trial (PYT) and the Stuttgart Initial Test (SIT) at two locations, Rice Research and Extension Center (RREC) at Stuttgart, Ark., and the Southeast Research and Extension Center, Rohwer Division (SEREC) at Rohwer, Ark., the Arkansas Rice Performance Trials (ARPT) at six locations in the state including two locations in producers fields and the Uniform Regional Rice nursery (URRN) conducted in cooperation with rice breeding programs in Texas, Louisiana, Missouri, and Mississippi. As in the past few years, the preliminary yield trial and SIT also were planted at the Pine Tree Branch Experiment Station, Colt, Ark., under high natural disease pressure using blast "spreader rows".

RESULTS AND DISCUSSION

About 367 cross combinations were made in 2008. Emphasis was placed on triple crosses with parents selected for tolerance to straighthead disorder, blast and panicle blight disease as well as yield and grain quality. Over 1,150 F_1 single plants from triple crosses were selected in 2008 and will be space planted at Stuttgart in 2009 (Table 1). Over 2,180 F_2 single plants were selected during the year. Several of these crosses were programmed with cold tolerant parents and, as in preceding years, the populations were exposed to cool temperatures in the field. Panicles from these plants were sent to the winter nursery for generation advancement. Due to late harvest of the space plants only one generation will be advanced at the winter nursery this year. Plants with known sources of blast genes *Pi-ta*, *Pi-z, Pi-b* ,and *Pi-9,* and diverse cooking quality alleles were evaluated using molecular aided selection (MAS) allowing for significant increase in efficiency of selection at Puerto Rico. At Stuttgart, panicles from over 165 F_4 rows were selected to advance to F_5 in 2009. From over 2,700 rows planted, about 385 F_5 lines were selected based on plant type, grain quality, earliness, and disease reaction to advance to preliminary yield trials.

Yields of selected semidwarf lines from the preliminary yield trial are shown in Table 2. The experimental line 1087 from the cross STG02F5-07-067/STG02F5-04-034//STG03P-03-041 was the highest yielder at RB while line 1175 (STG00F5-07-007/LM 1//CYBT) recorded the highest yield at SE. Line 1214 a medium-grain entry from the cross STG02P-01-039/STG02AC-15-002//RU0401067 had the highest mean yield across the two locations. Another medium-grain entry, line 1114 (MDRK/GP-2//STG02P-02-072), has improved disease reaction to blast, straighthead, and sheathblight compared to the check, Bengal. Several entries in the PYT had large panicle size and good early vigor (data not shown) indicating that selection for these traits is effective in early generations. Milling yields of all entries in the PYT were generally low this year due to fall rains prior to harvest. Entry 1175 shows a resistant reaction to straighthead. Superior selected lines from the PYT will be advanced to the 2009 SIT. All the experimental lines are semidwarf but variation in plant height was observed. The tornado that passed directly over the PYT in Stuttgart at early seedling stage adversely affected early growth and development this year. The use of blast spreader rows at Pine Tree to simultaneously evaluate for disease and agronomic traits continues to be successful. Plant growth was very good under the disease system and blast disease pressure was good enough to identify susceptible lines. In 2009 more experimental lines, including F2 populations, will be tested under similar conditions at Pine Tree.

Data for 10 semidwarf experimental lines and check cultivars from the semidwarf Stuttgart Initial Test (SIT) are shown in Table 3. These entries varied in grain yield with the experimental lines 2085, 2099, 2087, 2088, 2093, 2052, and 2031 averaging 194, 192, 192, 189, 188, 187, and 185 bu/acre, respectively. Medium-grain Bengal and long-grain checks 'Wells' and Cybonnet yielded 176, 166 and 182 bu/acre, respectively. Blast ratings varied and ranged from 0 for Cybonnet, 2085, 2099, and 2052 to 5 for 2087 and 2088. Milling yields varied from 67:72 (Head Rice:Total Rice) for entry 2099 to 45:67 for entry 2085. We are testing our material for "delayed harvest" milling effect and have identified sources for tolerance (data not shown). Identification and incorporation of parents with disease tolerance and diverse genetic backgrounds, while maintaining grain quality and yield in the progeny will continue to be a priority. The continued exchange and use of new germplasm is an important component of this project. The semidwarf line 2031 originates from a cross between an introduced indica long-grain rice and combines earliness with excellent disease tolerance (blast and straighthead), high yield and acceptable milling and grain quality, and is in line to be released as a variety in 2009.

SIGNIFICANCE OF FINDINGS

Promising semidwarf experimental lines with diverse genetic backgrounds have been identified that have good disease resistance, high yields, and good milling quality. Semidwarf long- and medium-grain rice varieties offer producers options in their choice of cultivar and management systems for Arkansas rice production. Continued utilization of new germplasm through exchange and introduction remains important for Arkansas rice improvement.

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Table 1. Number of early generation lines selected in project ARK02030 during 2008.

	Number of lines	
Evaluation phase	Planted	Selected
F_1 Transplants	7,100	1,150
F_2 Space plants	108,000	2,180
F_4 Panicle rows	1,400	165
F_5 & F_6 Panicle rows	1,400	385

Table 2. Data from the 2008 Semidwarf Preliminary Yield Trial (PYT) for selected experimental lines and check cultivars.

	Grain	Yield[z]			Disease[y]			50%				Milling[w]
Entry	type	RREC	SEREC	avg.	NB	SH	ShB	HD[x]	Height	Vigor	Kernel wt.	HR:TOT
		(bu/acre)							(in.)	(1-4)	(mg)	
1214[x]	M	226	203	215	5	7	8	86	38	4	20.8	64:72
1087	L	238	179	209	0	5	8	84	38	3	19.2	44:67
1194	L	218	191	204	ND	6	6	91	36	4	22.2	59:72
1091	L	212	182	197	0	5	8	84	38	4	19.0	54:70
Bengal	M	229	162	195	0	6	7	91	37	4	21.6	65:73
Wells	L	212	178	195	5	7	7	91	37	3	20.8	59:72
1175	L	169	217	193	0	2	8	88	35	4	18.0	50:67
1114	M	197	170	183	0	4	6	84	33	3	19.4	44:71

[z] The 2008 PYT consisted of one replication at two locations: the Southeast Research and Extension Center, Rowher division (SEREC), Rowher, Ark., and the Rice Research and Extension Center (RREC), Stuttgart, Ark.

[y] Disease scores from field evaluation: neck blast (NB) at Pine Tree Experiment Station where 0 = no blast and 9 = plants dead, Straighthead (SH) from RREC where 0=no straighthead and 9=complete sterility, and sheath blight (ShB) at RREC where 0 = no infection and 9 = plants dead.

[x] Data for 50% heading date (HD), height, vigor, kernal weight, and milling are from RREC. Vigor is on a scale of 1 to 4 where 1 = low vigor and 4 is very vigorous.

[w] Milling is expressed as Head Rice/Total Rice.

[x] Entry 1214 is from the cross STG02P-01-039/STG02AC-15-002//RU0401067, Entries1087 and 1091 are from the cross STG02F5-07-067/STG02F5-04-034//STG03P-03-041, entry 1194 is from STG00F5-07-007/YANGZI 95//CYBT, 1175 is from STG00F5-07-007/LM 1//CYBT, and 1114 is from MDRK/GP-2//STG02P-02-072.

Table 3. Data from the 2008 Semidwarf Stuttgart Initial Test (SIT) for selected experimental lines and check cultivars.

	Grain	Yield[z]			Disease[y]			50%				Milling[w]
Entry	type	RREC	SEREC	avg.	NB	SH	ShB	HD[x]	Height	Vigor	Kernel wt.	HR:TOT
		----------- (bu/acre) ---------							(in.)	(1-4)	(mg)	
2085[x]	L	225	163	194	0	2	6	91	33	4	18.1	45:67
2099	M	197	188	192	0	6	7	93	35	4	21.3	67:72
2087	L	204	181	192	5	8	7	91	35	4	20.9	59:70
2088	L	203	174	189	5	7	7	93	37	4	20.5	49:66
2093	M	176	200	188	3	6	6	90	33	4	17.8	58:68
2052	L	179	194	187	0	6	7	91	36	3	17.8	55:69
2031	L	199	170	185	1	2	9	83	38	5	16.5	49:64
Cybonnet	L	197	168	182	0	5	7	92	37	4	18.4	58:70
Bengal	M	180	173	176	1	6	6	92	36	4	21.1	65:70
Wells	M	171	161	166	1	6	6	92	39	4	20.9	55:70

[z] The 2008 SIT consisted of two replications at two locations, the Southeast Research and Extension Center, Rowher division (SEREC), Rowher, Ark., and the Rice Research and Extension Center (RREC), Stuttgart, Ark.

[y] Disease scores from field evaluation: neck blast (NB) at Pine Tree Experiment Station where 0 = no blast and 9 = plants dead, straighthead (SH) from RREC where 0=no straighthead and 9=complete sterility, and sheath blight (ShB) at RREC where 0 = no infection and 9 = plants dead.

[x] Data for 50% heading date (HD), height, vigor, kernal weight, and milling are from RREC. Vigor is on a scale of 1 to 4 where 1 = low vigor and 4 is very vigorous.

[w] Milling is expressed as Head Rice:Total Rice.

[v] Entry 2085 is from the cross CYBT/LM1, entry 2099 is from the cross VSNTLM//L201/9NRZ/3/MARS/TBNT//9827/4/VSTNLM//L201, Entries 2087 and 2088 are from RU9901133/JEFF, 2093 is from MDRK/PI312777//Jing 185-7, 2053 is from RU9901133/DREW//RU0101093, and 2031 is from DREW/UA99-167.

Taggart, High Yielding Large Kernel Long-grain Rice Variety

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ABSTRACT

'Taggart', a new mid-season, high yielding, long-grain rice cultivar was derived from the cross 'LaGrue'//'Katy'/'Starbonnet'/5/LaGrue//'Lemont'/RA73/3/LaGrue/4/LaGrue. Taggart has been approved for release to qualified seed growers for the summer of 2009. The major advantage of the cultivar, released as Taggart, is its high yield potential and larger kernel size desired for long-grain milled rice and the parboil industry. Taggart has good milling yield for a rice with a larger kernel, and high yield potential. Taggart is very susceptible to stink bug damage, susceptible to rice blast and kernel smut, and moderately susceptible to sheath blight and straighthead.

INTRODUCTION

Taggart was developed in the rice improvement program at the University of Arkansas System Division of Agriculture's Rice Research and Extension Center (RREC) near Stuttgart, Ark., and has been released to qualified seed growers for the 2009 growing season. Taggart has high rough rice grain yield, good milling yield, and the larger kernel desired by the parboil industry. It is similar in maturity to 'Drew' and similar in height to LaGrue. Taggart was developed with the use of rice grower check-off funds distributed by the Arkansas Rice Research and Promotion Board.

PROCEDURES

Taggart originated from the cross LaGrue//Katy/Starbonnet/5/LaGrue//Lemont/RA73/3/LaGrue/4/LaGrue (cross no.20001657), made at the Rice Research and Extension Center, Stuttgart, Ark., in 2000. LaGrue is a high yielding long-grain rice described by Moldenhauer et al. (1994). Katy (Moldenhauer et al., 1990) is a blast resistant rice cultivar, and Starbonnet (Johnston et al., 1968) is a long-grain cultivar. Lemont is a long-grain semidwarf rice cultivar released in by Bollich et al. (1985). RA73 is a selection from 'Bonnet 73' (Johnston et al., 1973) irradiated with a Fission Neutron rate of 1800 R (line # STG74MU429). The experimental designation for early evaluation of RU0601188 was STG03L-16-028, starting with a bulk of F5 seed from the 2003 panicle row L-16-028. RU0601188 was tested in the Arkansas Rice Performance Trials (ARPT) and the Cooperative Uniform Regional Rice Nursery (URRN) during 2006-2008 as entry RU0601188 (RU number indicated Cooperative Uniform Regional Rice Nursery;06 indicates year entered was 2006; 01 indicates Stuttgart, Ark.; and 188 its entry number).

In 2006, the ARPT was conducted at six locations in Arkansas: the Rice Research and Extension Center (RREC); the Pine Tree Experiment Station (PTES), Colt, Ark.; the Northeast Research and Extension Center (NEREC), Keiser Ark.; the Southeast Research and Extension Center (SEREC), Rohwer, Ark.; a Clay County producer field, Corning, Ark. (CCPF); and a Jackson County producer field, Newport, Ark. (JCPF). In 2007, the ARPT was grown at the RREC, NEREC, SEREC, CCPF, and JCPF, and in 2008 at the RREC, PTES, NEREC, SEREC, and JCPF. Each year the tests had three replications per location to reduce soil heterogeneity effects and to decrease the amount of experimental error. Taggart was also grown in URRN at RREC and Malden, Missouri (2007-2008); and from 2006-2008 at Crowley, Louisiana; Stoneville, Mississippi; and Beaumont, Texas. Data collected from these tests included plant height, maturity, lodging, kernel weight, percent head rice, percent total rice, and grain yield adjusted to 12% moisture and disease reaction information. Cultural practices varied somewhat among locations, but overall the trials were grown under conditions of high productivity as recommended by the University of Arkansas Cooperative Extension Service Rice Production Handbook MP192 (CES, 2001). Agronomic and milling data are presented in Tables 1 and 2. Disease ratings, which are indications of potential damage under conditions favorable for development of specific diseases, have been reported on a scale from 0 = least susceptible to 9 = most susceptible, or as VS, S, MS, MR, and R for very susceptible, susceptible, moderately susceptible, moderately resistant, and resistant, respectively. Straw strength is a relative estimate based on observations of lodging in field tests using the scale from 0 = very strong straw to 9 = very weak straw, totally lodged.

RESULTS AND DISCUSSION

Data, presented by year, are given in Table 1 for Taggart and other short and mid-season cultivars grown in the ARPT. Rough rice grain yields of Taggart have consistently ranked as one of the highest in the Arkansas Rice Performance Trials (ARPT) being equal to the yields of 'Francis', LaGrue, and 'Wells' in all three years. In 16 ARPT tests (2006-2008), Taggart, Francis, Wells, LaGrue, 'Cybonnet', and Drew averaged yields of 187, 189, 184, 182, 168, and 161 bu/acre at 12% moisture, respectively. Data from the URRN (Table 2) conducted at Louisiana, Mississippi, and Texas during 2006-2008 and in Arkansas and Missouri during 2007-2008, showed that the average grain yield of Taggart at 207 bu/acre at 12% moisture compared favorably with those of Francis, Wells, and Cybonnet, at 202, 199, and 184 bu/acre, respectively. Milling yields (percent whole kernel:percent total milled rice) at 12% moisture from the ARPT, 2006-2008, averaged 57:71, 58:71, 54:71, 56:70, 61:71, and 58:70, for Taggart, Francis, Wells, LaGrue, Cybonnet, and Drew, respectively. Milling yields for the URRN during the same period of time, 2006-2008, averaged 56:71, 57:68, 56:69, and 64:71, for Taggart, Francis, Wells, and Cybonnet, respectively.

Taggart is similar in maturity to Drew (Table 1). It has a straw strength similar to Francis which is an indicator of lodging resistance. On a relative straw strength scale (0 = very strong straw, 9 = very weak straw) Taggart, Francis, Wells, LaGrue, Drew, and Cybonnet rated 4, 4, 3, 5, 6, and 2, respectively. Taggart is 44 inches in plant height which is the same as its recurrent parent LaGrue (Tables 1 and 2).

Taggart, like Francis, Wells, and LaGrue, is susceptible to common rice blast [*Pyricularia grisea* (Cooke) Sacc.] races IB-1, IB-33, IB-49, IC-17, IE-1, and IE-1K with summary ratings in greenhouse tests of 5, 7, 5, 6, 6, and 6, respectively, using the standard disease scale of 0 = immune, 9 = maximum disease susceptibility. Taggart is rated MS to sheath blight (*Rhizoctonia solani* Kühn) using the standard disease R = resistant, MR = moderately resistant, MS = moderately suceptible, and S = suceptible to disease, which compares with Francis (MS), Wells (S), LaGrue (MS), Cybonnet (VS), Cocodrie (S), and Drew (MS), using the standard disease R = resistant, MR = moderately resistant, MS = moderately susceptible, S = susceptible, and VS = very susceptible to disease. Taggart is rated S for kernel smut [*Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc.] which compares to Francis (VS), Wells(MR), LaGrue (VS), Cybonnet (S), Cocodrie (VS), and Drew (MS).

Taggart is rated S to stem rot, MR to leaf smut (*Entyloma oryzae* Syd. & P. Syd.), R to brown spot [*Cochliobolus miyabeanus* (Ito & Kuribayashi in Ito) Drechs. ex Dastur], MS to narrow brown leaf spot (*Cercospora oryzae* Miyake), and S to false smut [*Ustilaginoidea virens* (Cooke) Takah]. Taggart, like Cypress is VS for discolored kernels caused by the rice stink bug (*Oebalus pugnax*).

Taggart is a standard height long grain rice cultivar similar to LaGrue in appearance and yield. According to 2008 observations, like LaGrue, it is MS crown (black) sheath rot and S to stem rot. Taggart was rated MS to bacterial panicle blight in 2008 in Arkansas. Taggart rates MS to straighthead like Wells, LaGrue, and Francis. While Taggart should be drained on the most severe straighthead soils, it should not have a big problem with this disorder overall.

Plants of Taggart have erect culms, olive green erect leaves, and glabrous lemma, palea, and leaf blades. The lemma and palea are straw colored with red and purple apiculi, many of which fade to straw at maturity and some short tip awns on the lemma when grown under high fertility. Kernels of Taggart are large. Individual milled kernel weights of Taggart, Francis, Wells, LaGrue, Cybonnet, and Drew averaged 20.1, 17.1, 18.8, 17.8, 17.6, and 16.3, respectively, in the ARPT, 2006-2008.

The endosperm of Taggart is nonglutinous, nonaromatic, and covered by a light brown pericarp. Rice quality parameters indicate that Taggart has typical southern U.S. long-grain rice cooking quality characteristics as described by Webb et al. (1985). Taggart has an average apparent starch amylose content of 22.3 g kg^{-1} and an intermediate gelatinization temperature (70 to 75°C), as indicated by an average alkali (17 g kg^{-1} KOH) spreading reaction of 3 to 5.

SIGNIFICANCE OF FINDINGS

The release of Taggart provides producers with a high yielding, long-grain rice replacement for Wells or Francis. It has the benefit of having a large kernel which is not only desirable for long-grain milled rice but also for the parboil industry.

ACKNOWLEDGMENTS

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Table 1. Three year average agronomic data from the 2006 to 2008 Arkansas Rice Performance Trials for Taggart and other cultivars.

	Yield					50%	Kernel	Milling
Cultivar	2006	2007	2008	mean[z]	Height	Heading	wt.	HR:TOT[y]
	(bu/acre)				(in.)	(days)	(mg)	
Taggart	204	190	165	187	44	94	20.1	57:71
Francis	208	185	170	189	39	90	17.1	58:71
Wells	198	185	165	184	41	91	18.8	54:71
LaGrue	197	186	161	182	44	92	17.8	56:70
Cybonnet	186	171	144	168	37	90	17.6	61:71
Drew	168	175	139	161	42	93	16.3	58:70
$C.V._{0.05}$	9.2	10.3	12.1					

[z] 2006 consisted of six locations, Rice Research and Extension Center (RREC), Stuttgart, Ark.; Pine Tree Experiment Station (PTES), Colt, Ark.; Northeast Research and Extension Center (NEREC), Keiser, Ark.; Southeast Research and Extension Center, Rohwer Division (SEREC), Rohwer, Ark.; Clay County producer field (CCPF); and Jackson County producer field (JCPF); 2007: RREC, NEREC, SEREC, CCPF, and JCPF; and 2008: RREC, PTES, NEREC, SEREC, and JCPF.

[y] Milling figures are head rice : total milled rice.

Table 2. Data from the 2006 to 2008 Uniform Regional Rice Nursery for Taggart and other check cultivars.

	Yield[z]							50%	Kernel	Milling
Cultivar	AR[y]	LA	MO[y]	MS	TX	mean	Height	Heading	wt.[x]	HR:TOT[w]
	(bu/acre)						(in.)		(mg)	
Taggart	189	211	185	202	234	207	44	92	20.7	56:71
Francis	189	218	167	228	194	202	39	86	18.1	57:68
Wells	176	204	163	228	207	199	41	89	20.5	56:69
Cybonnet	168	193	180	187	185	184	38	86	18.6	64:71

[z] AR = Rice Research and Extension Center, Stuttgart, Ark. (2004-2005 & 2007-2008); LA = Rice Research Station Crowley, La.;MO = Malden, Mo. (2005-2008); MS = Stoneville, Miss.; and TX = Texas A&M, Beaumont, Texas.

[y] AR & MO data from 2007-2008.

[x] Kernel weight data is only collected in Arkansas.

[w] Milling figures are %Head Rice :%Total Milled Rice.

Table 3. Preliminary greenhouse blast race rating[z] of Taggart (based upon 2005-2008 ARPT data) with other comparative varieties.

	IB-1		IB-49		IC-17		IE-1		IG-1		IH-1		IE-1K		IB-33	
Taggart	5	S	5	S	6	S	6	S	7	S	6	S	3[x]	--	7	S
Banks	2	R	1	R	0	R	0	R	1	R	1	R	7	S	8	S
Cybonnet	1	R	0	R	0	R	0	R	0	R	0	R	6	S	6	S
Drew	1	R	0	R	0	R	0	R	0	R	0	R	6	S	6	S
Francis	6	S	7	S	8	S	6	S	7	S	1	R	6	S	7	S
Wells	7	S	7	S	7	S	7	S	2	R	0	R	6	S	7	S

[z] *Pyricularia grisea* races as defined using the international set of blast differentials. Plants in the 3- to 4-leaf growth stage were sprayed with spore suspension, held in moist chamber 12 to 18 hours then moved to greenhouse conditions. Composite leaf blast ratings on the 0 (none) to 9 (maximum) disease scale in multiple comparative inoculated greenhouse tests conducted at the University of Arkansas Rice Research and Extension Center, Stuttgart, Ark. Ratings indicate relative susceptibility under conditions favorable for seedling blast.

[y] Disease ratings vary between tests. For conversion of the 0 to 9 disease scale to symbols R (resistant) = 0 to 3, MR (moderately resistant) = 3 to 4, MS (moderately susceptible) = 5 to 6, S (susceptible) = 7, and VS (very susceptible) = 8 to 9. Varieties rated MS may be damaged and those rated S or VS may be severely damaged under favorable blast conditions.

[x] Mean value of variable data presented. Ratings from four tests were less than two (R). However, mean ratings from one additional tests was 6 (S). Data are insufficient to accurately indicate susceptibility to this race.

Templeton, a Blast Resistant Long-Grain Rice Variety

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ABSTRACT

'Templeton' is a new mid-season, high yielding, long-grain rice cultivar with resistance to the common blast races in Arkansas as well as moderate resistance to the race IE-1k, and was derived from the cross 'Drew'/5/'Newbonnet'/3/'Dawn'/CI9695//'Starbonnet'/4/'Katy'/Starbonnet. Templeton has been approved for release to qualified seed growers for the summer of 2009. The major advantage of the cultivar released as Templeton is its blast resistance to the race IE-1k which was the problem on the cultivar 'Banks'. Templeton has good milling yield, and high yield potential. Templeton, similar to 'LaGrue', is slightly better than other cultivars for stink bugs damage, susceptible to kernel smut, moderately susceptible to sheath blight, and very susceptible to straighthead.

INTRODUCTION

Templeton was developed in the rice improvement program at the University of Arkansas Systems Division of Agriculture's Rice Research and Extension Center (RREC) near Stuttgart, Ark., and has been released to qualified seed growers for the 2009 growing season. Templeton has good blast resistance to the common races in Arkansas and is moderately resistant to the race IE-1k. Templeton is similar in maturity to Drew and similar in height to 'Wells'. Templeton was developed with the use of rice grower check-off funds distributed by the Arkansas Rice Research and Promotion Board.

PROCEDURES

Templeton originated from the cross Drew/5/Newbonnet/3/Dawn/CI9695//Starbonnet /4/Katy/Starbonnet (cross no.19981441), made at the Rice Research and Extension Center (RREC), Stuttgart, Ark., in 1998. Drew is a blast resistant long-grain rice described by Moldenhauer et al. (1998). Newbonnet is a high yielding long-grain rice described by Johnston et al. (1984). Dawn is a blast resistant, long-grain gold hulled cultivar which was described by Bollich et al. (1968). CI9695 has the pedigree CI9453/CI9187//'Bluebonnet 50'. Starbonnet is a long-grain cultivar described by Johnston et al. (1968). The experimental designation for early evaluation of RU0401182 was STG01L-58-123, starting with a bulk of F6 seed from the 2001 panicle row L58-123. RU0401182 was tested in the Arkansas Rice Performance Trials (ARPT) and the Cooperative Uniform Regional Rice Nursery (URRN) during 2004-2008 as entry RU0401182 (RU number indicated Cooperative Uniform Regional Rice Nursery;04 indicates year entered was 2004; 01 indicates Stuttgart, Ark.; and 182 its entry number).

In 2004, the ARPT was conducted at six locations in Arkansas: the Rice Research and Extension Center (RREC); the Pine Tree Experiment Station (PTES), Colt, Ark.; the Northeast Research and Extension Center (NEREC), Keiser, Ark.; the Southeast Research and Extension Center, Rohwer Division (SEREC), Rohwer, Ark.,; a Clay County producer field, Corning, Ark. (CCPF); and Jackson County producer field, Newport, Ark. (JCPF). In 2005, the ARPT was grown at the RREC, PTES, NEREC, CCPR, and JCPF. In 2006, the ARPT was grown at the RREC, PTES, NEREC, SEREC, CCPF, and JCFC. In 2007, the ARPT was grown at the RREC, NEREC, SEREC, CCPF, and JCPF, and in 2008 at the RREC, PTES, NEREC, SEREC, and JCPF. Each year the tests had three replications per location to reduce soil heterogeneity effects and to decrease the amount of experimental error. Templeton was also grown in URRN at RREC (2004-2005 and 2007-2008); Malden, Missouri (2005-2008); and from 2004-2008 at Crowley, Louisiana; Stoneville, Mississippi; and Beaumont, Texas. Data collected from these tests included plant height, maturity, lodging, kernel weight, percent head rice, percent total rice, and grain yield adjusted to 12% moisture and disease reaction information. Cultural practices varied somewhat among locations, but overall the trials were grown under conditions of high productivity as recommended by the University of Arkansas Cooperative Extension Service Rice Production Handbook MP192 (CES, 2001). Agronomic and milling data are presented in Tables 1 and 2. Disease ratings, which are indications of potential damage under conditions favorable for development of specific diseases, have been reported on a scale from 0 = least susceptible to 9 = most susceptible, or as VS, S, MS, MR, and R for very susceptible, susceptible, moderately susceptible, moderately resistant, and resistant, respectively. Straw strength is a relative estimate based on observations of lodging in field tests using the scale from 0 = very strong straw to 9 = very weak straw, totally lodged.

RESULTS AND DISCUSSION

Data, presented by year, are given in Table 1 for Templeton and other short and mid-season cultivars grown in the ARPT. Rough rice grain yields of Templeton have been equal to the yields of LaGrue, and Wells in all five years and 'Francis' in 2004, 2005 and 2007. In 27 ARPT tests (2004-2008), Templeton, Francis, Wells, LaGrue, 'Cybonnet', and Drew averaged yields of 184, 190, 187, 182, 173, and 168 bu/acre, respectively. Data from the URRN (Table 2) conducted at Arkansas, Louisiana, Missouri, Mississippi, and Texas during 2004-2008, showed the average grain yield of Templeton at 190 bu/acre compared favorably with the yields of Francis, Wells, and Cybonnet, at 194, 194, and 184 bu/acre at 12% moisture, respectively. Milling yields (percent whole kernel:percent total milled rice) at 12% moisture from the ARPT, 2004-2008, averaged 59:71, 60:71, 57:72, 58:70, 63:72, and 61:71 for Templeton, Francis, Wells, LaGrue, Cybonnet, and Drew, respectively. Milling yields for the URRN during the same period of time, 2004-2008, averaged 60:69, 57:69, 55:70, and 63:71, for Templeton, Francis, Wells, and Cybonnet, respectively.

Templeton is similar in maturity to Drew (Table 1). Templeton has a straw strength similar to Francis which is an indicator of lodging resistance. On a relative straw strength scale (0 = very strong straw, 9 = very weak straw) Templeton, Francis, Wells, LaGrue, Drew, and Cybonnet rated 4, 4, 3, 5, 6, and 2, respectively. Templeton is 41 inches in plant height which is similar to Wells (Tables 1 & 2).

Templeton, like Banks, Katy, 'Kaybonnet', Cybonnet and Drew, is resistant to common rice blast (*Pyricularia grisea* (Cooke) Sacc.*)* races IB-1, IB-49, IC-17, IE-1, IG-1, and IH-1 (Table 3) under Arkansas conditions, with ratings of 1, 0, 0, 0, 0, and 0, respectively, using the standard disease scale of 0 = immune, 9 = maximum disease susceptibility. Like Banks, Katy, Kaybonnet, Cybonnet, and Drew, Templeton rates a 6 to 8 to the blast race IB-33, and unlike Banks, Katy, Kaybonnet, Cybonnet, and Drew which rate 6 to 7 to race IE-1k, Templeton rates a 2 to the race IE-1k. Templeton is rated MS to sheath blight (*Rhizoctonia solani* Kühn) using the standard disease R = resistant, MR = moderately resistant, MS = moderately suceptible, and S = suceptible to disease, which compares with Francis (MS), Wells (S), LaGrue (MS), Cybonnet (VS), and Drew (MS). Templeton is rated S for kernel smut [*Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc.] which compares to Francis (VS),Wells (MS), LaGrue (VS), Cybonnet (S), Cocodrie (VS), and Drew (MS).

Templeton is rated S to stem rot, MR to leaf smut (*Entyloma oryzae* Syd. & P. Syd.), R to brown spot [*Cochliobolus miyabeanus* (Ito & Kuribayashi in Ito) Drechs. ex Dastur], MS to narrow brown leaf spot (*Cercospora oryzae* Miyake), and S to false smut [*Ustilaginoidea virens* (Cooke) Takah]. Templeton, is MR for discolored kernels caused by the rice stink bug (*Oebalus pugnax*).

Templeton is a standard height long-grain rice cultivar similar to Wells in appearance and yield. In most cases, unlike LaGrue, Francis, or Wells, Templeton is resistant to the common races of rice blast disease when grown under Arkansas conditions. According to 2008 observations it is MS crown (black) sheath rot and S to stem rot. Templeton was rated MS to bacterial panicle blight in Arkansas. Templeton like 'Cocodrie' has a VS reaction to straighthead. It should be drained on straighthead soils.

Plants of Templeton have erect culms, green erect leaves, and glabrous lemma, palea, and leaf blades. The lemma and palea are straw colored with straw and purple apiculi which fade to straw at maturity, and some short tip awns on the lemma at maturity. Kernels are similar in size to those of Ahrent and Drew. Individual milled kernel weights of Templeton, Francis, Wells, LaGrue, Cybonnet, and Drew, averaged 16.4,17.1, 18.8, 17.9, 17.6, and 16.4, respectively, in the ARPT, 2004-2008.

The endosperm of Templeton is nonglutinous, nonaromatic, and covered by a light brown pericarp. Rice quality parameters indicate that Templeton has typical southern U.S. long-grain rice cooking quality characteristics as described by Webb et al. (1985). Templeton has an average apparent starch amylose content of 21.9 g kg^{-1} and an intermediate gelatinization temperature (70 to 75°C), as indicated by an average alkali (17 g kg^{-1} KOH) spreading reaction of 3 to 5.

SIGNIFICANCE OF FINDINGS

The release of Templeton provides producers with a high yielding blast resistant replacement for the Wells rice cultivar which has moderate resistance to the blast race IE-1k which is a definite improvement over the blast resistance in the Banks cultivar. Templeton also has good milling and cooking quality.

ACKNOWLEDGMENTS

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Table 1. Five year average agronomic data from the 2004 to 2008 Arkansas Rice Performance Trials for Templeton and other cultivars.

	Yield							50%	Kernel	Milling
Cultivar	2004	2005	2006	2007	2008	mean[z]	Height	Heading	wt.	HR:TOT[y]
	(bu/acre)						(in.)	(days)	(mg)	
Templeton	177	211	197	179	156	184	41	93	16.4	59:71
Francis	177	210	208	185	170	190	40	89	17.1	60:71
Wells	174	213	198	185	165	187	41	91	18.8	57:72
LaGrue	156	205	197	186	161	182	44	92	17.9	58:70
Cybonnet	163	202	186	171	144	173	37	90	17.6	63:72
Drew	167	193	168	175	139	168	42	93	16.4	61:71
$C.V._{0.05}$	9.4	7.1	9.2	10.3	12.1					

[z] 2004 consisted of six locations, Rice Research and Extension Center (RREC), Stuttgart, Ark.; Pine Tree Experiment Station (PTES),Colt, Ark.; Northeast Research and Extension Center (NEREC), Keiser, Ark.; Southeast Research and Extension Center Rohwer Division (SEREC), Rohwer, Ark.; Clay County producer field (CCPF); and Jackson County producer field (JCPF); 2005, consisted of RREC, PTES, NEREC, JCPF, and CCPF; 2006 consisted of RREC, PTES, NEREC, SEREC, CCPF, and JCPF: 2007 RREC, NEREC, SEREC, CCPF, and JCPF; and 2008 RREC, PTES, NEREC, SEREC, and JCPF.

[y] Milling figures are head rice : total milled rice.

Table 2. Data from the 2004 to 2008 Uniform Regional Rice Nursery for Templeton and other check cultivars.

	Yield[z]							50%	Kernel	Milling
Cultivar	AR	LA	MO	MS	TX	mean	Height	Heading	wt.[y]	HR:TOT[x]
	(bu/acre)						(in.)	(days)	(mg)	
Templeton	193	176	160	214	202	190	41	90	17.3	60:69
Francis	198	204	169	204	193	194	39	87	17.5	57:69
Wells	183	189	166	217	205	194	41	88	20.0	55:70
Cybonnet	187	190	176	181	185	184	38	87	18.1	63:71

[z] AR = Rice Research and Extension Center, Stuttgart, Ark. (2004-2005 & 2007-2008); LA = Rice Research Station Crowley, La.;MO = Malden, Mo. (2005-2008); MS = Stoneville, Miss.; and TX = Texas A&M, Beaumont, Texas.

[y] Kernel weight data is only collected in Arkansas.

[x] Milling figures are % head rice :% total milled rice.

Table 3. Preliminary Greenhouse Blast Race rating[z] of Templeton (based upon 2005-2008 ARPT data) with other comparative varieties.

	IB-1		IB-49		IC-17		IE-1		IG-1		IH-1		IE-1K		IB-33	
Templeton	1	R[y]	0	R	0	R	0	R	0	R	0	R	2[x]	MR-R	7	S
Banks	2	R	1	R	0	R	0	R	1	R	1	R	7	S	8	S
Cybonnet	1	R	0	R	0	R	0	R	0	R	0	R	6	S	6	S
Drew	1	R	0	R	0	R	0	R	0	R	0	R	6	S	6	S
Francis	6	S	7	S	8	S	6	S	7	S	1	R	6	S	7	S
Wells	7	S	7	S	7	S	7	S	2	R	0	R	6	S	7	S

[z] *Pyricularia grisea* races as defined using the international set of blast differentials. Plants in the 3- to 4-leaf growth stage were sprayed with spore suspension, held in moist chamber 12 to 18 hours then moved to greenhouse conditions. Composite leaf blast ratings on the 0 (none) to 9 (maximum) disease scale in multiple comparative inoculated greenhouse tests conducted at the University of Arkansas Rice Research and Extension Center, Stuttgart, Ark. Ratings indicate relative susceptibility under conditions favorable for seedling blast.

[y] Disease ratings vary between tests. For conversion of the 0 to 9 disease scale to symbols R (resistant) = 0 to 3, MR (moderately resistant) = 3 to 4, MS (moderately susceptible) = 5 to 6, S (susceptible) = 7, and VS (very susceptible) = 8 to 9. Varieties rated MS may be damaged and those rated S or VS may be severely damaged under favorable blast conditions.

[x] Mean value of variable data presented. Ratings from seven tests were less than zero (R). However, mean ratings from four additional tests was 4.5 (S). Entry may likely to be susceptible to this race in moisture stress conditions.

[w] Mean value of variable data presented. Ratings from four tests were less than two (R). However, mean ratings from one additional tests was 6 (S). Data are insufficient to accurately indicate susceptibility to this race.

Rice Blast Control Strategies for New Rice Cultivars 'Taggart' and 'Templeton

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ABSTRACT

Disease data for new rice varieties 'Taggart' 'and 'Templeton' are examined. With the exception of rice blast susceptibility, these cultivars have similar disease package relative to the common diseases found in Arkansas. Taggart tested susceptible to common blast races IB-1, IB-49, IC-17, IE-1, IG-1, IG-1, and IE-k. Research and performance data indicates Taggart has good field resistance to rice blast when standard flood irrigated cultural practices are practiced. Templeton, with the *Pi-ta* blast resistance gene, tested resistant to common blast races IB-1, IB-49, IC-17, IE-1, IG-1, and IH-1. Templeton, and possibly Taggart, are more tolerant to race IE-1k than reference *Pi-ta* gene varieties 'Banks', 'Cybonnet', 'Drew', 'Francis', and 'Wells'. All varieties were susceptible to race IB-33. Growers selecting Taggart and Templeton should be careful about field choice and cultural practices while these varieties are evaluated in the ultimate test – three or four years exposure to widespread field production.

INTRODUCTION

Efficacious disease control is critical to successful rice production in Arkansas where variety selection and performance are often limited by individual rice diseases adversely impacting yield, quality, and economic returns. Funded by grower check-off funds distributed by the Arkansas Rice Research and Promotion Board, the rice disease research program routinely evaluates breeding program entries to provide disease data required for superior variety development. Our objectives are to increase varietal disease resistance and to define disease liabilities of new varieties prior to release for Arkansas rice production.

Following stringent evaluation, new cultivars Taggart and Templeton were released to Arkansas producers for statewide rice production and as potential replacements of high-yield, blast-susceptible Wells or Francis (Moldenhauer et al., 2009a, Moldenhauer et al., 2009b). Taggart is a high-yield, long-grain rice variety which has the large kernel desired for long-grain milled rice and the parboil industry. Templeton is a high-yield, long-grain rice variety with good milling yield coupled with resistance to common blast races and tolerance to the previously rare race IE-1k (Lee et al., 2005).

With the exception of rice blast disease, test results show both varieties to have disease packages comparable to each other and applicable reference varieties. Respective to rice blast, Taggart, although susceptible, exhibits good field resistance. Templeton contains the *Pi-ta* blast resistance gene which provides genetic resistance to all common blast races occurring in Arkansas.

PROCEDURES

Disease severity is usually rated using a visually numerical scale where the 0 rating indicates complete disease immunity and the 9 rating indicates complete disease susceptibility ending with total yield loss and/or plant death. Ratings are often summarized where ratings of 0 to 3 = R (resistant), 3 to 4 = MR (moderately resistant), 5 to 6 = MS (moderately susceptible to susceptible), 7 = S (susceptible), and 8 to 9 = VS (very susceptible). Variation and/or exceptions to established ratings occur with variation in location and year, research procedures, environmental changes, and pathogen adaptation.

Greenhouse tests were used to evaluate reaction to the many blast races occurring in Arkansas production areas and provide an reasonably accurate definition of inherent blast resistance and race-entry genetic interactions. Blast field nurseries, utilizing both natural- and lab-produced inoculum, were established in an effort to better define blast susceptibility under field conditions using current production practices. In addition, multiple disease nurseries, yield and disease observation tests including the Arkansas Rice Production Trials (ARPT) and the Arkansas Rice Disease Monitoring Plots (ARDMP) document variety performance under typical conditions in Arkansas production fields.

RESULTS AND DISCUSSION

Greenhouse test reactions to common blast races in Arkansas are presented (Table 1). Entries with individual race ratings less than five or six typically exhibit an acceptable level of field resistance when using good cultural practices including proper flood management. Except for race IH-1, Taggart susceptibility ratings for individual races is equal to or less than those of field resistant varieties Francis and Wells which are currently producing record-per-acre rough rice yields (Wilson and Branson, 2005). Race IH-1 severity in Taggart compares with that of other common races. Templeton, with *Pi-ta*, has good resistance all common blast races IB-1 through IH-1. Race IE-1k severely damaged drought stressed fields of cultivar Banks (Lee et al., 2005) which is no longer utilized (Table 3). Templeton appears to be tolerant to race IE-1k, perhaps the result of eliminating highly susceptible individual panicle rows inoculated with race IE-1k in greenhouse tests. Race IB-33 is not found in Arkansas but is tested as a potentially damaging blast race adaptation.

The inoculated Pine Tree Experiment Station (PTES) blast nursery provides an estimate of susceptibility to panicle blast when entries growing under upland conditions are stressed by low soil moisture (Table 2). Taggart exhibited blast field resistance comparable to that of Francis and Wells. As expected, Templeton was blast resistant growing in the upland nursery. However, the PTES plots were not inoculated with race IE-1k which is not observed in local production fields.

Disease ratings for Taggart, Templeton, and reference varieties were selected from Arkansas Rice Production Test summaries published 2004 through 2008 (Table 3). These ratings and all available disease data collected to date indicate rice blast should not seriously damage Taggart when using typical irrigated crop management practices. Templeton has potential for use in droughty fields. However, the final disease assessment, especially with rice blast, for all new varieties comes after three or four years of grower use in Arkansas production fields. We are especially interested in the long term blast resistance to race IE-1k in Templeton.

The comparison between varieties with field resistance or major R gene resistance as the primary blast control mechanism emphasizes two important issues long encountered in variety development. First, techniques are not currently available to accurately identify and quantify variety blast field resistance which historically serves as the primary blast control strategy for Arkansas growers. Molecular techniques and other methods (inclined field plots) to assess root zone environmental conditions necessary to establish field resistance are being investigated. The second issue concerns the need for field selection and entry evaluation using highly virulent races not present in the local production areas. Relative to race IE-1k which quickly spread throughout Arkansas after 2004 (Table 3), 2009 blast field nurseries are being located in production areas where this race has occurred on the Banks variety.

SIGNIFICANCE OF FINDINGS

Two new rice varieties with desirable disease control packages were released. Taggart exhibits rice blast field resistance comparable to, or better than, the widely grown Wells. With the *Pi-ta* gene, Templeton provides high resistance to common blast races and good resistance to the *Pi-ta* virulent race IE-1k.

ACKNOWLEDGMENTS

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Table 1. Summary of available leaf blast rating data[z] from plants inoculated with the indicated race using standard techniques[y] in University of Arkansas Rice Research and Extension Center greenhouse tests, Stuttgart, Arkansas, 2005-2008.

	IB-1		IB-49		IC-17		IE-1		IG-1		IH-1		IE-1K		IB-33	
Variety	Visual	Text	Visual	Text	Visual	Text	Visual	Text	Visual	Text	Visual	Text	Visual	Text	Visual	Text
Taggart	5	S	5	S	6	S	6	S	7	S	6	S	3[x]	--	7	S
Templeton	1	R	0	R	0	R	0	R	0	R	0	R	2[w]	MR-MS	7	S
Banks	2	R	1	R	0	R	0	R	1	R	1	R	7	S	8	S
Cybonnet	1	R	0	R	0	R	0	R	0	R	0	R	6	S	6	S
Drew	1	R	0	R	0	R	0	R	0	R	0	R	6	S	6	S
Francis	6	S	7	S	8	S	6	S	7	S	1	S	6	S	7	S
Wells	7	S	7	S	7	S	7	S	2	S	0	S	6	S	7	S

[z] Standard visual numerical rating scale of 0 to 9 where 0 = resistant and 9 = very susceptible. Text conversion: R = Resistant; MR = Moderately Resistant; MS = Moderately Susceptible; S = Susceptible; VS = Very Susceptible.

[y] Plants in the 3- to 4-leaf growth stage were sprayed with spore suspension, held in moist chamber 12 to 18 hours then moved to greenhouse conditions.

[x] Mean value of variable data presented. Ratings from four tests were less than two (R). However, mean ratings from one additional test was 6 (S). Data are insufficient to accurately indicate susceptibility to race IE-1k.

[w] Mean value of variable data presented. Ratings from seven tests were one or less (R). However, mean of ratings from four additional tests was 4.5 (MS). Entry may be susceptible to race IE-1k if growing under moisture stress conditions.

Table 2. Summary of available blast rating data[z] from inoculated upland blast field nurseries located on the University of Arkansas Pine Tree Experiment Station, Colt Arkansas[y], 2005-2008.

	PTES panicle blast rating		PTES leaf blast rating	
Variety	Visual	Text	Visual	Text
Taggart	4.0	MR	3.7	MR
Templeton	2.0	R	0.9	R
Banks	3.7	R-MR	0.5	R
Cybonnet	2.7	R	1.3	R
Francis	7.5	S-VS	6.0	S
Wells	6.1	S	5.6	S

[z] Standard visual rating scale 0 to 9 where 0 = resistant (S) and 9 = very susceptible (VS). Leaf blast ratings were made on plants soon after inoculation. Panicle blast ratings were made at or near grain fill.

[y] Upland nursery plants in 4- to 6-leaf growth stage were artificially inoculated with multiple races including IB-1, IB-49, IC-17, IE-1, IH-1, and IG-1 growing on grass seed. Upland plots were flooded as necessary with plants being drought stressed during the growing season, particularly after panicle exsertion.

Table 3. Disease ratings[z] for Taggart, Templeton, and reference varieties extracted from the Arkansas Rice Production Trials summaries for years 2004-2008.

Variety / Year of summary	Sheath blight	Blast[y]	Bacterial panicle blight	Narrow brown leaf spot	Stem rot[x]	Kernel smut	False smut	Brown spot	Black sheath rot
Taggart 2008 (RU0601188)	MS	S	MS	MS	S	S	S	R	MS
Templeton 2008 (RU0401182)	MS	R	MS	MS	S	S	S	R	MS
Cybonnet 2008	VS	R	S	MS	S	S	S	R	S
Drew 2004	MS	R	.	.	MS	MS	S	S	MS
Francis 2008	MS	VS	VS	S	S	VS	S	R	MS
Wells 2008	S	S	S	S	VS	S	S	R	MS
Banks 2004	MS	R	.	.	S	VS	S	R	MS
Banks 2005	MS	MS	S	.	S	VS	S	R	MS
Banks 2006	MS	S	S	S	S	VS	S	R	MS
Banks 2007-2008	No longer a viable variety for Arkansas								

[z] Reaction: R = Resistant; MR = Moderately Resistant; MS = Moderately Susceptible; S = Susceptible; VS = Very Susceptible. Reactions were determined based on historical and recent observations from test plots and in grower fields across Arkansas. In general, these reactions would be expected under conditions that favor severe disease development including excessive nitrogen rates (most diseases) or low flood depth (blast).

[y] Based on reaction to common races of the rice blast fungus in Arkansas for the most part; however, Banks and other *Pi-ta* resistant gene based varieties are susceptible to Race IE-1k, a previously rare race that has increased in importance in the state since 2004. All rice varieties should be monitored periodically for blast since the blast fungus is capable of developing new races that can overcome known resistance genes.

[x] Other notes: Most cultivars will be susceptible to stem rot under low K and high N conditions. Bengal and certain other cultivars become very susceptible to brown spot under low K conditions. Most cultivars are susceptible to false smut under high N, late planted conditions. Kernel smut is increased by excessive nitrogen fertilization.

Reducing False Smut (*Ustilaginoidea virens*) and Kernel Smut (*Neovossia horrida*) Disease Severity Through Crop Management Practices

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ABSTRACT

False smut (FS) and kernel smut (KS) are known to be minor diseases of rice in Arkansas. Changes in production management are known to promote the severity of these diseases. This study was undertaken to evaluate the effect of rotation, tillage, fertility, and variety, treatments contained in an existing long-term study, on FS and KS severity in 'Wells', 'Cybonnet', and 'XL 723'. False smut was reduced 69% in no-till plots when compared to conventional-till. Reducing fertilizer applications resulted in a 33% reduction in FS. Changing from a rice-soybean rotation to continuous rice reduced FS by 88%. Using conventional-till in a rice-soybean rotation resulted in the highest incidence of FS (211 sori/kg seed) while no-till continuous rice was the lowest at 9 sori/kg seed. Kernel smut incidence was not affected by tillage or rotation but was significantly reduced by decreasing fertilizer applications. Rotation and tillage treatment combinations showed lowest KS incidence in the no-till, continuous rice management combination. None of the three varieties used in this experiment were immune to either disease.

INTRODUCTION

False smut and kernel smut are generally regarded as minor rice diseases in Arkansas (Cartwright et al., 1999; Slaton et al., 2004). This may be, in part, because they do not regularly cause significant yield or quality reductions or that they have been kept at minimum levels because of fungicides applied to fields to control more important diseases such as blast and sheath blight. With the recent introduction of varieties that are highly tolerant or resistant to blast and sheath blight there is a potential for farmers to increase their profits by eliminating fungicide sprays from their management program. This could result in a significant increase in FS and KS levels in farmers fields.

False smut was first reported in Arkansas in 1997 (Cartwright et al., 1998) and is now present in all rice-producing counties (Cartwright et al., 1999). This trend of increasing importance has been noted throughout the rice-producing areas of the world (Webster and Gunnell, 1992; Zhou et al., 2008). There is no evidence indicating this disease will diminish in importance nor has there been progress in identifying genetic resistance.

Unlike FS, KS epidemics have been reported (Cartwright et al., 1994). In years that KS is found in production fields it not only impacts yield but reduces grain quality. Currently USDA has stipulated that any rice containing more than 3% infected kernels cannot be used as parboiled rice. Producers are docked when infection levels in harvested grain are above 3%. Cultivars are known to vary in their susceptibility to KS (Cartwright et al., 2001; Tsuda et al., 2006). How cultivar resistance might interact with different management options is less understood. Prior symptom scouting for FS and KS is not feasible. When symptoms of either disease are identified as present in a farmers field it is too late to apply fungicide for control. This study was undertaken to identify and quantify the potential to reduce the severity of these diseases through a range of crop-management practices.

PROCEDURES

A site at the University of Arkansas Rice Research and Extension Center was selected for this study and cut to a 0.15% slope in February of 1999. Soil at the site is characterized as a Stuttgart silt loam and classified as a fine, smectitic, thermic Albaqultic Hapludolf. Initial soil samples showed a pH range of 5.6 to 6.2 with carbon content averaging 0.84% and nitrogen 0.08%. Plots measuring 250 ft by 40 ft were laid out in a north-south direction. These plots were then divided in half east-west with each side randomized as conventional or no-till treatments. Each tillage treatment was then split into a standard and high fertility treatment. For rice, ‘standard’ fertility consisted of a single pre-flood N application of 100 lb urea/acre plus 40 lb/acre P_2O_5, and 60 lb/acre K_2O applied prior to planting. Rates increased to 150 lb/acre N, 60 lb/acre P_2O_5, and 90 lb/acre K_2O for the ‘enhanced’ treatment with application times remaining the same. Two varieties of each crop species were planted in a continuous strip across the conventional- and no-till treatments. The following rotations that started in 1999 were continued: 1) continuous rice, 2) rice-soybean, 3) soybean-rice, 4) rice-corn, 5) corn-rice, 6) rice (wheat) rice (wheat), 7) rice (wheat)-soybeans (wheat), 8) soybeans (wheat)-rice (wheat), 9) rice-soybeans-corn, 10) rice-corn-soybeans. There have been no fungicide sprays applied to these plots since they were established in 1999.

At rice harvest in 2006 and 2007 grain samples were collected from each plot at the combine for the continuous rice and rice-soybean rotations. In 2006, Wells and Cybonnet were grown while in 2007 Wells and XL 723 were grown. False smut severity was determined by counting the number of sori (smut balls) recovered from a 1 to 1.5 kg sub-sample and is reported as sori number per kg seed. Kernel smut severity was determined by collecting four 50-g sub-samples from the larger grain sample. Each sub-sample was wrapped in Miracloth (Calbiochem, La Jolla, Calif.) and soaked overnight in 0.27 M KOH to clear hulls (palea and lemma) according to Lee et al. (1992). Infected kernels were counted visually over a light box and are reported as kernels per kg of seed harvested.

Data from both years and three varieties were pooled and analyzed using GLIMMIX procedure in SAS (Version 9.1.3). The fixed effects in each model were rotation, tillage, fertility, and their interaction, and the block and variety effects were random. The Kenward-Roger degree of freedom method was used. Estimated means, standard errors, and differences of means were calculated using LSMEANS option. Specific hypotheses of cultivar and fertility differences were calculated using the ESTIMATE option.

RESULTS AND DISCUSSION

Tillage, fertility, and rotation main effects significantly affected false smut incidence (Table 1). There was also a significant interaction of tillage by rotation. Changing from conventional-till to no-till resulted in a 69% reduction of sori number from 84 to 26/kg (Table 2). Reducing fertility from an enhanced level to standard level resulted in a 33% reduction in disease incidence. Greatest reductions (88%) in FS incidence were observed with the continuous rice rotation when compared to the rice-soybean rotation. These results indicate that farmers using conventional-tillage in a rice-soybean rotation and applying high fertility rates can expect this disease to increase in the future; particularly if they plant varieties that do not require fungicide sprays for blast and sheath blight control.

Because varieties were not consistent across years they were treated as random effects in the model and ranked as to their infection levels. Rotation effects were significant and none of the varieties were immune, thus varieties were ranked within each crop rotation. For the continuous rice rotation, Cybonnet had the highest FS incidence at 36 sori/kg grain followed by Wells at 18 and XL 723 at 6 sori/kg grain, respectively. For the rice-soybean rotation, Wells had the highest infection with 189 sori/kg grain followed by Cybonnet at 140 sori/kg grain.

Kernel smut responded to crop management treatments somewhat differently than FS. There were no significant differences in KS incidence between the tillage or rotation main effect comparisons (Table 3). There was a statistically significant difference between fertility treatments and a significant interaction of tillage by rotation.

Reducing fertility from the ‘enhanced’ level to ‘standard’ resulted in a 60% reduction in KS incidence (Table 4). This trend of reduced disease levels attributed to lower fertilizer application rates was also found in our FS analysis (Table 1). Even though rotation comparisons were not significantly different in the ANOVA there was a trend of decreased KS incidence in the continuous rice (R-R) rotation when compared to rice-soybean (R-S) regardless of tillage treatment (Table 4). As with FS, lowest KS disease levels were with the no-till, continuous rice management combination.

Varieties were ranked within rotation treatments over the two years. For the continuous rice rotation mean KS numbers were 99, 26, and 23 infected kernels/kg grain for Wells, XL 723, and Cybonnet, respectively. For the rice-soybean rotation, Wells had 147 and Cybonnet had 19 infected kernels/kg grain, respectively. These results confirm differences between the varieties in their susceptibility to KS.

Both FS and KS disease incidence can be reduced by proper variety selection and field management. Reducing fertility levels resulted in a reduction in both diseases. In this study there was not a significant reduction in grain yield (data not presented) with reduced fertilizer applications thus producers would not only increase their profit margin from reduced fertilizer costs but would potentially avoid grain price reductions because of grain quality issues and possible yield losses from disease. Shifting management from conventional-to no-till resulted in a decreased incidence of both diseases. Economic analysis of this study has shown that profits are greater and more stable in the no-till treatment when compared to the conventional-till treatment (Watkins et al., 2006). Results from this study indicate FS and KS incidence will also be reduced as producers move from conventional-to no-till production. Producers growing continuous rice will need to worry less about these diseases as long as they do not over-fertilize their crops.

SIGNIFICANCE OF FINDINGS

This work illustrates the potential for Arkansas rice producers to address potential FS and KS disease problems if they adopt proper crop rotation, tillage, and fertility practices. For both diseases there is a trend of reduced disease severity when fertility is reduced, no-till management is used, and continuous rice is grown. Variety selection is important in minimizing both diseases but we did not test enough varieties to identify those best suited. Management strategies outlined in this study will assist farmers in reducing their production costs while maintaining high grain quality.

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Table 1. Probability of significance for treatments on false smut incidence for 2006 and 2007 pooled data in a long-term rotation study carried out at the University of Arkansas Rice Research and Extension Center, Stuttgart, Ark.

Treatment	Probability F value
Tillage	<0.0001
Fertility	0.0410
Tillage x fertility	0.1139
Rotation	0.0007
Tillage x rotation	<0.0001
Fertility x rotation	0.3276

Table 2. False smut values (sori/kg grain) and Tukey-Cramer groupings for main effects and significant interactions.

Effect	Treatment	Mean false smut sori	T grouping[z]
		(# sori/kg seed)	
Tillage (Till.)	Conventional-till	84	A
	No-till	26	B
Fertility (Fert.)	Enhanced	66	A
	Standard	44	B
Rotation (Rot.)	Rice-soybeans	164	A
	Rice-rice	19	B
Till. x rot.	CT[y] x R-SB	211	A
	NT x R-SB	114	AB
	CT x R-R	29	BC
	NT x R-R	9	C

[z] Values are significantly different at a P < 0.05 value.
[y] CT = conventional-till, NT = no-till, R-SB = rice-soybean rotation, R-R = continuous rice.

Table 3. Probability of significance for treatments on kernel smut severity for 2006 and 2007 pooled data in a long-term rotation study carried out at the University of Arkansas Rice Research and Extension Center, Stuttgart, Ark.

Treatment	Probability F value
Tillage	0.8504
Fertility	0.0042
Tillage x Fertility	0.3205
Rotation	0.9082
Tillage x rotation	<0.0001
Fertility x rotation	0.1315

Table 4. Kernel smut values (sori/kg grain) and Tukey-Cramer groupings for main effects and significant interactions.

Effect	Treatment	Mean false smut sori	T grouping[z]
		(#/kg seed)	
Fertility	Enhanced	133	A
	Standard	53	B
Till. x rot.	CT x R-SB[y]	82	A
	NT x R-SB	78	A
	CT x R-R	75	A
	NT x R-R	49	B

[z] Values are significantly different at a P < 0.05 value.
[y] CT = conventional-till, NT = no-till, R-SB = rice-soybean rotation, R-R = continuous rice.

Utilization of On-Farm Testing to Evaluate Rice Cultivars for Disease Reaction and Yield

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ABSTRACT

Rice diseases reduce yield, milling quality, and profit in Arkansas rice production each year. Resistant cultivars are the first line of defense against disease, and the correct cultivar choice for a particular field will result in lower production costs and higher profits to the grower, by minimizing disease problems. Diseases are greatly influenced by the environment as well, and rice is grown in dozens of field situations around the state. Therefore, performance evaluations across many environments are important to overall cultivar selection. The Disease Monitoring Program (DMP) was initiated in 1995 with three main objectives. These objectives include: 1) to monitor the disease pressure in the different regions of Arkansas, 2) to determine reactions of rice cultivars to diseases not commonly observed on Experiment Stations, and 3) to compare the yield potential of commercially-available cultivars and advanced experimental lines. Field studies consisting of 20 to 25 cultivars are implemented in 15 to 20 grower fields annually. Rice cultivars are seeded in 8-row (7-in. spacing) x 25 ft long plots and replicated 3 times in a randomized complete block design. Beginning in 2007, additional locations were dedicated to only Clearfield cultivars. Rice Tec 'XL 723', 'Francis', and 'Neptune' were the highest yielding cultivars during 2008. Rice Tec hybrids 'CL XL 729', 'XL 745', and 'CL XL 746' were the highest yielding entries in the Clearfield cultivar study.

INTRODUCTION

Rice diseases can be a major constraint to profitable rice production in Arkansas. Based on IPM disease management methods, we encourage the use of host resistance, optimum cultural practices, and fungicides when necessary, to reduce disease potential. These options provide growers the maximal profit at the lowest disease control cost, all other factors being equal.

The use of resistant cultivars remains the foundation for rice disease management in Arkansas. With some knowledge of field history, growers can pick the cultivar that offers the highest yield potential with the minimal risk for their situation; however, the knowledge to make these selections accurately each year requires on-going field research. Cultivars are developed under controlled experiment station conditions. A large set of data on yield, quality, growth habit, and major disease resistance is collected during the process. Unfortunately, the dataset is incomplete for the many environments where rice is grown in the state because diseases or other problems may not be observed in nurseries conducted on experiment stations. The Disease Monitoring Program was designed to better address the many risks faced by newly- released cultivars. Replicated plots are planted in grower fields across Arkansas and monitored for the development of problems, and for their performance under grower management.

Rice cultivars and management change over time. Research-based change is usually positive overall, but some changes result in increased risks. For example, kernel smut increased over the past decade as more susceptible, but higher yielding cultivars became widespread and false smut became a consistent problem where it had never been noticed before. The risk of blast has been increasing as high-yielding, but susceptible, cultivars continue to be planted on larger and larger acreage.

Monitoring these types of changes allows extension specialists and agents to provide early warning to researchers and growers. It also assists in development of management information to deal with increased risks until solid research data is available to solve new problems. Monitoring of diseases, cultivar reaction, and cultivar performance must be conducted over time and across different environments to be of value. Replicated variety plots on different farms provide research data to make these evaluations, but also are the basis for hands-on education of county agents, consultants, and producers.

The distribution of the different research sites requires considerable travel across the rice producing area of the state. This is beneficial in that it establishes area networking for personnel, and leads to inspection of nearby sites and problems in addition to the variety plots.

The Rice Disease Monitoring Program has evolved into a major part of the rice cultivar development process. The goal of the Rice Extension Program is to have a complete production package when cultivars are released. This includes yield potential, disease reactions, N fertilizer recommendations, and DD50 thresholds. The on-farm evaluation of new cultivars allows a complete disease management package to be developed as well as better information on yield potential and yield response under various environmental and cultural management conditions. Yield potential varies among locations, even within a single year. Examples of data obtained from 2008 demonstrate the variability and suitability of cultivars depending on the conditions on a given farm.

The current study was initiated due to the need for more information about cultivars available to producers. The objectives, therefore, include: 1) to monitor the disease pressure in the different regions of Arkansas, 2) to determine disease reactions of rice cultivars to diseases not commonly observed on experiment stations, and 3) compare the yield potential of commercially-available cultivars and advanced experimental lines.

PROCEDURES

Field studies were conducted at 15 locations in ten counties during 2008. Counties included Craighead, Desha, Jackson, Lincoln, Lonoke, Poinsett, Pope, Prairie, Randolph, and Woodruff. Beginning in 2007, an additional 5 locations were dedicated to only Clearfield cultivars. The varieties in the conventional test included 'Bengal', 'Jupiter', Neptune, 'CL 131', 'CL 151', 'CL 161', 'CL 171 AR', 'Bowman', 'Catahoula', 'Cheniere', 'Cybonnet', Francis, 'JES', 'Taggart', 'Templeton', 'Trenasse', 'Wells', Bayer Cropscience Hybrid 'Arize 1003', and Rice Tec hybrid XL 723. Varieties in the Clearfield test included, CL 131, CL 151, CL 161, CL 171 AR, Rice Tec hybrids CL XL 729, 'CL XL 730' , CL XL 745, and CL XP 746, and fifteen University of Arkansas experimental lines (STG05IMI-01-113, STG05IMI-02-021, STG05IMI-02-043, STG05IMI-02-055, STG05IMI-03-002, STG05IMI-03-101, STG05IMI-04-019, STG05IMI-04-077, STG05IMI-04-091, STG05IMI-05-031, STG05IMI-05-082, STG05IMI-05-123, STG06IMI-02-066, and STG06IMI-02-129). The tests in Pope County and Jackson County were abandoned due to poor emergence and insufficient grass control and subsequent lodging.

Cultivars were planted in 8-row (7-in. spacing) x 25-ft long plots and replicated 3 times in a randomized complete block design. Conventional rice cultivars were seeded at 80 lb/acre while all hybrids were seeded at 30 lb/acre.

Plots were managed by the grower with the rest of the field with respect to fertilization, irrigation, weed and insect control, but in most cases did not receive a fungicide application (Table 1). If a fungicide was applied, it was considered in the disease ratings. Under normal conditions, tests do not receive applications of imazethapyr (Newpath®) herbicide labeled for Clearfield rice. However, the four locations that consisted of only Clearfield cultivars were planted in Clearfield rice fields. These tests received two applications of Newpath and one application of imazamox (Beyond®) per Clearfield rice stewardship. Application of this herbicide allows evaluation of cultivar tolerance and hopefully provides advanced knowledge of cultivars that may not have complete resistance.

Plots were inspected periodically and rated for disease, then harvested at maturity with yield adjusted to 12% grain moisture. Data were analyzed using analysis of variance with means separation using a standard LSD test. Milling analysis was conducted following harvest on selected locations.

RESULTS AND DISCUSSION

Conventional DMP

Rice Tec hybrids were the highest yielding entries in the conventional studies at each location (Table 2). Across all eight harvested locations, the top three entries were

Rice Tec XL 723 (208 bu/acre), Francis (181 bu/acre), and Neptune (178 bu/acre). Among the medium-grain cultivars, Neptune had the best overall yield followed by Bengal and Jupiter. Rice Tec XL 723 was the highest yielding entry at six of the eight harvested locations. Francis was the highest yielding entry at Desha County while Wells was the highest yielding entry at one of the Prairie County locations.

Because of the severe weather conditions encountered during the fall of 2008, lodging notes proved to be quite informative (Table 3). Among all cultivars evaluated, the new experimental line RU0801076 demonstrated extremely good straw strength. Bengal, Bowman, Presidio, and Taggart also exhibited very good straw strength. In contrast, cultivars most susceptible to lodging included Arize 1003 and CL 151. In spite of being a semi-dwarf cultivar, CL 151 should be managed to avoid potential lodging.

Monitoring the severity of disease and the reaction of the various cultivars to the presence of disease is a significant part of this program. The information observed in these plots is often the basis for disease ratings developed for use by growers (Table 4). This is particularly true for minor diseases that may not be encountered frequently, such as narrow brown leaf spot, false smut, and kernel smut.

Diseases in general were not substantial in the 2008 DMP trials and the hot dry weather after mid-July diminished foliar disease development in the state. Cultivar disease reactions were adjusted based on 2008 observations and presented in Table 2. In general, hybrids remained the most disease-resistant cultivars under Arkansas conditions.

Clearfield DMP

Rice Tec Clearfield hybrids were generally the highest yielding entries in the Clearfield studies (Table 5). Rice Tec CL XL 729 yielded the highest over all locations, followed by CL XL 745 and CL XL746. However, two of the University of Arkansas experimental lines (STG05IMI-01-113 and STG05IMI-04-091) had yields that were very competitive with the hybrids. These two experimental lines have been submitted to Horizon Ag and BASF for potential release. This program and other testing programs have become essential for determining the fate of these new lines.

Lodging was observed in three cultivars (Table 6). Rice Tec CL XL 745 had the highest amount of lodging, followed by Rice Tec CL XL 729 and CL 151. The cultivars should be managed to avoid lodging. We observed small amounts of shattering by the hybrids during 2008. Since severe weather can enhance shattering problems, hybrids should be harvested in a timely manner to avoid having the rice in the field during tropical storms. When choices are being made, hybrids should be harvested first, and should commence when moisture contents reach 20%.

SIGNIFICANCE OF FINDINGS

The 2008 on-farm rice evaluation and disease monitoring program provided additional data to the rice breeding and disease resistance programs. These plots and other field observations associated with the program provided early warning for Arkansas growers about leaf blast epidemics in the state as well as information on sheath blight activity on different cultivars in various regions during the summer. The program provided supplemental performance and disease reaction data on new varieties and hybrids that will be more widely grown in Arkansas in 2009. Plots served as the centerpiece for seven different local rice field days and 28 winter grower meetings.

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Table 1. Cultural practices for the Conventional and Clearfield Rice Disease Monitoring Program conducted during 2008.

Location (County)	Seeding date	Field variety	Harvest date
Conventional			
Desha	4/23	Wells	9/16
Craighead	5/1	CL XL 730	10/1
Jackson	5/22	--	9/16
Lonoke	4/14	Wells	9/8
Poinsett	5/6	--	9/25
Pope	5/13	XL 723	10/27
Prairie	4/17	Wells	9/8
Prairie	5/20	Jupiter	10/21
Randolph	5/20	Wells	10/9
Woodruff	5/1	Jupiter	9/22
Clearfield			
Craighead	4/16	CL XL 729	9/9
Jackson	5/22	--	10/1
Lincoln	5/1	CL XL 729	9/10
Poinsett	5/6	--	9/25

Table 2. Performance of selected cultivars in replicated rice disease monitoring tests located in grower fields in Arkansas during 2008.

	Craighead	Desha	Lonoke	Poinsett	Prairie-DA	Prairie-HA	Randolph	Woodruff	Mean	C.V.[z]
	(bu/acre)									
Arize 1003	158		164	188	211	142	152	163	150	36.4
Bengal	157	162	136	181	194	142	209	175	161	20.0
Bowman	130	131	138	167	200	120	190	149	148	19.2
Catahoula	142	101	123	165	211	132	177	153	143	24.0
Cheniere	153	116	136	169	195	139	225	154	153	23.1
CL 131	145	133	120	150	203	151	202	156	149	22.4
CL 151	125	138	143	184	196	133	184	186	147	30.7
CL 161	139	129	127	158	186	148	186	152	147	16.6
CL 171 AR	136	120	120	150	188	152	189	156	143	20.2
Cocodrie	152	112	112	171	218	156	220	180	157	25.9
Cybonnet	141	140	129	158	208	133	197	143	151	19.3
Francis	145	182	148	191	205	155	226	206	179	16.1
Jupiter	151	174	147	173	147	152	193	182	161	11.4
JES	90	107	149	161	209	128	173	149	137	28.3
Neptune	170	152	134	182	220	166	223	177	166	23.8
Presidio	134	153	142	151	173	129	200	137	152	13.8
Rondo	118	135	152	147	154	143	200	168	148	15.5
RT XL 723	190	148	175	195	272	170	294	225	199	25.0
Templeton	156	154	145	163	229	149	204	187	163	23.1
Taggart	123	125	144	175	208	141	212	146	157	21.1
RU0701124	104	141	130	129	164	117	169	158	135	18.6
RU0801076	166	106		178		112	214	170	158	24.1
Trenasse	115	116	114	155	166	146	190	164	135	26.8
Wells	143	154	144	164	209	175	217	160	166	16.5
Mean	141	137	137	167	202	143	202	166	166	
LSD	30.0	20.9	21.1	16.4	49.3	23.5	31.3	19.4		
C.V.	13.0	9.4	9.4	6.0	14.7	10.0	9.4	7.1		

[z] C.V.= coefficient of variation, provides an indication of yield variability across environments. Lower numbers are better.

Table 3. Lodging of selected cultivars in replicated rice disease monitoring tests located in grower fields in Arkansas during 2008.

	Craighead	Desha	Lonoke	Poinsett	Pope	Prairie-DA	Prairie-HA	Randolph	Woodruff	Mean
	(%)									
Arize 1003	96.7	0.0	43.3	0.0	100.0	86.7	86.7	76.7	73.3	66.3
Bengal	0.0	0.0	13.3	0.0	43.3	20.0	0.0	0.0	0.0	7.7
Bowman	0.0	6.7	0.0	0.0	43.3	0.0	0.0	0.0	0.0	5.0
Catahoula	0.0	0.0	50.0	0.0	46.7	0.0	0.0	3.3	0.0	10.0
Cheniere	36.7	16.7	33.3	0.0	26.7	0.0	0.0	0.0	0.0	11.3
CL 131	0.0	0.0	76.7	0.0	60.0	0.0	0.0	0.0	0.0	13.7
CL 151	76.7	6.7	53.3	0.0	96.7	56.7	40.0	43.3	0.0	37.3
CL 161	16.7	0.0	76.7	0.0	83.3	16.7	0.0	0.0	0.0	19.3
CL 171 AR	0.0	0.0	90.0	0.0	70.0	3.3	0.0	0.0	0.0	16.3
Cocodrie	13.3	16.7	76.7	0.0	43.3	13.3	0.0	3.3	0.0	16.7
Cybonnet	13.3	0.0	66.7	0.0	53.3	0.0	0.0	0.0	0.0	13.3
Francis	46.7	0.0	70.0	0.0	56.7	26.7	0.0	0.0	0.0	20.0
Jupiter	66.7	0.0	70.0	20.0	20.0	63.3	3.3	0.0	0.0	24.3
JES	40.0	0.0	0.0	33.3	76.7	0.0	13.3	0.0	0.0	16.3
Neptune	0.0	0.0	33.3	0.0	53.3	20.0	0.0	0.0	0.0	10.7
Presidio	0.0	0.0	26.7	0.0	6.7	0.0	0.0	0.0	0.0	3.3
Rondo	53.3	0.0	3.3	0.0	66.7	66.7	13.3	0.0	0.0	20.3
RT XL 723	50.0	46.7	63.3	23.3	23.3	0.0	0.0	20.0	0.0	22.7
Templeton	56.7	0.0	60.0	20.0	83.3	6.7	6.7	33.3	0.0	26.7
Taggart	60.0	0.0	3.3	0.0	10.0	23.3	0.0	0.0	0.0	9.7
RU0701124	80.0	0.0	23.3	0.0	90.0	16.7	26.7	96.7	0.0	33.3
RU0801076	0.0	0.0		0.0	40.0		0.0	0.0	0.0	5.0
Trenasse	93.3	76.7	63.3	10.0	66.7	13.3	6.7	36.7	0.0	36.7
Wells	66.7	0.0	80.0	0.0	40.0	16.7	20.0	0.0	0.0	22.3

Table 4. Rice variety reactions[z] to diseases (2009).

Variety/Hybrid	Sheath blight	Blast[y]	Straighthead	Bacterial panicl blight	Narrow brown leaf spot	Stem rot[x]	Kernel smut	False smut	Brown spot	Lodging	Black sheath rot
Arize 1003	MR					MS		MS	R	S	MR
Bengal	MS	S	VS	VS	S	VS	MS	MS	VS	MR	MR
Bowman	MS	S	MS	S	MR	S	S	S	R	MR	MS
Catahoula	VS	R	S	S	MR	S	S	S	R	MR	MS
Cheniere	S	S	MS	S	S	S	S+	S+	R	MR	MS+
CL 131	VS	MS	VS	VS	VS	S	S	S	R	R	S
CL 151	VS	VS	VS	S	S	S	S	S	R	MR	S
CL 161	VS	S	MS	S	MS	S	S	S	R	MS	S
CL 171AR	VS	S	MS	S	MS	S	S	S	R	MS	S
Cocodrie	S	MS	VS	VS	MS	S	S+	S	R	MR	MS
Cybonnet	VS	R	MS	S	MS	S	S	S	R	MR	S
Francis	MS	VS	MS	VS	S	S	VS	S	R	MS	MS
JES	MS			MS		S			R	MS	MS
Jupiter	MS+	S	MS	MR	MS	S	MS	MS	R	MR	MR
Neptune	MS				MS	S	MS	MS	?	MR	MR
Presidio	S			MS	MS	S	S	S	R	MR	S
Rondo	MR	R		S	MR	MS	MS	VS	R	S	MR
RT CL XL 729	MS	MR	MR	MR	MS	MS	MS	S	R	S	MS
RT CL XL 730	MS	MR	MR	MR	MS	MS	MS	S	R	S	MS
RT CL XL 745	MS	R		MR	MS	MS	MS	S	R	S	MS
RT XL723	MS	R	MR	MR	MS	MS	MS	S	R	MS	MS
RU0701124	MS	R		S		S			?	MR	MS
RU0801076	MS			S	MS	S	S	S	R	MR?	MS
Spring	S	MS	VS	S	MS	VS	MS	MS	R	S	MS
Taggart	MS	S		MS	MS	S	S	S	R	MS	MS
Templeton	MS	R		MS	MS	S	S	S	R	MS	MS
Trenasse	VS	S	VS	S	S	S	S	S	R	MS	MS
Wells	S	S	MS	S	S	VS	S	S	R	MS	MS

continued

Table 4. Continued.

[z] Reaction: R = Resistant; MR = Moderately Resistant; MS = Moderately Susceptible; S = Susceptible; VS = Very Susceptible. Reactions were determined based on historical and recent observations from test plots and in grower fields across Arkansas. In general, these reactions would be expected under conditions that favor severe disease development including excessive nitrogen rates (most diseases) or low flood depth (blast).

[y] Based on reaction to common races of the rice blast fungus in Arkansas for the most part; however, Banks and other Pi-ta resistant gene based varieties are susceptible to Race IE-1k, a previously rare race that has increased in importance in the state since 2004. All rice varieties should be monitored periodically for blast since the blast fungus is capable of developing new races that can overcome known resistance genes.

[x] Other notes: Most cultivars will be susceptible to stem rot under low K and high N conditions. Bengal and certain other cultivars become very susceptible to brown spot under low K conditions. Most cultivars are susceptible to false smut under high N, late planted conditions. Kernel smut is increased by excessive nitrogen fertilization.

Table prepared by R.D. Cartwright, Professor/Extension Plant Pathologist and F.N. Lee, Professor of Plant Pathology

Table 5. Performance of selected Clearfield cultivars and experimental lines in replicated rice disease monitoring tests located in grower fields in Arkansas during 2008.

	Grain yield				
Cultivar	Craighead	Lincoln	Poinsett	Mean	C.V.
	---------- (bu/acre) ----------				(%)
CL 131	178	179	160	172	6.0
CL 151	172	190	171	178	6.2
CL 161	168	196	174	180	8.1
CL 171 AR	156	186	166	169	8.9
RT CLXL729	213	223	218	218	2.3
RT CLXL730	182	204	188	192	6.0
RT CLXL745	207	220	190	206	7.1
RT CLXP746	212	220	182	205	9.9
STG05IMI-01-113	178	206	197	194	7.2
STG05IMI-02-021	150	184	198	177	14.0
STG05IMI-02-043	169	175	172	172	1.7
STG05IMI-02-055	154	187	182	174	10.1
STG05IMI-03-002	132	180	184	165	17.3
STG05IMI-03-101	149	202	156	169	17.1
STG05IMI-04-019	178	181	194	184	4.5
STG05IMI-04-077	159	173	179	170	6.1
STG05IMI-04-091	176	194	190	187	5.0
STG05IMI-05-031	159	170	171	167	4.0
STG05IMI-05-082	142	176	185	167	13.6
STG05IMI-05-123	161	184	198	181	10.2
STG06IMI-02-066	123	185	180	163	21.2
STG06IMI-02-129	162	194	200	185	11.2
Mean	167	191	183	181	
$LSD_{(0.05)}$	43.7	19.7	27.4		
C.V. (%)	15.8	6.3	9.1		

Table 6. Lodging of selected Clearfield cultivars and experimental lines in replicated rice disease monitoring tests located in grower fields in Arkansas during 2008.

Cultivar	Lodging			
	Craighead	Lincoln	Poinsett	Mean
	------------------------(%)------------------------			
CL 131	0.0	0.0	0.0	0.0
CL 151	0.0	6.7	0.0	2.2
CL 161	0.0	0.0	0.0	0.0
CL 171 AR	0.0	0.0	0.0	0.0
RT CLXL729	0.0	13.3	0.0	4.4
RT CLXL730	0.0	0.0	0.0	0.0
RT CLXL745	0.0	0.0	30.0	10.0
RT CLXP746	0.0	0.0	0.0	0.0
STG05IMI-01-113	0.0	0.0	0.0	0.0
STG05IMI-02-021	0.0	0.0	0.0	0.0
STG05IMI-02-043	0.0	0.0	0.0	0.0
STG05IMI-02-055	0.0	0.0	0.0	0.0
STG05IMI-03-002	0.0	0.0	0.0	0.0
STG05IMI-03-101	0.0	0.0	0.0	0.0
STG05IMI-04-019	0.0	0.0	0.0	0.0
STG05IMI-04-077	0.0	0.0	0.0	0.0
STG05IMI-04-091	0.0	0.0	0.0	0.0
STG05IMI-05-031	0.0	0.0	0.0	0.0
STG05IMI-05-082	0.0	0.0	0.0	0.0
STG05IMI-05-123	0.0	0.0	0.0	0.0
STG06IMI-02-066	0.0	0.0	0.0	0.0
STG06IMI-02-129	0.0	0.0	0.0	0.0

Role of Soil Salinity in Rice Seedling Disease Severity Caused by *Pythium* Species

M.A. Eberle, C.S. Rothrock, N.A. Slaton, and R.D. Cartwright

ABSTRACT

Pythium spp. are the most common seedling disease pathogens isolated from rice in producers' fields in Arkansas. *Pythium arrhenomanes* and *P. irregulare* are the most frequently isolated and virulent of the *Pythium* species in Arkansas. Non- or less virulent *Pythium* species include *P. catenulatum*, *P. torulosum,* and *P. diclinum*. This study examined the role of soil salinity on seedling disease severity using *P. torulosum*. Soil salinity was shown to be an important factor in rice stand establishment in the presence of *P. torulosum*. Damage from *P. torulosum* increased dramatically at salinity levels that would not normally cause stand losses or reductions in growth. In addition, for electrical conductivity treatments greater than 2022 µS/cm, soil salinity reduced root and foliar weight of seedlings and increased leaf necrosis. This research suggests that the interaction between seedling disease pathogens commonly found in soils and salinity may result in greater stand losses.

INTRODUCTION

Stand establishment problems consistently cause significant production losses and management problems in Arkansas rice fields. The causes of stand problems are often difficult to determine; thus practices that would eliminate or reduce the amount of losses are not able to be implemented. Stand problems have been associated with environmental and soil factors, herbicides, insects, and seedling diseases (Rush, 1992). *Pythium* spp., especially *P. arrhenomanes* and *P. irregulare,* are often the most important seedling pathogens on rice and damage is increased under cold soil temperatures (Cother and Gilbert, 1993; Eberle et al., 2008; Rush, 1992). Other less virulent *Pythium* species isolated from rice include *P. catenulatum*, *P. torulosum,* and *P. diclinum*. Research, funded by the Rice Research and Promotion Board, has identified cold-tolerant *Pythium*-resistant rice genotypes that hold the promise for more reliable rice stand establishment in Arkansas under marginal planting environments (Rothrock et al., 2004, 2005, 2006). Soil salinity is another soil factor that may affect rice stand establishment. Rice is very sensitive to increasing soil salinity levels (Maas and Hoffman, 1977; Shannon et al., 1998), and the seedling stage is more sensitive than other growth stages (Heenan et al., 1988; Kaddah, 1963; Lutts et al., 1995; Pearson and Bernstein, 1959).

The objective of this study was to examine the role of soil electrical conductivity (salinity) in rice stand establishment and the development of rice seedling disease caused by *Pythium torulosum*.

PROCEDURES

The importance of soil salinity on seedling disease caused by *Pythium* spp. was examined in an experiment using two infestation treatments, noninfested and infested, and five salinity treatments in a factorial arrangement. Soil from a field near Lake Hogue in Poinsett County, Ark., was pasteurized at ~70°C for 30 minutes to remove soilborne plant pathogens and 375 g of soil, equivalent oven dry weight, was placed in styrofoam containers (115 mm x 75 mm). Inoculum of *P. torulosum* was grown on sand-corn meal medium for 10 days prior to adding to soil for the infested soil treatments. Electrical conductivity (EC) was adjusted with a 1 *M* calcium chloride ($CaCl_2$) solution. The range of EC treatments used were based on ranges found in Arkansas from soil samples taken previously (400 to 5000 μS/cm) (data not shown). Five EC treatments were established by adding 1 *M* $CaCl_2$ solution to the soil in each pot: 18.75 mL, 12.5 mL, 6.25 mL, 3.13 mL, and 0 mL per pot, respectively. The 1 *M* $CaCl_2$ solution was added with enough water to saturate the soil and each container was placed in a saucer to prevent loss of $CaCl_2$ during the duration of the experiment. Soil EC was measured in each pot using a 1:2 soil weight:water volume mixture. Six seed of the cultivar ‘Wells’ were planted in each pot and pots were arranged in a randomized complete block design with four replications. The experiment was conducted in the greenhouse, with an average temperature of 24°C. Containers were watered with deionized water when the soil matric potential reached levels between -10 J/kg and -30 J/kg.

Stand counts were taken at 2 (emergence) and 5 weeks (final stand). At the termination of the experiment, seedlings were removed and leaf number, root weight, root discoloration, percent leaf necrosis, and aboveground seedling dry weight were recorded. Root discoloration and leaf necrosis were assessed on a 1 to 5 scale with 1 = none, 2 = 1 to 10%, 3 = 11 to 25%, 4 = 26 to 50%, and 5 = 51 to 100% discoloration or necrosis. Isolation was done by harvesting the seedlings from the soil and rinsing them for 20 minutes under tap water. After rinsing, the above- and below-(roots) ground plant parts were cut apart and the roots were disinfested in 0.5% NaOCl for 1.5 minutes, blotted dry, and plated on water agar for isolation of the pathogen. Analysis was done by GLM using SAS for the main effects of infestation and soil salinity and main effects and interactions examined as appropriate. Means were separated using a protected Fisher's LSD.

RESULTS AND DISCUSSION

Electrical conductivity levels in the experiment averaged 428 µS/cm for the field soil. Soil EC levels for the other treatments receiving increasing amounts of $CaCl_2$ were: 1144 µS/cm, 2022 µS/cm, 3543 µS/cm, and 4862 µS/cm. Seedling emergence after two weeks averaged 4.2 plants of the 6 seed planted for soil infested with *P. torulosum* and 3.7 plants for the non-infested control across salinity treatments. Emergence was reduced in soil having an EC >2022 µS/cm (Table 1). There was a significant salinity by infestation interaction for final plant stands at five weeks after planting ($p = 0.0493$), indicating the effect of *P. torulosum* on rice was dependent on soil salinity. In the presence of *P. torulosum*, stands were reduced at salinities as low as the 1144 µS/cm salinity treatment, but differences between infested and non-infested treatments were most apparent in the 2022 µS/cm salinity treatment. For soil having an EC of 2022 µS/cm, stands for the infested treatment significantly differed from those of the non-infested treatment and the *P. torulosum* 428 µS/cm salinity treatment (Table 1). In soil that did not have any $CaCl_2$ solution added, *P. torulosum* had a stand of 5.2 compared to 4.2 for the non-infested control suggesting that this *Pythium* species is not important in rice stand establishment under conditions when rice is not under another stress. Results of this study suggest that in fields having soil with moderate salinity problems, damage from *Pythium* species will be more severe. Stand losses due to salinity were not significantly different from the control for the non-infested treatments until a salinity treatment of 3543 µS/cm. The salinity effect is most likely producing a stress on the plant increasing its susceptibility to *Pythium* spp. rather than salinity increasing the activity of the pathogen.

In addition to stand losses, soil having ECs ≥ 2022 µS/cm increased root discoloration compared to the control (428 µS/cm) (Table 2). Root and shoot weights were decreased and leaf necrosis increased at 3543 µS/cm compared to the control. This research is similar to other research showing soil salinity is important in rice development (Heenan et al., 1988; Kaddah, 1963; Lutts et al., 1995; Pearson and Bernstein, 1959; Shannon et al., 1998).

SIGNIFICANCE OF FINDINGS

Field and controlled environmental studies to date have examined the importance of different seedling pathogens and soil and environmental factors on establishment of rice. Five different *Pythium* species have been identified and their importance characterized; *Pythium arrhenomanes, P. irregulare, P. torulosum*, *P. catenulatum*, and *P. diclinum.* Soil salinity is an important soil factor in rice stand establishment and was shown to increase the virulence of *P. torulosum* on rice seedlings. Additional research needs to be done on different pathogenic species of *Pythium* to better define the importance of soil salinity levels on stand establishment. It is likely that the more virulent species will cause even more stand losses and an increase in disease symptoms at moderate soil salinities. The research suggests that salinity may be a significant factor affecting rice stand density as a result of its interaction with seedling disease pathogens commonly found in soils. The knowledge of salinity and its effects on the virulence of different pathogens could be a useful tool to assist producers in determining environmental conditions that may limit stands and seedling development in the field and help to select appropriate management practices.

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Table 1. Effect of soil salinity and *Pythium torulosum* on emergence, averaged across soil infestation, and final rice seedling stands as affected by the interaction of salinity and soil infestation[z].

Soil electrical conductivity	Emergence	Plant stand	
		Non-infested	*P. torulosum*
(µS/cm)			
428	4.9 a[y]	4.2 abc	5.2 a
1144	5.5 a	4.8 ab	4.0 bc
2022	4.8 a	3.5 c	0.5 de
3543	3.0 b	1.2 d	0.5 de
4862	1.6 c	0.5 de	0.0 e

[z] Emergence (2 weeks) and stand (5 weeks) from 6 seed per container with 4 replications.
[y] Means for emergence or stands, followed by the same letter are not significantly different, Fisher's protected LSD (p=0.05).

Table 2. Effect of soil salinity on plant development in noninfested soil.

Electrical conductivity	Leaf number	Root discoloration[z]	Root fresh weight	Leaf necrosis[z]	Foliar dry weight
(µS/cm)			(g)		(g)
428	3.3 a[y]	9.9 c	0.247 a	0.2 a	0.041 a
1144	3.3 a	15.8 bc	0.220 a	5.3 a	0.039 a
2022	3.4 a	39.2 ab	0.150 ab	9.7 a	0.034 a
3543	2.6 a	58.0 a	0.056 b	28.5 a	0.014 b
4862[x]	--	--	--	--	--

[z] Average percentage of root discoloration or leaf necrosis (mid-percentile values) for the scale: 1 = none, 2 = 1 to 10%, 3 = 11 to 25%, 4 = 26 to 50%, and 5 = 51 to 100% discoloration or necrosis.
[y] Means in a column followed by the same letter are not significantly different, Fisher's protected LSD (p=0.05).
[x] Means are not given as a result of limited number of plants and replications for analysis as a result of plant death.

Control of Rice Water Weevil by Seed Treatments with Rynaxypyr and Thiamethoxam

J.L. Bernhardt

ABSTRACT

Rice water weevil adults, *Lissorhoptrus oryzophilus* Kushel, are commonly found in rice fields after the permanent flood is applied. Sometimes control is necessary to prevent heavy infestations from pruning so many roots that yield is reduced. Treating for weevils postflood requires careful scouting to ascertain if enough weevils are present to justify treatment. Should the option be available, seed coated with an insecticide simplifies management decisions for weevils. Two insecticides applied as coating on seed were tested in small plots at the Rice Research and Extension Center in 2007 and 2008. Both rynaxypyr (Dermacor X-100) and thiamethoxam (Cruiser 5FS) gave excellent control of rice water weevil larvae at the rates tested. Should one or both insecticides become available, then growers will be faced with the difficult decision of whether to use a seed treatment and not know if the weevil population will be above threshold, or whether to use a postflood insecticide application after scouting a field for weevil adults.

INTRODUCTION

The onset of the permanent flood attracts rice water weevil adults, *Lissorhoptrus oryzophilus* Kuschel, a pest common to Arkansas rice fields. Characteristic narrow longitudinal scars that parallel the mid-vein of rice leaves are evidence of feeding by adults. The presence of submerged plants simulates female weevils to lay eggs in the submerged portions of leaf sheaths. The larvae feed on rice roots and when the damage is severe, grain yields will be reduced. Differences in field tolerance to root pruning by larvae were found in rice cultivars that were planted in yearly studies from 1998 to 2002 with multiple planting dates (Bernhardt and Richards, 2003). Unfortunately infestations sometimes become so large that any tolerance can be overcome. In order to prevent damaging levels of larvae, insecticides such as lamba cyhalothrin (KarateZ, for example), zeta cypermethrin (Mustang Max), gamma cyhalothrin (Prolex), and etofenprox (Trebon) are available that control adults. However, any application must be applied within 7 to 10 days postflood to control adults before eggs are laid. Ideally any insecticide applied postflood would result from careful scouting of the field 2 to 5 days after the permanent flood so that the application could be timed for maximum benefit. Certainly the use of seed coated with insecticide at planting simplifies procedures, but requires a decision for treatment many months prior to planting and scouting for occurrence of adult weevils after flood.

These studies investigated the use of the insecticides rynaxypyr (Dermacor X-100) and thiamethoxam (Cruiser 5FS) for control of rice water weevil larvae when applied as seed treatments.

PROCEDURES

One study was conducted in 2007 and two studies in 2008. In each study, rice plots were arranged in a randomized block design with four replications at the Rice Research and Extension Center near Stuttgart. Plots had 9 rows with a 7-in. spacing, were 25 ft long, and had a seeding rate of 90 lb/acre in 2007 and 75 lb/acre in 2008. Each plot of rice was surrounded by levees and flood depth was maintained at four inches all season. In 2007, plots were planted with 'Wells' rice on 19 April, emerged on 29 April, fertilized with 120 lb N/acre as urea, and flooded on 23 May. Treatments in 2007 consisted of an untreated check, a standard KarateZ (lambda cyhalothrin) at 0.03 lb active ingredient (ai)/acre sprayed onto plots at eight days after permanent flood, and rynaxypyr was coated on seed at 0.047, 0.095, 0.189, and 0.378 lb ai/acre.

In 2008, plots in the rynaxypyr study were planted with Wells rice on 21 April, emerged on 2 May, were fertilized with 120 lb N/acre as urea, and flooded on 3 June. Treatments were an untreated check, KarateZ at 0.03 lb ai/acre sprayed on 11 June, and rynaxypyr coated on seed at 0.095, 0.189, and 0.378 lb ai/acre. In 2008, plots in the thiamethoxam study were planted with 'CL 161' rice on 23 April, emerged to a stand on 9 May, were fertilized with 120 lb N/acre as urea, and flooded on 5 June. Treatments were an untreated check and seed treatments of thiamethoxam at 0.114 lb ai/acre, two other formulations at 0.128 lb ai/acre, thiamethoxam at 0.076 and 0.114 lb ai/acre plus 0.095 lb ai/acre rynaxypyr, and rynaxypyr at 0.095 lb ai/acre. Preflood herbicides were applied according to weed species present. Nitrogen fertilizer was applied in a 2-way split with 80% at flood and 20% (30 lb) added on 25 June, 2007 and 3 July, 2008 for the rynaxypyr study, and 1 July for the thiamethoxam study.

For each study, three soil/plant core samples 4-in. diameter by 4-in. depth were taken from each plot at three and four weeks after the permanent flood and evaluated for rice water weevil larvae. In the laboratory, each soil core was washed with pressurized water to loosen soil and remove larvae from the roots into a 40-mesh sieve.

The sieve was immersed in a saturated salt solution to float the larvae. Larvae were removed, sized, and counted. A central portion of each plot measuring 4 rows by 20 ft was cut with a small plot binder and threshed in a Vogel thresher. Grain moisture was corrected to 12% prior to analyses. Rice water weevil larval numbers and grain yields are analyzed with PROC ANOVA (Statistical Analysis System) to determine significant control of weevils and the impact on yields.

RESULTS AND DISCUSSION

In 2007, the natural population of rice water weevils in the untreated plots was high and ranged from 23 to 91 in an individual core sample, but averaged about 45/core at three and four weeks after the permanent flood (Table 1). The plots treated with rynaxypyr had significantly lower densities of weevil larvae. Also, a rate response was evident with the average number of larvae decreasing as the rate of rynaxypyr increased. Overall control with rynaxypyr was excellent and was comparable to control with a postflood foliar application of KarateZ. Residual control was also excellent and extended into the fourth week after flood. Generally, by the fourth week after flood the distribution of larvae shifts from the small sizes to large larvae and pupae (Table 2) which indicates the population has peaked and will soon start to decline. The grain yields for the rynaxypyr treatments averaged about 15 bu/acre more than the untreated and about 10 bu/acre more than the KarateZ treatment. The KarateZ and rynaxypyr control was about the same, yet yield in the seed treatments was much higher. Perhaps the rynaxypyr seed treatment had some other effect on the plants.

In 2008, the natural population of weevils in the untreated plots was moderate and ranged from 11 to 41/core sample in the rynaxypyr (Dermacor X-100) study and from 10 to 50/core in the thiamethoxam (Cruiser) study. As in 2007, the plots treated with rynaxypyr had significantly lower densities of weevil larvae when compared to the untreated, and a rate response was also observed, and residual control extended into the fourth week after flood (Table 3). There were no significant differences in grain yields between the treatments. Also, no evidence of a plant stimulus (i.e., higher yield) was found in 2008 as was observed in 2007. The moderate infestation of weevils in this study was near the threshold level of 25 larvae/core established for Wells rice in previous studies that would be needed before weevil larvae would have a significant impact on yields (Bernhardt and Richards, 2003).

The rates or formulations of Cruiser had not given adequate control of weevil in studies conducted in the six years prior to this study. In 2008, the formulations of thiamethoxam (Cruiser) at and above 0.114 lb ai/acre gave excellent control of larvae (Table 4). The addition of a rynaxypyr coating to the Cruiser seed coating did not significantly improve control at 3 and 4 weeks after flood. As in the other test in 2008, weevil populations were only slightly higher than the 25 larvae/core that were needed to influence yields (Bernhardt and Richards, 2003).

SIGNIFICANCE OF FINDINGS

The use of insecticide coated seed at planting certainly simplifies control, but the decision between the use of treated seed or a postflood application of insecticide can be difficult. If a grower knows that certain rice fields get heavy infestations of weevils, the decision could be simple. However, if a grower does not know what type of infestation fields normally get, then the decision could be more difficult. Both rynaxypyr (Dermacor X-100) and thiamethoxam (Cruiser 5FS) when coated on rice seed will give excellent control of rice water weevil larvae.

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Table 1. Densities of rice water weevil (RWW) larvae in core samples from plots untreated and treated with insecticides, and average plot yields at Stuttgart, Ark., 2007.

	Avg. RWW		Control		
Treatment	3 WAF[z]	4 WAF	3 WAF	4 WAF	Yield[y]
	------- (#/core)-------		---------- (%) ----------		(bu/acre)
Untreated	45.17 a	45.23 a	--	--	194.8
Rynaxypyr 0.047[x]	3.08 b	4.75 b	93.2	89.5	209.8
Rynaxypyr 0.095	1.50 b	2.08 b	96.7	95.3	202.0
Rynaxypyr 0.189	0.83 b	0.92 b	98.1	97.9	209.6
Rynaxypyr 0.378	0.75 b	0.42 b	98.3	99.1	209.0
KarateZ 0.03	1.00 b	0.83 b	97.8	98.2	199.4
LSD	8.85	11.4			NS

[z] WAF = weeks after permanent flood.
[y] Grain yield in bushels per acre corrected to 12% moisture.
[x] lb active ingredient/acre.

Table 2. A distribution of the size of rice water weevil larvae taken from untreated plots at Stuttgart, Ark., 2007 and expressed as a percentage of the total number collected.

Weeks after	Size of rice water weevil larvae				
flood	Very	Small	Medium	Large	Pupa
	(%)				
3	19.2	43.3	20.3	17.2	0
4	14.2	27.6	19.9	35.9	2.4

Table 3. Densities of rice water weevil (RWW) larvae in core samples from plots untreated and treated with insecticides, and average plot yields at Stuttgart, Ark., 2008.

	Avg. RWW		Control		
Treatment	3 WAF[z]	4 WAF	3 WAF	4 WAF	Yield[y]
	(#/core)		(%)		(bu/acre)
Untreated	24.0 a	27.7 a	--	--	210.7
Rynaxypyr 0.095[x]	4.4 b	4.5 b	81.6	83.8	211.3
Rynaxypyr 0.189	3.4 bc	3.5 b	85.8	87.4	217.5
Rynaxypyr 0.378	1.1 c	1.5 b	95.0	94.6	219.5
KarateZ 0.03	0.9 c	1.25 b	96.2	95.5	212.9
LSD	3.22	5.47			NS

[z] WAF = weeks after permanent flood.
[y] Grain yield in bushels per acre corrected to 12% moisture.
[z] lb active ingredient/acre.

Table 4. Densities of rice water weevil larvae in core samples from plots untreated and treated with insecticides, and average plot yields at Stuttgart, Ark., 2008.

	Avg. RWW		Control		
Treatment	3 WAF[z]	4 WAF	3 WAF	4 WAF	Yield[y]
	(#/core)		(%)		(bu/acre)
Untreated	25.2 a	23.8 a	--	--	195.6
Cruiser 0.114[x]	2.3 b	5.4 b	90.7	77.3	201.0
Cruiser A 0.128	1.9 b	3.7 b	92.4	84.5	196.8
Cruiser B 0.128	2.7 b	4.3 b	89.4	81.9	197.4
Cruiser 0.076 + rynaxypyr 0.095	2.5 b	1.5 b	90.1	93.7	202.9
Cruiser 0.114 + rynaxypyr 0.095	2.1 b	2.6 b	91.7	89.1	199.1
Rynaxypyr 0.095	1.0 b	2.3 b	96.0	90.3	205.0
LSD		5.3	6.8		NS

[z] WAF = weeks after permanent flood.
[y] Grain yield in bushels per acre corrected to 12% moisture.
[x] lb active ingredient/acre.

Susceptibility of Nine Indica Germplasm Lines to Three Rice Insect Pests and Selected Kernel Diseases

J.L. Bernhardt

ABSTRACT

Nine indica germplasm lines developed and released by the U.S.D.A. were evaluated for susceptibility to three rice insect pests and selected kernel diseases. In these studies where yields were compared between untreated and plots treated with the insecticide fipronil to protect against rice water weevils, seven (indica 1, 2, and indica 4 through 8) of the nine indica lines were very tolerant to root pruning by moderate to high densities of weevils. Of note was indica-3 that had properties similar to that of the typical southern japonica cultivar 'Wells' in which the rice was apparently less attractive to weevils and had low infestations, and required more than 25 larvae/core to have a modest yield loss. Also similar to Wells, the indica lines were not very susceptible to whiteheads caused by the rice stalk borer. Unlike the southern japonicas Wells, 'LaGrue', and 'Cocodrie', the indica lines were resistant to kernel infection by kernel smut. The indica lines were susceptible to damage that is caused by rice stink bugs and infection by false smut, a disease of rice kernels.

INTRODUCTION

The U.S. long-grain cultivars are typically tropical japonicas, while short- and medium-grain cultivars are temperate japonicas (Mackill 1995). Grain quality and cooking requirements in the U.S. are so demanding that infusions of germplasm from non-japonicas usually has been limited to individual characters followed by backcrossing to a japonica parent to recover satisfactory grain quality. In 2005, the USDA-ARS and the Arkansas Agricultural Experiment Station released nine indica germplasms of rice (indica-1 to -9, PI 634575 to PI 634583) (Rutger et al., 2005). The nine lines are recombinants from indica by indica crosses. A Chinese indica cultivar, 'Zhe 733' (PI 629016), was the female parent and the male parent was 'IR64' (PI 497682) for indica-9 or one of six indica experimentals provided by G. S. Khush of International Rice Research Institute for indica-1 to indica-8. The nine indica germplasm lines were selected for early maturity and amylose content similar to U.S. long-grains, and a means of broadening the narrow base of U.S. rice cultivars. Although having weak straw compared to japonicas, the nine indicas generally were competitive in yield.

The initial crosses for the nine indicas were made in 1998 and were followed by four years of field tests and selections for early maturity and amylose content. In 2001 plant/soil core samples were taken from six of the 59 F_7 selections, the tropical japonica check 'Drew', and two of the indica parents, Zhe 733 and IR64. The cores were evaluated for rice water weevil larvae, *Lissorhoptrus oryzophilus* Kuschel. Drew had an average of 65 larvae/core and had a grain yield of 115 bu/acre. The parental lines Zhe 733 and IR64 had an average of 63 and 121 larvae/core, respectively, and grain yields of 132 and 160 bu/acre, respectively. The six indica selections had infestations that ranged from 62 to 98 larvae/core and yields from 130 to188 bu/acre. The apparent field tolerance to extremely heavy infestation of some indicia lines to injury was interesting but not enough samples were taken for conclusive data. So, more tests were planned in 2003 and again in 2007.

The field tests were to evaluate the nine indica lines for susceptibility to three insect pests: the rice water weevil; the rice stalk borer, *Chilo plejadellus* Zincken; and the rice stink bug, *Oebalus pugnax* (F.). During evaluations for stink bug damage, the brown rice was examined for kernel smut and false smut. The results of the 2001 preliminary evaluations were presented in Bernhardt and Rutger (2005) and Rutger et al. (2005). The results of the 2003 and 2007 evaluations are presented in this article.

PROCEDURES

In 2003 and 2007, plots were arranged in a split plot design with four replications. The main plots were insecticide treated or not and rice lines were the subplots. Fipronil (Icon 6.2FS) at 0.05 lb ai/acre was applied to the surface and incorporated in 2003, but applied as a seed treatment in 2007. Plots had 9 rows with a 7-in. spacing and were 8 ft long. Rice was drill-seeded at a rate of 90 lb/acre. Each subplot group was surrounded by levees. In 2003 and 2007, respectively, rice was planted on 9 June and 12 June, emerged on 14 June and 23 June, was flooded on 8 July and 16 July, soil cores were taken 3 and 4 weeks after flood, and plots were harvested on 13 October and 19-20 October. Herbicides were applied according to weed species present and for residual activity. Nitrogen fertilizer was applied in a 2-way split with recommended amounts for japonica checks and 100 lb/acre urea preflood for the indicas. The tests were planted in June to take advantage of the usual late-season high populations of weevils, stalk borers, and stink bugs.

Sampling for each rice insect pest and kernel discoloration required different procedures. For rice water weevil larvae, sampling began at three and four weeks after permanent flood when 2 soil/plant core samples (4-in. diameter by 4-in. depth) were taken from each plot. In the laboratory, each soil core was washed with water to loosen the soil and remove larvae from the roots into a 40-mesh sieve. The sieve was immersed in a saturated salt solution to float the larvae. Larvae were removed, sized, and counted. Sampling for rice stalk borers began at two weeks after initial heading when whole plots were examined for the number of whiteheads. A whitehead is a panicle with all sterile florets that emerges from the boot and shortly thereafter becomes completely white. The sterile florets are a result of the feeding and tunneling efforts of rice stalk borer larvae in the rice stem. Another count was taken about 10 days later. The total number of whiteheads was used as an indicator of the susceptibility of a line to rice stalk borer. Sampling for rice stink bug damage and diseased kernels is started only after harvest and drying of the grain. A 0.5-lb rough rice sample was dehulled with a McGill No.2 rice sheller. The brown rice was passed three times through an electronic color sorter that separates at 98 to 99% of the discolored kernels from the undamaged kernels. The discolored kernels are then categorized as: (1) damage by rice stink bug; (2) kernels infected with kernel smut (*Tilletia barclayana* (Bref.) Sacc. & Syd.) or false smut (*Ustilaginoidea virens* (Cooke) Takah.); (3) linear damage; and (4) any discoloration not caused by agents described in 1, 2, or 3. The amount in each category is weighed and a percentage, by weight, was calculated for each category.

Plots were cut with a Mitsubishi binder, threshed with a Vogel thresher, and grain yields per acre were estimated from 8 ft of row from 4 central rows. Grain moisture was corrected to 12% prior to analyses. Statistical Analysis Systems (SAS) PROC ANOVA was used for analyses.

RESULTS AND DISCUSSION

Each year of the study had a different density of rice pests and diseases. Rice water weevil populations were high each year, but densities were slightly higher in 2007. Rice stalk borers were present at moderate levels in 2003, but were nearly absent in 2007. Using the amount of damage kernels as an indicator, it was apparent that rice stink bugs were more numerous in 2003 than 2007. Environmental conditions favored kernel smut in 2003, but not in 2007. The reverse was true for false smut. Also, when compared to 2003, the weather was dry and very hot during flowering in 2007 and caused many sterile florets and lowered grain yields. Each year plots treated with fipronil had a significant lower densities of rice water weevils and rice stalk borers, but fipronil did not influence rice stink bug and disease populations.

Rice Water Weevil

Both years had high infestations of rice water weevils. In 2003, there were no significant differences between any indica line or check variety for average weevils per core sample (Table 1). However, there appeared to be some checks and indica lines that were preferred by weevils in the 2003 study, and certainly in the 2007 study the same indica lines checks were significantly preferred by weevils. The check lines ‘Cocodrie’ and ‘Jupiter’ and indica-6 and -7 were preferred over the other lines. The check lines ‘Wells’ and ‘LaGrue’ and indica-3 were the least preferred.

In 2003, seven of the indica lines displayed good tolerance to injury from weevils at moderate to high densities (Table 1). Only two lines, indica-3 and -9, had slight yield losses at moderate weevil densities. In 2007, indica-3 and -9 again had yield losses, but so did indica-5, -6, and -7. Indica-6 and -7 both had higher larval densities than the previous year. Apparently the tolerance of the indica lines has limits. The indica lines had much greater tolerance than Cocodrie and LaGrue, and better than Wells and Jupiter. Also, Jupiter displayed good tolerance to high weevil densities by having low yield losses.

Rice Stalk Borer

The number of whiteheads in a plot was used as an indicator of susceptibility to the stalk borer (Table 2). In 2007, the overall infestation was very low and only a few were observed throughout in the whole study. The study in 2003 gave more information on susceptibility. None of the indica lines were as susceptible as the very susceptible cultivar Cocodrie. Indica-3, -5, and -9 had only slight susceptibility similar to that of cultivar LaGrue. Indica-1, -2, -4, -6, -7, and -8 were as resistant to the rice stalk borer as the cultivar Wells.

Rice Stink Bug

Susceptibility to rice stink bug feeding and pathogen infection was monitored by examining brown rice for the presence of specific types of discolorations (Table 2). The percentage amount of damage, by weight, was higher in samples from 2003 than in those from 2007, and was due to variations in the rice stink bug populations. However, in both years all indica lines were susceptible to rice stink bug. No lines had the apparent low susceptibility consistently found in Wells and LaGrue.

Kernel Smut and False Smut

Susceptibility to kernel smut infection was monitored by examining brown rice for the presence of blistered bran and spherical black spores (Table 3). The hot and dry weather in 2007 did not favor kernel smut infection and incidence was quite low. Based on data from both years, all indica lines were highly resistant to kernel smut. The japonica varieties Cocodrie, LaGrue, and Wells were not resistant.

Not enough false smut was found in 2003 to adequately evaluate the study for susceptibility to the disease. However, in 2007 environmental conditions must have favored the disease (Table 3). All indica lines appeared susceptible to false smut. Further studies would be needed to verify that indica-1 and indica-8 were more susceptible than the other indica lines.

SIGNIFICANCE OF FINDINGS

The nine indica germplasm lines developed and released by the USDA had interesting qualities when evaluated for susceptibility to three rice insect pests and selected kernel diseases.

In general, most of the indica lines were tolerant to root pruning by rice water weevils, not very susceptible to whiteheads caused by the rice stalk borer, resistant to kernel infection by kernel smut, but were susceptible to damage by rice stink bugs and infection by false smut, a disease of rice kernels. Perhaps, the good qualities of the indica germplasm lines could be infused into the rice breeding programs and give new lines with tolerance to two insect pests and a kernel disease.

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Table 1. Average densities of rice water weevil immatures found in untreated plots of nine indica germplasm lines and japonica rice varieties in tests conducted in 2003 and 2007, Stuttgart, Ark.

	Larvae/Core 3[z]		Yield loss[y]	
Rice line	2003	2007	2003	2007
	---------- (WAF) ----------		-------- (bu/acre)--------	
Cocodrie	38.9	45.2	42.6	38.6
Indica 6	37.3	50.5	0.0	5.2
Indica 7	36.5	41.7	0.0	5.9
Indica 4	34.0	33.0	0.0	0.0
Indica 2	31.8	33.4	0.0	0.0
Indica 1	31.6	35.1	0.0	0.0
Indica 8	30.3	35.6	0.0	0.0
Indica 9	28.5	32.2	15.5	8.0
Indica 5	26.9	29.9	0.0	4.9
LaGrue	24.6	--	23.9	--
Jupiter	--	51.7	--	3.7
Indica 3	23.5	25.9	4.3	2.2
Wells	22.0	37.4	9.3	5.9
LSD	NS[x]	10.9		

[z] WAF = weeks after permanent flood.
[y] Yield loss calculated by subtracting yield in the untreated plot from yield in the treated plot.
[x] NS = no significant differences.

Table 2. Average damage by rice stink bug and rice stalk borer in nine indica germplasm lines and check japonica rice varieties in tests conducted in 2003 and 2007, Stuttgart, Ark.

	Rice stink bug damage[z]		Whiteheads[y]
Rice line	2003	2007	2003
Indica 1	1.22	1.11	2.25
Indica 2	2.26	1.10	0.75
Indica 3	2.31	0.72	9.00
Indica 4	1.12	0.68	0.50
Indica 5	1.76	0.83	8.50
Indica 6	1.84	1.05	1.75
Indica 7	1.60	1.23	2.25
Indica 8	1.49	0.45	0.25
Indica 9	1.82	0.57	10.25
Cocodrie	1.05	0.52	65.00
LaGrue	0.69	--	11.75
Jupiter	--	0.45	--
Wells	0.54	0.18	2.25
LSD	0.663	0.96	6.85

[z] Amount of damage presented as average percentage, by weight, in 0.5-lb samples of rough rice from treated and untreated plots.
[y] Number of plants damaged by rice stalk borer presented as the average number per plot in untreated rice.

Table 3. Average amount of kernels damaged by kernel smut and false smut in nine indica germplasm lines and check japonica rice varieties in tests conducted in 2003 and 2007, Stuttgart, Ark.

	Kernel smut[z]		False smut[y]
Rice line	2003	2007	2007
Indica 1	0.000	0.000	13.25
Indica 2	0.002	0.003	0.50
Indica 3	0.001	0.004	1.50
Indica 4	0.000	0.000	1.00
Indica 5	0.009	0.000	0.25
Indica 6	0.002	0.000	1.25
Indica 7	0.008	0.003	4.75
Indica 8	0.000	0.000	33.25
Indica 9	0.010	0.000	0.25
Cocodrie	0.160	0.015	0.50
LaGrue	0.132	--	--
Jupiter	--	0.109	5.50
Wells	0.029	0.029	10.25
LSD	0.0867	0.064	20.9

[z] Amount of damage presented as average percentage, by weight, in 0.5-lb samples of rough rice from treated and untreated plots.

[y] Presented as the average number in 1-lb samples of rough rice from treated and untreated rice.

Molecular Detection and Genetic Characterization of the Panicle Rice Mite, *Steneotarsonemus spinki*

R.J. Sayler, A.P.G. Dowling, and R.D. Cartwright

ABSTRACT

The panicle rice mite, *Steneotarsonemus spinki* Smiley, has been a serious pest of rice (*Oryza sativa*) across tropical Asia (Tseng, 1984) and was introduced to the tropical Americas in the late 1990's. Since introduction to the Americas, *S. spinki* has been responsible for crop losses ranging from 30 to 90% per year (Almaguel et al., 2000). Damage caused by mite infestations and the vectored sheath rot fungus (*Sarocladium oryzae*), leads to deformation, yield loss, and sterility in rice plants. The mite was recently found in the United States, primarily in greenhouse and research facilities in Texas, Puerto Rico, Louisiana, Arkansas, New York, and California. The potential for damage by the panicle rice mite in temperate climates is unknown at this time if it becomes established in agricultural plots. We have begun to obtain population genetic data from the panicle rice mite in order to aid in identification, and detection so we can monitor the spread of the mite in the United States. We have extracted and sequenced the mitochondrial cytochrome oxidase subunit I (COI) for several U.S. populations of *S. spinki* collected in 2007 and 2008. All COI sequences from U.S. populations have been identical supporting the hypothesis that these infestations are very recent invasions into these research greenhouses, likely occurring around the same time period since they haven had a chance to diverge yet.

INTRODUCTION

The United States produces approximately 9 million metric tons of rice, worth roughly $2.5 billion, yearly and is one of the top five rice exporters worldwide. The panicle rice mite has caused 30 to 90% yield loss since introduction to the Caribbean and Central America. When in association with sheath rot fungus (*Sarocladium oryzae*), which it is thought to commonly vector among rice plants, losses and plant sterility are often greater than 70% (Chen et al., 1979). Recent discovery of the mite in Puerto Rico, which provides seed to rice researchers and certain commercial seed companies, and in Louisiana, Arkansas, Texas, and recently California, could potentially cause problems for the United States rice industry. Successful establishment of the mite in U.S. rice fields could result in economic losses, as yet unknown but of concern. If the mites become established in the southern U.S. there are no labeled pesticides which work to control them, and they reside in the leaf sheath and are hard to kill. Another concern is that many pest mites have shown abilities to quickly form resistance to pesticides, increasing the yearly expense for control and the hazards for producers and consumers. Studies need to be conducted to see if the panicle rice mite can overwinter in Arkansas and the southern U.S., and to learn if quarantines will be necessary to maintain in the future. Potentially, natural predators might be used to control mite populations. Traditionally with invasive species, U.S. policy has dictated that a project is not worth funding until the invasive organism has reached pest status (e.g., emerald ash borer, red fire ants, zebra mussels). Unfortunately, once an invasive species becomes established and widespread it is often very difficult to control or eradicate. Additionally, most research on control programs takes numerous years before any applicable procedures or treatments are ready for wide scale field testing. Because of the early detection of this mite, we have the opportunity to get ahead in the game and develop control methods before the mite establishes and causes major damage. The objective of this study was to determine the genetic diversity of the U.S. rice panicle mite populations to: 1) determine if they are a recent introduction or a longtime resident; and 2) compare them with foreign mite specimens and potentially understand where U.S. populations came from. A subsequent objective of this study is to develop molecular detection tools for rapid and conclusive identification of the pest and to assist quarantine efforts in preventing infested seed lots (a suspected source of entry) from being imported to the U.S.

PROCEDURES

The identity of ethanol preserved rice panicle mite samples received from aphis was confirmed by visual examination using a dissecting microscope. Representative mites from each sample were slide mounted and several individual mites from each sample were selected for DNA extraction. Mite DNA was extracted using the QIAamp DNA Micro Kit from (Qiagen Inc. Valencia, Calif.). The COI gene and ITS region was amplified using Platinum TAQ DNA polymerase (Invitrogen™, Carlsbad, Calif.) with conditions described at the following web site (http://www.dnabarcoding.ca/pa/ge/research/protocols/amplification). COI primers were HCOI 5’-TAAACTTCAGGGT-GACCAAAAAATCA-3’ and LCOI 5’- GGTCAACAAATCATAAAGATATTGG-3’. COI PCR conditions were as follows: 1) 94°C 3 min; 2) 94°C 30 sec; 3) 45°C 40 sec; 4) 72°C 1 min; 5) Goto 2 4 times; 6) 94°C 30 sec; 7) 51°C 40 sec; 8) 72°C 1 min; 9)

Goto 6 34 times; 10) 72°C 10 min; and 11) 4°C. The ITS sequences were amplified using primers ITS-318SF 5'-AGAGGAAGTAAAAGTCGTAACAAG-3', ITS-528SR 5'-ATATBCTTAAATTCAGGGGG-3'. The ITS PCR conditions were as follows: 1) 95°C 5 min; 2) 95°C 30 sec; 3) 48°C 30 sec; 4) 72°C 3 min; 5) Goto 2 35 times; 6) 72°C 10 min; and 7) 4°C. PCR amplified DNA samples were analyzed on a 1% agarose gel and stained with GelRed™ (Biotium Inc., Hayward, Calif.). PCR were purified using the QIA-quick PCR Purification Kit (Qiagen Inc., Valencia, Calif.). PCR products were sequenced by Macrogen Inc. (Rockville, Md.) and sequences were analyzed using Vector NTI software (Invitrogen™, Carlsbad, Calif.).

RESULTS AND DISCUSSION

We began work on this project in April 2008 to determine the genetic diversity, occurrence, and mode of dispersal of the panicle rice mite (*Steneotarsonemus spinki*) in the rice growing area of Arkansas. Our initial objective was to determine the genetic diversity of the panicle rice mite. Given this objective requires DNA extraction, PCR amplification, and DNA sequencing of a large number of panicle rice mite samples, we initiated experiments to optimize the protocols for each step. This optimization was intended to maximize data quality while minimizing the cost of research supplies early in the data collection process.

Extracting a sufficient quantity of DNA from an individual microscopic panicle rice mite for PCR amplification is technically challenging. Prior to this project, we used the DNeasy kit from Qiagen for other mite species, but switched to the DNA Micro Kit for the especially small panicle rice mite and found it to be superior. We then tested the effect of freezing the panicle mite in the kits suspension buffer, because researchers reported that this improved DNA yield. No improvement in PCR amplification was observed in our laboratory. We also found that the addition of trehalose to the PCR reaction mixture improved PCR amplification over the standard PCR conditions using Invitrogen Platinum TAQ. This protocol was developed by the Canadian Centre for DNA Barcoding and is published on their website (http://www.dnabarcoding.ca/pa/ge/research/protocols/amplification).

In order to reduce costs, we tested "home-made" TAQ DNA polymerase prepared by Dr. Burt Bloom at the Department of Plant Pathology at the University of Arkansas against the Invitrogen Platinum TAQ. Unfortunately, only the Platinum TAQ amplified target DNA from our highly dilute mite DNA samples.

We have extracted and sequenced the mitochondrial cytochrome oxidase subunit I (COI) for numerous U.S. populations of *S. spinki* collected in 2007 and 2008. Specimens from 2007 came from a Cornell greenhouse (N.Y.), Rice Tec, Inc. (Houston, Texas), a Texas research greenhouse, and LSU research fields (La.). Specimens from 2008 were obtained via USDA, APHIS Inland Inspection (Austin, Texas) from locations in New York (Cornell University Greenhouse), Arkansas (Dale Bumpers National Rice Research Center), and Texas (RiceTec, Inc.). All samples obtained to date have been extracted and all successful extractions have been amplified and sequenced. Cytochrome oxidase

I (COI) was the gene of choice for this study because of its high copy number, fast mutation rate, and a comparatively small variance within species making it an excellent candidate for molecular diagnostics as well as for the analysis of genetic diversity. Multiple COI sequences have been obtained for *S. spinki* from all locations previously mentioned and results have indicated that all posses identical COI sequences. We have also sequenced COI for *Tarsonemus bilobatus* found in rice from a research field at LSU collected in 2007. *T. bilobatus* is another mite commonly found in rice plants and we need these sequences to distinguish them from the panicle rice mite sequences. This is especially useful for the purpose of molecular diagnostics. We will continue to receive and analyze other rice associated specimens in order to distinguish all possible species from PRM.

To date, confirmed panicle rice mites have been collected from Arkansas, Louisiana, Texas, and New York. We are currently pursuing panicle rice mite DNA from Latin America and other rice-growing regions in the world. We are also including other mites commonly found on rice for use in our genetic diversity and molecular diagnostic studies. We are currently in the process of selecting at least four individual mites under a dissection scope for DNA analysis and several for morphological documentation. DNA sequences of these individual mites will be obtained through a process of DNA extraction, PCR amplification of the COI gene, and/or ITS region followed by DNA sequence analysis.

In order to further characterize the genetic diversity of rice panicle mites collected in the U.S., we initiated experiments to PCR amplify the ITS region of *S. spinki* and related mites. The initial attempt at PCR amplification failed to produce visible bands on an agarose gel. To determine if differences in the size of the ITS region was the cause of this failure, the ITS region from a related group of mites (Red palm mite) was amplified using a longer extension time 3 min vs. 1 min. These experiments were necessary due to the limited quantity of the rice panicle mite DNA. A larger, nonrelated mite, *Dermanyssus gallinae*, was also used a positive control in these ITS amplification experiments. Agarose gel electrophoresis of the ITS PCR amplifications of these mites revealed dramatic differences in size between the positive control and the larger ITS region of the palm mite (Fig. 1). Purification of the palm mite ITS fragment by gel extraction and subsequent reamplification produced a much larger amount of target DNA suitable for sequencing (data not shown). Sequence analysis confirmed the identity of both the positive control and palm mite ITS DNA. Further refinement of this modified protocol for ITS amplification is necessary in order to successfully sequence PRM, but we now suspect the gene region may be very large and can modify the approach taken.

SIGNIFICANCE OF FINDINGS

These findings lead to a few preliminary conclusions. First, this indicates that these are very recent invasions into these research greenhouses, likely occurring around the same time period since they haven't had a chance to diverge yet. This contradicts the belief that this mite is a common pest of no importance around since at least the

1960's. If this were the case we would expect to see significant divergence between these populations, as well as find specimens outside of research greenhouses and plots. We plan to also sequence a faster nuclear gene like ITS to see if any variability is detected. Panicle rice mites often reproduce parthenogenetically, so it is possible that using a maternally inherited gene like COI may have confounded the results. However, many asexual mite groups still show COI divergence across populations, so we feel that data from the maternally inhereted COI gene has provided a sound basis for our conclusion. Either way, sequencing of ITS will shed more light on the situation. We cannot make any claims as to where this mite came from at this point because we have not yet obtained specimens from any localities outside the United States. We have contacted numerous international researchers in order to obtain PRM, but to this point have been unsuccessful. A colleague at the USDA is also contacting international colleagues on our behalf. We are continuing to receive and analyze specimens collected in the U.S.

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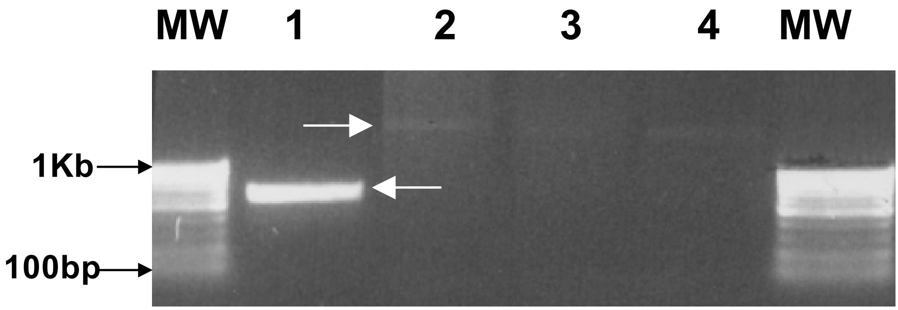

Fig. 1. Agarose gel electrophoresis of ITS amplification of lane 1. *Dermanyssus gallinae,* 2. Red palm mite, 3. Red palm mite, 4. Red palm mite. MW represents the lanes containing 100 bp molecular weight markers. Note: Arrows point to the much larger ITS fragment in lanes 2 to 4 for the Red palm mites and the smaller ITS fragment for *Dermanyssus gallinae* in lane 1.

PEST MANAGEMENT: INSECTS

Delimiting Survey for Panicle Rice Mite in Arkansas

N.M. Taillon, G.M. Lorenz, III, H. Wilf, K. Colwell, and J.L. Wallace

ABSTRACT

The panicle rice mite, *Steneotarsonemus spinki* Smiley, is a major pest of rice worldwide. The mite has been detected in Kenya, China, Taiwan, India, Japan, Korea, Thailand, Sri Lanka, Philippines, Cuba, Dominican Republic, Haiti, Colombia, Costa Rica, Panama, Nicaragua, Honduras, Guatemala, and Venezuela (Hummel et al., 2007). Recent field introductions into Puerto Rico, Texas, Louisiana, and Arkansas have created the need to conduct a delimiting survey for the panicle rice mite. The 2008 survey indicated no panicle rice mite movement from the initial infestation area in Arkansas.

INTRODUCTION

Steneotarsonemus spinki Smiley, panicle rice mite (PRM), are small mites (200 to 300 µm) which are translucent to pale white in color, and are pests of rice. Males tend to be smaller than females and have highly modified hind legs that are carried above the body. Females are parthenogenic, meaning that their unfertilized eggs will hatch as males when there are no males available for reproduction (Xu et al., 2001). The PRM can be found in the inner part of the rice sheath and, as the rice grain develops, in the panicles. It is thought that PRM feeding and reproductive activities reach their peak during the milky stage of grain development. Symptoms of PRM infestation include parrot beaking, blanking, grain discoloration, and possibly the presence of bacterial panicle blight or sheath blight pathogens. PRM has been a serious pest of rice crops in China, the Philippines and Taiwan since the 1970’s where it has caused average yield losses of 5 to 20%, and in some areas losses of 70 to 90%. Since 1997, the PRM has caused 30 to 90% loss of yield in Cuba, 30% yield loss in the Dominican Republic and

Haiti, as well as 40 to 60% yield loss in Costa Rica, Panama, and Nicaragua (Castro et al., 2006). In 2007, PRM was found in breeding facility greenhouses in Texas, Arkansas, Louisiana, and New York, as well as a limited number of fields in Arkansas.

PROCEDURES

A survey of 60 fields from 15 counties, with a minimum of two fields selected per county, was conducted in Arkansas during the 2008 rice season. Fields were selected primarily by availability with first priority given to fields of 'Cheniere' rice that had been purchased from Louisiana and Texas. Secondary consideration was given to accessibility. Suspect fields were sampled upon notification from county extension agents. Samples were taken when the majority of rice plants within the field were between the heading and milking stage, when mite populations are expected to be at their highest. Each field was sampled beginning at the water inlet, where a GPS coordinate was taken, at the four corners of the field, and at even intervals around the perimeter of the field when accessible. Samples were identified by county, field, and sample number, and consisted of three tillers per sample wrapped in a dry paper towel and stored in a sealed plastic bag. Sixty samples were taken from each field and stored, on ice, in a cooler until being sent to the USDA, APHIS, PPQ, CPHST lab in Mission, Texas for processing. Before and after sampling each field, all equipment, boots, and hands were disinfected to prevent cross-contamination of any kind.

RESULTS AND DISCUSSION

Of the 60 fields sampled in Arkansas, there was no indication of panicle rice mite movement from the initial infestation area. Further sampling will be done to monitor this pest. It is not yet known if the PRM will have a serious impact on crop yields in Arkansas; however, yield losses in Central America and other countries around the world have ranged from 30 to 90%. Chemical control of the PRM has been difficult because of the mite's location on the rice tiller, in the inner part of the rice sheath. There are currently no miticides labeled for field management of the PRM in the United States, although research is being conducted to develop chemical options for management of this pest.

SIGNIFICANCE OF FINDINGS

It appears that the rice panicle mite has not yet become established in Arkansas. However, due to the history of this pest and its ability to move from one place to another through the transport of seed, wind dispersal, greenhouse and field workers, agricultural machinery, plant to plant transmission, hitchhiking on insects and birds, and floating on debris on flooded fields (USDA APHIS, 2008), it is in the best interest of rice growers that we continue to monitor for the mite.

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Fig. 1. Counties where samples were taken and the number of fields sampled in each.

Efficacy of Foliar Treatments of Rice Insecticides for Control of Rice Water Weevil (*Lissorhoptrus oryzophilus*) and Rice Stinkbug (*Oebalus pugnax*)

H. Wilf, G. Lorenz, III, K. Colwell, and N. Taillon

ABSTRACT

Two of the most important pests of Arkansas rice are the rice water weevil (*Lissorhoptrus oryzophilus*) (Coleoptera: Curculionidae) and rice stinkbug (*Oebalus pugnax*) (Heteroptera: Pentatomidae). Trials were conducted in Lonoke and Lincoln counties in Arkansas during the 2008 growing season. The objective of these studies was to evaluate the efficacy of selected foliar insecticides for control of rice water weevil and rice stinkbug. Studies indicated considerable variation in the levels of control for both pests.

INTRODUCTION

The rice water weevil is the most common and the most destructive insect pest of rice in the United States (Way et al., 2005). Female weevils lay their eggs after fields have been flooded. Once the field has been flooded, the female weevil swims from plant to plant and deposits eggs in the leaf sheaths, below the water surface. Eggs are usually laid 1 to 2 weeks after flooding and hatching usually occurs 4 to 9 days after oviposition. Newly hatched larvae feed in the leaf sheath for a few days and then sink to the soil surface, where they begin feeding on the rice roots. The larval stage is the most damaging (Lorenz et al., 2006). When the rice root system is damaged by larval feeding, the uptake of nutrients by the plant is reduced, and symptoms of nutrient deficiency may occur (Bernhardt et al. 2001). Severely damaged plants become yellow and stunted and will have delayed maturity and reduced yield. Occasionally root pruning will be so severe that plants cannot remain anchored in the soil and the plants will float to the water surface.

Another pest that has been of concern to Arkansas rice producers is the rice stinkbug. The adult is a to small, tan, shield-shaped insect, about 0.375- to 0.5-in. long, and which produces a strong odor when disturbed. Adults move to grassy, covered shelter for hibernation during the winter and then emerge from over-wintering in late April or early May. Adults emerging in the spring feed almost exclusively on developing seeds on non-cultivated grass species, such as barnyard grass, dallisgrass, crabgrass, johnsongrass, and broadleaf weeds that surround the field. Feeding on these early grasses in the spring enables the rice stinkbug to reproduce and increase in numbers before cultivated host plants are available (Johnson et al., 2000). Females lay clusters of 10 to 40 eggs, placing them on the leaves and seed heads of plants. Eggs hatch about 5 days after being laid, and the nymph stage lasts about 28 days. As the rice seed heads emerge, rice stinkbugs begin moving into cultivated fields. The rice stinkbug damages the rice by piercing the kernels of grain and sucking out the juices needed for development. Stink bugs feeding on developing seeds cause several different types of damage to rice. Early feeding during the early milk stages cause the heads to blank or abort. Rice stink bugs that feed during the milk to soft dough stage result in kernel shrinkage or discoloration. This type of damage is commonly known as “pecky rice”. Pecky rice is created by a combination of the bug’s injection of saliva and the creation of an entry site for fungi and bacteria that may cause discoloration. Pecky rice is also subject to breaking easily and causing shattered kernels (Johnson et al., 2000).

PROCEDURES

The location for the foliar insecticide trial for rice water weevil was at the UAPB Farm in Lonoke County. Plot sizes were 5 ft in width by 50 ft in length in a randomized complete block design with three replications. To prevent any movement of the insecticides, each plot was surrounded by an individual levee. The foliar insecticide treatments were applied one time just before early flood (1- to 3-leaf stage) with a hand-boom. The hand-boom was fitted with TX6 hollow cone nozzles at 19-in. nozzle spacing. Spray volume was 10 gal/acre, at 40 psi. The objective of applying the treatments just before flood was because of the sensitivity of pyrethroids to sunlight. Numbers of rice water weevil larvae were evaluated by taking 4 core samples per plot with a 4-in. by 4-in. cylinder core sampler, 3 weeks after permanent flood. All samples were processed by using a wash technique, which removed larvae from the soil and roots and captured them in a mesh sieve. After larvae were removed from the soil and roots, a salt solution was then used to allow all larvae to float to the top of the water surface giving an accurate count.

The rice stinkbug trial was located in Lincoln County. Plot sizes were 12.5 ft in width by 30 ft in length in a randomized complete block design with four replications. Rice stinkbug density was determined by taking 10 sweeps per plot with a standard 15-in. diameter sweep net. Numbers of nymph and adult rice stinkbugs were then counted. All foliar treatments were applied with a hand-boom that was fitted with TX6 hollow-cone nozzles at 19-in. nozzle spacing. Spray volume was 10 gal/acre, at 40 psi. Foliar treatments are listed in the results section. Data was processed using Agriculture Research Manager Version 8, AOV, and Duncan's New Multiple Range Test (P=0.10).

RESULTS AND DISCUSSION

Results from evaluation of the efficacy of foliar treatments for control of rice water weevil showed that all treatments reduced weevil larvae numbers, compared to the untreated check (Table 1). However, plots treated with Karate Z at 2.08 lb ai/acre and V10170 at 2.13 oz/acre had significantly fewer larvae than plots treated with Mustang Max at 0.08 lb ai/acre and the untreated check plot. No significant differences were observed in yields at harvest (Table 2).

Results from the rice stinkbug trial indicated that all treated plots had fewer rice stinkbugs compared to the untreated check plots (Table3). However, only Karate Z at 2.08 ai/acre had significantly fewer rice stinkbugs than the untreated check. The same trends were observed when nymph and adult totals were combined.

SIGNIFICANCE OF FINDINGS

The rice water weevil trial indicated that growers can reduce numbers of weevil larval by foliar/ground applications, if flooding the field is achieved immediately after treatment. This is critical because pyrethroids are photo-sensitive and efficacy is reduced considerably by delaying the flood.

The significance of the stink bug trial is that it is essential to determine the efficacy of insecticide treatments that are effective and economical to control stinkbugs when they occur in growers fields.

ACKNOWLEDGMENTS

The authors would like to thank the UAPB Farm and the Nuckols Farm for their cooperation. Also we would like to acknowledge Cheminova Inc., FMC, Syngenta, Valent, and the Arkansas Rice Research and Promotion Board.

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Table 1. Average numbers of rice water weevil larvae found in 4 core samples per plot. All of the core samples were taken at 3 weeks after permanent flood. The test was located on the UAPB Farm in Lonoke County, Ark., in 2008.

Treatments	Rice water weevil larvae
Untreated check	29.0 a
Mustang Max 0.08 lb ai/acre	5.5 b
Karate Z 2.08 lb ai/acre	1.5 c
V10170 2.13 oz/acre	0.5 c

Table 2. Rice yields (bu/acre) in foliar rice water weevil trial, Lonoke County, Ark., 2008.

Treatments	Harvest
	(bu/acre)
Untreated check	129.9
Mustang Max 0.08 lb ai/acre	154.6
Karate Z 2.08 lb ai/acre	154.4
V10170 2.13 oz/acre	157.3

Table 3. Average numbers (10 sweeps per plot) of rice stinkbug nymphs and average combined nymphs and adults in plots in Lincoln County, Ark., in 2008.

Treatments	Nymphs	Total nymphs and adults
Untreated check	17.3 a	21.0 a
Methyl parathion 0.25 + Prolex 0.00855 lb ai/acre	7.3 ab	9.0 ab
Methyl parathion 0.375 + Prolex 0.0127 lb ai/acre	6.0 ab	6.0 ab
Methyl parathion 0.5 + Prolex 0.0171 lb ai/acre	4.3 ab	5.0 ab
Methyl Parathion 0.5 lb ai/acre	4.5 ab	10.0 ab
Prolex 0.0171 lb ai/acre	11.3 ab	14.0 ab
Karate Z 0.0325 ai/acre	1.8 b	3.0 b

Efficacy of Rice Insecticide Seed Treatments for Control of Grape Colaspis (*Colaspis brunnea*) and Rice Water Weevil (*Lissorhoptrus oryzophilus* Kuschel)

H. Wilf, G.M. Lorenz, III, K. Colwell, and N.M. Taillon

ABSTRACT

Two of the major pests of rice are the grape colaspis, (*Colaspis brunnea*) also known as the "lespedeza worm," and rice water weevil (*Lissorhoptrus oryzophilus*). With the loss of Icon in recent years there are no current insecticides that provide acceptable control of these pests. However, new seed treatments are currently being investigated that may provide some level of control for these pests. These products include: rynaxapyr (Dermacor X-100), thiamethoxam (Cruiser), and clothianidin (NipsIt INSIDE). Results of studies conducted in Arkansas the past two years indicate these products provide excellent control of rice water weevil and marginal control of grape colaspis.

INTRODUCTION

The rice water weevil (Coleoptera: Curculionidae) is an important biological constraint on rice yields in the southern United States and has been recognized as long as rice has been grown in the south (Stout et al., 2005). The seasonal history of this pest in Arkansas begins in early spring when adult weevils migrate from their overwintering sites to fields where seedlings have emerged. Upon arrival to a rice field they then feed on the upper layer of leaf blades causing long, narrow scars that parallel the mid-vein of the leaf. This feeding is considered evidence that the weevil is present in the field. Leaf scarring can be heavy but even the heaviest scarring rarely results in economic damage. Female weevils do not lay their eggs until fields have been flooded. Once the field has been flooded, the female rice water weevil swims from plant to plant and deposits eggs in the leaf sheaths below the water surface. Eggs are usually laid 1 to 2 weeks after flooding. The hatching period usually occurs 4 to 9 days after the egg has been laid. Newly hatched larvae feed in the leaf sheath area for a few days and then sink into the soil surface and begin feeding on the rice roots. The larval stage is the most damaging stage of the life cycle (Lorenz et al., 2006). When the rice root system is damaged by the larval feeding, the plant's uptake of nutrients is reduced and nutrient deficiency symptoms may occur. Severely damaged plants become yellow and stunted and will have delayed maturity and reduced yield. Occasionally root pruning will be so severe that plants cannot remain anchored in the soil and the plants will float to the water surface when disturbed (Bernhardt et al., 2001).

Another common pest in Arkansas rice fields is grape colaspis (Coleoptera: Chrysomelidae). Adults are about 0.1875-in. long, oval, golden brown in color and the elytra (wing covers) have rows of longitudinal ridges. Larvae are grubs, white to tan in color with a brown head; they also have three pairs of thoracic legs. Larvae eat away at the rice stem and roots causing the "girdling" effect, which causes the plant to yellow and become stunted and, in many cases, causes significant stand reduction (Lorenz et al., 2006). Fields most likely to sustain injury from grape colaspis are those that were planted in corn or soybeans in the previous year (Thomas et al., 2009). High densities of grape colaspis larvae can lead to a significant stand loss resulting in a year-end yield reduction (Lorenz et al., 2006). Therefore, the objective of these studies was to evaluate the efficacy of rice insecticide seed treatments for the control of rice water weevil and grape colaspis.

PROCEDURES

The sites for these seed treatment trials in 2008 were Tichnor, Ark. (Arkansas Co.); Price Bros. Farm (Prairie Co.); Robert Moery Farm (Lonoke Co.); McGee, Ark. (Poinsett Co.); S.P. Schwartz Farm (Poinsett Co.); and Pine Tree Experiment Station (St. Francis Co.). Plot sizes were 5-ft wide by 25-ft long, in a randomized complete block design with four replications. Stand count and plant height data were collected 2 to 3 weeks after planting date. Data were collected by counting plants in 10-row ft. per plot, and plant heights were recorded by measuring average height of 10 plants per plot. Rice water weevils and grape colaspis larvae were evaluated by taking 4 core samples per plot with a 4-in. by 4-in. cylinder core sampler, 2 to 3 weeks after permanent flood. All samples then were brought back to the Lonoke Extension and Applied Research Center, and were processed using a wash technique removing all larvae from the soil and roots, and captured them in a 40-gauge mesh sieve. After larvae were removed from the soil and roots, a salt solution was then added to allow all larvae to float to the top of the water surface, giving an accurate count. Also, plant lodging was rated from 0 to 100% per plot during harvest. Rice seed treatments are listed in the results section. Data were processed using Agriculture Research Manager Version 8, AOV, and Duncan's New Multiple Range Test (P=0.10).

RESULTS AND DISCUSSION

Evaluation of plant stand counts and plant heights in Prairie County (Table 1) indicated that HGW86, V10170 100, and V10170 150 had significantly higher stand count than the untreated check. All treatments had a significantly higher plant height than the untreated check. However plots treated with Cruiser 0.03 mg ai/seed had significantly taller plants than plots treated with Dermacor 0.025 mg a/seed and the untreated check (Table 1).

Efficacy of rice insecticides for control of weevils in Prairie County indicated that all treated plots had significantly fewer weevil larvae than the untreated check plots (Table 2).

Plots treated with Dermacor 0.025 mg a/seed and V10170 100 g ai/100,000 seed had significantly greater yields than the untreated check plots (Table 3). No significant difference in plant lodging was observed among treatments or untreated check.

SIGNIFICANCE OF FINDINGS

With the recent loss of Icon, there currently are no effective treatments for control of grape colaspis and rice water weevils. It is vital to the Arkansas rice industry to find effective, economical ways to control these pests. It appears that seed treatments may be the best means to control these pests.

ACKNOWLEDGMENTS

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Table 1. Plant stand counts and plant heights in Prairie County, Ark., in 2008.

Treatments	Plant stand count	Mean plant height
		(Avg. of 10 plants/plot)
Untreated check	68 b	16.32 c
Dermacor 0.025 mg a/seed	101 ab	16.93 b
Dermacor 0.05 mg a/seed	96 ab	17.33 ab
Dermacor 0.1 mg a/seed	111 ab	17.1 ab
HGW86 0.01 mg a/seed	122 a	17.55 ab
V10170 100 g ai/100000	131 a	17.73 ab
V10170 150 g ai/100000	120 a	17.5 ab
Cruiser 0.03 mg ai/seed	111 ab	17.84 a
Cruiser 80 mg ai/seed + Dermacor 0.025 mg a/seed	113 ab	17.4 ab
Cruiser 120 g ai/cwt + Dermacor 0.025 mg a/seed	117 ab	17.5 ab

Table 2. Mean numbers of rice water weevil larvae, sampled 2 to 3 weeks after permanent flood. Test 1 was located in Prairie County and test 2 was located in St. Francis County, Ark., in 2008.

	Rice water weevil larvae	
Treatments	Test 1	Test 2
	---- (avg. of 4 core samples/plot)-----	
Untreated check	23.3 a	9.3
Dermacor 0.025 mg a/seed	2.3 b	2.3
Dermacor 0.1 mg a/seed	0.0 b	4.5
V10170 25 g ai/100000 seed	8.5 b	2.8
V10170 50 g ai/100000 seed	5.8 b	2.0
V10170 75 g ai/100000 seed	2.3 b	3.5
V10170 100 g ai/100000 seed	3.5 b	3.0
V10170 125 g ai/100000 seed	2.5 b	2.3
V10170 150 g ai/100000 seed	1.3 b	1.0
Cruiser 0.03 mg ai/seed	4.8 b	3.0
Cruiser 120 g ai/cwt + Dermacor 0.05 mg a/seed	0.5 b	6.3

Table 3. Average rice yield in all trials, 2008.

Treatments	Yield
	(bu/acre)
Untreated check	193.5 b
Cruiser 0.03 mg a/seed	205.2 ab
Dermacor 0.025 mg a/seed	210.5 a
Dermacor 0.05 mg a/seed	199.9 ab
Dermacor 0.1 mg a/seed	200.8 ab
HGW86 0.01 mg a/seed	204.9 ab
V10170 100 g ai/100000 seed	208.5 a
V10170 150 g ai/100000 seed	204.6 ab
Cruiser 80 g ai/cwt + Dermacor 0.025 mg a/seed	196.9 ab
Cruiser 120 g ai cwt + Dermacor 0.025 mg a/seed	204.7 ab

Efficacy of Rice Insecticide Seed Treatments for Control of Rice Water Weevil (*Lissorhoptrus oryzophilus* Kuschel) At Two Seeding Rates

H. Wilf, G.M. Lorenz, III, K. Colwell, and N.M. Taillon

ABSTRACT

One of the most destructive early pests in Arkansas rice is the rice water weevil (RWW) *(Lissorhoptrus orzophilus* Kuschel). Two trials were conducted comparing seed treatments at two seeding rates of 90 and 120 lb seed/acre. The trials were conducted in Prairie County and St. Francis County, during the 2008 growing season. The objective of these studies was to evaluate the efficacy of selected rice insecticide seed treatments for control of RWW while comparing two seeding rates typically used by growers in Arkansas.

INTRODUCTION

The rice water weevil overwinters as an adult in accumulated leaf litter in well drained, wooded or grassy areas, and any other sheltered areas near rice fields. The RWW adults fly into fields in early spring and begin feeding on rice leaves. This feeding is characterized by long linear scars. These scars signal detection that the RWW adults are present in the field. Female RWW do not lay their eggs until fields have been flooded. Once the field has been flooded the female RWW swims from plant to plant and deposits eggs in the leaf sheaths below the water surface. Eggs are usually laid 1 to 2 weeks after flooding. The hatching period usually occurs 4 to 9 days after the egg has been laid. Newly hatched larvae feed in the leaf sheath for a few days and then sink into the soil surface and begin feeding on the rice roots. The larval stage is the most damaging period of the RWW life cycle (Lorenz et al., 2006). When the rice root system is damaged by larval feeding, the plant's uptake of nutrients is reduced and nutrient deficiency symptoms may occur (Bernhardt et al., 2001). Severely damaged plants become yellow and stunted and will have delayed maturity resulting in a stand loss and yield reduction. Occasionally root pruning will be so severe; plants cannot remain anchored in the soil. The larvae are tiny in size but grow quickly through four larval stages in four weeks. When RWW larvae become fully grown they build a water tight, oval mud cell in which they pupate. They then emerge as adults (Lorenz et al., 2006).

PROCEDURES

The two locations for this trial were in Prairie County on the Price Bros. Farm and in St. Francis County on the Pine Tree Experiment Station. Plot sizes were 5 ft in width by 25 ft in length in a randomized complete block design with four replications. Field seeding rates of 90 and 120 lb seed/acre were compared on selected insecticide seed treatments. Stand count and plant height data was collected 2 to 3 weeks post planting date. Data were collected by counting plants in 10 row feet per plot and plant heights were recorded by measuring 10 plants height per plot. Rice water weevil larvae were rated by taking 4 core samples per plot with a 4-in. by 4-in. cylinder core sampler at 3 weeks after permanent flood. All samples then were brought back to the Lonoke Extension and Applied Research Center and processed using a wash technique removing all larvae from soil and roots into a 40-gauge mesh sieve. After larvae were removed from the soil and roots, samples were immersed in a salt solution to allow all RWW larvae to float to the top of the water surface giving an accurate count. Data was processed using Agriculture Research Manager Version 8, AOV, and Duncan's New Multiple Range Test (P=0.10)

RESULTS AND DISCUSSION

The results of stand counts and plant heights from Prairie and St. Francis counties indicate that the 90 lb/acre untreated check had a significantly lower plant stand count than all treated plots and than the 120 lb/acre untreated check (Table 1). No significant differences were observed for plant heights. Test 1 results indicate that the 90 and 120 lb/acre untreated check had statistically more RWW larvae than all other treatments (Table 2). Test 2 results indicate that all seed treatments significantly reduced RWW larval populations compared to both untreated checks (Table 2).

SIGNIFICANCE OF FINDINGS

This work indicates that the use of seed treatments can increase stand counts by 10 to 15%. This would allow growers to reduce seeding rates and offset the cost of the seed treatment and increase overall average yield.

ACKNOWLEDGMENTS

The authors would like to thank the Price Bros. Farm and the Pine Tree Experiment Station for their permission to use the rice fields in these studies. Also we would like to acknowledge DuPont, Syngenta, and the Arkansas Rice Research and Promotion Board for their support of these studies.

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Table 1. Summary of plant stand counts and plant heights from a grower field was located in Prairie County, Ark., 2008.

Treatments	Stand count	Plant height
	(#/10 row ft)	(avg. of 10 plants/plot)
Untreated check		
120 lb/acre	125.8 b	15.60
Dermacor 0.0625 mg a/seed		
120 lb/acre	146.8 ab	15.03
Dermacor 0.125 mg a/seed		
120 lb/acre	142.5 ab	15.33
Cruiser 0.03 mg ai/seed		
120 lb/acre	166.3 a	16.15
Dermacor 0.125 mg a/seed		
90 lb/acre	131.5 ab	15.40
Dermacor 0.025 mg a/seed		
90 lb/acre	134.8 ab	15.55
Cruiser 0.03 mg ai/seed		
90 lb/acre	155 ab	15.90
Untreated check		
90 lb/acre	96.3 c	14.93

Table 2. Total average number of rice water weevil larvae from Test 1, located in Prairie County, and Test 2, located in St. Francis County, Ark., 2008.

	Rice water weevil[z]	
Treatments	Test 1	Test 2
	(avg. # of larvae/4 core samples/plot)	
Untreated check 120 lb/acre	35.8 b	23.5 a
Dermacor 0.00625 mg a/seed 120 lb/acre	9.5 c	2.8 b
Dermacor 0.125 mg a/seed 120 lb/acre	2.5 c	1.8 b
Cruiser 0.03 mg ai/seed 120 lb/acre	5.3 c	3.3 b
Dermacor 0.125 mg a/seed 90 lb/acre	2.0 c	1.0 b
Dermacor 0.025 mg a/seed 90 lb/acre	1.0 c	1.0 b
Cruiser 0.03 mg ai/seed 90 lb/acre	11.5 c	1.5 b
Untreated check 90 lb/acre	56.0 a	25.5 a

[z] All core samples were taken at 2 to 3 weeks after permanent flood.

Weed Management in Furrow-Irrigated Clearfield® Rice Production System

S.K. Bangarwa, J.K. Norsworthy, R.C. Scott, G. Griffith, M.J. Wilson, and J. Still

ABSTRACT

Research was conducted at the Pine Tree Branch Experiment Station in Colt, Ark., in 2007 and 2008 to evaluate weed control options in a Clearfield® rice-production system. Raised beds were formed and imidazolinone-tolerant hybrid rice 'CL XL 730' was drill-seeded on beds. Five herbicide programs applied up to the 4- to 6-leaf (lf) stage of rice were evaluated with and without additional 'as needed' herbicide at later stages. All the herbicide combinations tested in this research were labeled for rice, and no injury was observed. Weeds emerged throughout the growing season, and additional herbicides were needed following the 4- to 6-lf stage of rice for weed management. Most of the Palmer amaranth at this site appeared to be insensitive to imazethapyr (possibly ALS resistant). Therefore, application of 'as needed' herbicide with a different mode of action was needed to improve Palmer amaranth control. Rice yield was numerically higher in plots that received additional herbicide after the 6-lf stage of rice.

INTRODUCTION

Rice is the most economically important crop in Arkansas, contributing $1,459 million annually to the state economy (NASS, 2009). Like other crops, weeds are a major limiting factor in rice production. If not controlled, weeds can cause considerable economic losses in terms of reducing the yield and quality of rice grains and by reducing harvesting efficiency (Baldwin and Slaton, 2001). Conventional rice-production practices in Arkansas involve dry-seeding of rice followed by a permanent flood at the 4- to 6-lf stage of rice (Slaton, 2001). One reason for flooding rice is to manage a broad spectrum of terrestrial weed species that are sensitive to flooding. Flooding effectively controls many problematic weed species, but it also requires pumping of a large amount of groundwater to flood the rice bays (Scott et al., 1998). The extensive pumping of water for rice production is perceived to be contributing to the depletion of groundwater in Arkansas. This problem can be partially solved by shifting to irrigation practices which more efficiently utilize water for crop production. Furrow irrigation is one such practice which has shown promising results in other crops like corn, soybean, and cotton grown on raised beds.

Weed management in the absence of a permanent flood will be more challenging to the rice producers because of the presence of terrestrial weeds. Furthermore, prolonged moist conditions in furrows will extend the period of weed emergence during the growing season. Therefore, an effective weed management program for furrow-irrigated rice needs herbicides which can provide broad-spectrum, residual weed control. Clomazone, imazethapyr, and quinclorac are three residual herbicides that can be used in Clearfield® rice (Baldwin and Slaton, 2001; Norsworthy et al., 2008). Clomazone is most commonly used as a preemergence (PRE) herbicide for controlling annual grass weeds, except red rice. Imazethapyr controls red rice, annual grasses, and many broadleaf weeds. Quinclorac is another broad-spectrum herbicide and can be applied either preemergence or early postemergence (POST) in rice. The objective of this research was to develop an effective weed management program in a furrow-irrigated, Clearfield® rice production system.

PROCEDURES

Field experiments were conducted at the Pine Tree Branch Experiment Station in Colt, Ark., in 2007 and 2008. Raised beds were formed at 30-in. spacing on a Calloway silt loam (fine-silty, mixed active, thermic Glossaquic Gragiudalf) soil. Imidazolinone-tolerant hybrid rice 'CL XL 730' was drill-seeded at 30 lb/acre on raised beds on 23 April 2007 and 13 May 2008. Crop management practices were similar both years. Experimental plots were 40 ft long and 7.5 ft wide. The experimental design was a randomized complete block with a 2 by 5 factorial treatment arrangement with four replications. Five herbicide programs applied up to the 4- to 6-lf stage of rice were evaluated with and without additional 'as needed' herbicide at later stages. Treatments included imazethapyr (Newpath 2 AS) applied preemergence followed by (fb) imazethapyr at 4- to 6-lf rice, imazethapyr at 2- to 3-lf rice fb imazethapyr at 4- to 6-lf rice, imazethapyr plus quinclorac (Facet 75 DF) at 0.5 lb ai/acre PRE fb imazethapyr at 4- to 6-lf rice, imazethapyr PRE fb imazethapyr plus quinclorac at 0.5 lb/acre applied at 4- to 6-lf rice, and clomazone (Command 3 ME) PRE at 0.3 lb ai/acre fb propanil (Stam) at 4 lb ai/acre at 4- to 6-lf rice. All imazethapyr was applied at 0.063 lb ai/acre, with 1% v/v nonionic surfactant (Induce) when applied postemergence. All 'as needed' treatments in 2007 received triclopyr (Grandstand) at 0.25 lb ai/acre plus 1% v/v nonionic surfactant (Induce) fb propanil at 4 lb/acre plus carfentrazone (Aim) at 0.032 lb/acre. In 2008, all 'as needed' treatments received propanil at 4 lb/acre plus acifluorfen (Ultra Blazer) at 0.25 lb ai/acre fb 2,4-D (Weedar) at 1.4 lb ai/acre plus 1% v/v nonionic surfactant (Induce), except for the clomazone fb propanil treatment which only received 2,4-D.

Data were collected on visual injury and weed control up to 12 wk after planting rice (WAP), and rice grain yield at maturity. Weeds evaluated both years included Palmer amaranth and broadleaf signalgrass. Additionally, barnyardgrass infested the test site in 2007, and pitted morningglory, prickly sida, and hophornbeam copperleaf were evaluated in 2008. Weed control and rice injury were evaluated throughout the growing season on a scale of 0 to 100%, with 0 equal to no control or no rice injury and 100 equal to complete weed control or rice death. Data were subjected to analysis of variance for all parameters evaluated, and means were separated using Fisher's protected Least Significance Difference test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

No rice injury was observed from any herbicide treatment both years (data not shown), which indicates that all evaluated herbicide programs were safe on rice. In 2007, all herbicides provided ≥79% control of broadleaf signalgrass at 12 WAP (Table 1). Barnyardgrass control was ≥79% with all herbicide programs, except clomazone fb propanil applied to 4- to 6-lf rice and imazethapyr PRE fb imazethapyr 4- to 6-lf rice treatments. However, broadleaf signalgrass and barnyardgrass control was improved up to 83 to 95% at 12 WAP when 'as needed' herbicides were included in the herbicide programs. Palmer amaranth control was also improved by application of 'as needed' herbicides, but no herbicide program provided satisfactory control of Palmer amaranth. A maximum of 53% control of Palmer amaranth was achieved with imazethapyr PRE fb imazethapyr at 4- to 6-lf rice fb 'as needed' herbicides. The difficulty in controlling Palmer amaranth with the 'as needed' herbicide treatments was partially due to its size and the ineffectiveness of earlier treatments in providing acceptable control. The additional use of herbicide after the 4- to 6-lf stage of rice resulted in numerical yield improvement (often not statistically significant).

In 2008, all herbicide programs provided ≥78% control of broadleaf signalgrass, pitted morningglory, prickly sida, and hophornbeam copperleaf, with numerically higher control when additional herbicides were applied later in the season 'as needed' treatments (Table 2). Similar to the previous year, Palmer amaranth was the most difficult-to-control weed in 2008, and application of 'as needed' treatments improved Palmer amaranth control of all five herbicide programs. Two herbicide programs, including imazethapyr PRE fb imazethapyr at 4- to 6-lf rice and clomazone PRE fb propanil 4- to 6- lf rice, when supplemented with 'as needed' herbicides provided ≥81% control of Palmer amaranth at 12 WAP. Due to moist soil conditions from frequent furrow irrigation, most weeds emerged throughout the crop season, resulting in failure of herbicide applications terminated at the 4- to 6-lf stage of rice to provide season-long weed control. Therefore, additional herbicides were needed throughout the season following the 4- to 6-lf stage of rice for control of Palmer amaranth. Due to the presence of large-sized Palmer amaranth in the non-treated control, plots could not be harvested for rice yield in 2008. Similar to 2007, all 'as needed' treatments were numerically greater than their corresponding treatment terminated at the 4- to 6-lf stage of rice in 2008.

SIGNIFICANCE OF FINDINGS

This research indicates that Palmer amaranth and other terrestrial weeds will be difficult to control in furrow-irrigated Clearfield rice due to continual emergence and possibly the presence of resistant Palmer amaranth biotypes. Applying herbicides up to 4- to 6-lf stage of rice, including imazethapyr alone or in combination with other modes of action herbicide, was not sufficient to provide effective, season-long weed control. Additional herbicides with alternative modes of action will be needed beyond the 4- to 6-lf stage if high yields are to be maintained in furrow-irrigated rice, meaning that weed management may be more costly and quite challenging in this system.

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Table 1. Effect of herbicide treatments on visual weed control at 12 weeks after planting and rice yield at Pine Tree, Ark., in 2007.

Herbicide combinations and application timing[z]	Weed control: Broadleaf signalgrass	Weed control: Barnyard-grass	Weed control: Palmer amaranth	Rice yield
	(%)	(%)	(%)	(bu/acre)
Imazethapyr PRE fb imazethapyr 4-6 lf rice	79	74	10	185
Imazethapyr PRE fb imazethapyr 4-6 lf rice fb as needed[yx]	94	91	63	210
Imazethapyr 2-3 lf rice fb imazethapyr 4-6 lf rice	79	79	5	184
Imazethapyr 2-3 lf rice fb imazethapyr 4-6 lf rice fb as needed	95	93	53	219
Imazethapyr +quinclorac PRE fb imazethapyr 4-6 lf rice	94	94	25	177
Imazethapyr +quinclorac PRE fb imazethapyr 4-6 lf rice fb as needed	93	90	33	208
Imazethapyr PRE fb imazethapyr + quinclorac 4-6 lf rice	90	88	15	178
Imazethapyr PRE fb imazethapyr + quinclorac 4-6 lf rice fb as needed	91	89	38	210
Clomazone PRE fb propanil 4-6 lf rice	78	70	28	201
Clomazone PRE fb propanil 4-6 lf rice fb as needed[yx]	91	83	50	195
Non-treated check	--[w]	--	--	143
LSD (0.05)	11	12	22	NS

[z] Application rates: imazethapyr at 0.5 lb ai/acre, quinclorac at 0.5 lb ai/acre, clomazone at 0.6 lb ai/acre, and propanil at 4 lb ai/acre.

[y] 'As needed' treatments were triclopyr at 0.25 lb ai/acre fb propanil at 4 lb ai/acre + carfentrazone at 0.032 lb ai/acre.

[x] POST applications of imazethapyr and triclopyr were applied with a non-ionic surfactant (Induce) at 1.0% v/v.

[w] Non-treated check plots were excluded from weed control analysis.

Table 2. Effect of herbicide treatments on visual weed control at 12 weeks after planting and rice yield at Pine Tree, Ark., in 2008.

Herbicide combinations and application timing[zy]	Weed control					Rice yield
	Broadleaf signalgrass	Palmer amaranth	Pitted morningglory	Prickly sida	Hophornbeam copperleaf	
	----------	----------	(%)	----------	----------	(bu/acre)
Imazethapyr PRE fb imazethapyr 4-6 lf rice	85	33	91	78	80	87
Imazethapyr PRE fb imazethapyr 4-6 lf rice fb as needed[xw]	90	81	94	95	90	104
Imazethapyr 2-3 lf rice fb imazethapyr 4-6 lf rice	93	45	95	88	90	105
Imazethapyr 2-3 lf rice fb imazethapyr 4-6 lf rice fb as needed	94	73	95	95	95	105
Imazethapyr +quinclorac PRE fb imazethapyr 4-6 lf rice	95	65	94	95	95	91
Imazethapyr +quinclorac PRE fb imazethapyr 4-6 lf rice fb as needed	93	71	95	95	90	104
Imazethapyr PRE fb imazethapyr + quinclorac 4-6 lf rice	95	44	95	94	91	114
Imazethapyr PRE fb imazethapyr + quinclorac 4-6 lf rice fb as needed	91	75	94	94	94	119
Clomazone PRE fb propanil 4-6 lf rice	86	69	94	94	84	111
Clomazone PRE fb propanil 4-6 lf rice fb as needed	84	93	94	93	93	117
Non-treated check	--[y]	--	--	--	--	--[v]
LSD (0.05)	10	30	3	16	NS	25

[z] Application rates: imazethapyr at 0.5 lb ai/acre, quinclorac at 0.5 lb ai/acre, clomazone at 0.6 lb ai/acre, and propanil at 4 lb ai/acre.
[y] Non-treated check plots were excluded from weed control analysis.
[x] 'As needed' treatments were propanil at 4 lb ai/acre + acifluorfen at 0.25 lb ai/acre fb 2,4-D at 1.4 lb ai/acre, except for the clomazone fb propanil treatment which only received 2,4-D.
[w] POST applications of imazethapyr and 2,4-D were applied with a non-ionic surfactant (Induce) at 1.0% v/v.
[v] Non-treated check plots were not harvested.

Broadleaf Weed Control on Arkansas Rice Levees

S.K. Bangarwa, J.K. Norsworthy, R.C. Scott, M.J. Wilson, J. Still, and G.M. Griffith

ABSTRACT

Broadleaf weed control on rice levees is an emerging problem faced by growers and consultants in Arkansas. Field experiments were conducted at Lonoke and Stuttgart, Ark., in 2007 and 2008 to evaluate the effectiveness of various postemergence herbicides applied alone or in tank mixture with propanil or quinclorac for large-sized broadleaf weed control on rice levees. Rice injury was minimal (≤5%) from all herbicides at 2 wk after treatment (WAT), and no injury was observed at 4 WAT. Prickly sida and Palmer amaranth were the most difficult-to-control weeds on levees. Herbicides applied in combination with propanil or quinclorac improved the efficacy and spectrum of broadleaf weed control over individual herbicides alone. An application of 2,4-D at 1.25 lb ai/acre alone or with quinclorac at 0.5 lb ai/acre provided consistent control of most broadleaf weeds. Propanil at 4 lb ai/acre antagonized activity of triclopyr on Pennsylvania smartweed.

INTRODUCTION

Until recently, weed control on rice levees has not been a component of weed-management research programs in rice. However, weed management on levees is critical to many rice farmers, especially for those whose levees comprise a large percentage of the overall field and ultimately of rice yield. Weeds continually emerge on levees due to season-long moist conditions. Late-season weeds on levees are often larger than those in bays and are difficult to control with an individual herbicide application. Because weed control recommendations in rice bays are based on small-sized weeds followed by a permanent flood, there is an important research need for weed control on rice levees in Arkansas (Baldwin and Slaton, 2001; Norsworthy et al., 2007). We hypothesize that herbicide combinations will increase the efficacy and spectrum of control of large-size broadleaf weeds on rice levees. The objective of this research was to develop effective late-season management programs for broadleaf weeds on rice levees.

PROCEDURES

Field experiments were conducted in a randomized complete block design replicated four times at Lonoke and Stuttgart, Ark., in 2007 and 2008. Rice levees 50 ft long and 2 ft high were constructed using standard practices and were broadcast seeded with 'Wells' rice and various broadleaf weed species. Propanil (Stam) at 4 lb ai/acre, triclopyr (Grandstand) at 0.25 lb ai/acre, 2,4-D (Weedar) at 1.25 lb ai/acre, acifluorfen (Ultra Blazer) at 0.25 lb ai/acre, carfentrazone (Aim) at 0.02 lb ai/acre, penoxsulam (Grasp) at 0.03 lb ai/acre, quinclorac (Facet) at 0.5 lb ai/acre, halosulfuron (Permit) at 0.06 lb ai/acre, bentazon (Basagran) at 0.75 lb ai/acre, and bispyribac (Regiment) at 0.02 lb ai/acre were evaluated alone and in combination with propanil or quinclorac. All herbicides were applied postemergence at labeled rates at 10 gal/acre, and the combinations that resulted in double the labeled rates for propanil or quinclorac were excluded. A nontreated control was also included. Applications were made when most weeds were 18 to 24 in. tall or had 18- to 24-in. runners. Hemp sesbania (*Sesbania herbacea*) and prickly sida (*Sida spinosa*) were evaluated at both locations, whereas palmleaf morningglory (*Ipomoea wrightii*), entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula*), Pennsylvania smartweed (*Polygonum pensylvanicum*), and Palmer amaranth (*Amaranthus palmeri*) were evaluated at a single site for at least one year. Visual ratings for rice injury and weed control were recorded at 2 and 4 wk after treatment application (WAT) on a scale of 0 to 100%, with 0 equal to no weed control or rice injury and 100 equal to complete control or rice death. All data were subjected to analysis of variance, and means were separated using Fisher's protected Least Significance Difference test at 5% level of significance.

RESULTS AND DISCUSSION

No rice injury was observed from herbicide treatments except 2,4-D applied alone or with propanil or quinclorac, which caused ≤5% injury at 2 WAT at Stuttgart in 2007 (data not shown). Symptoms depicted typical phenoxy herbicide injury, in the form of reduced rice tillering. However, injury was transit, and rice plants recovered by 4 WAT.

Propanil, triclopyr, 2,4-D, acifluorfen, and carfentrazone applied alone, and all herbicides in combination with propanil and quinclorac, controlled hemp sesbania >90% through 4 WAT at both locations (Fig. 1). Prickly sida was selectively responsive to 2,4-D and was controlled 83 to 85% when applied alone or with quinclorac at 4 WAT at Stuttgart and Lonoke (Fig. 2). Palmleaf morningglory was more sensitive than entireleaf morningglory to herbicides. Triclopyr and 2,4-D, alone or mixed with quinclorac or propanil, generally provided excellent (≥90%) palmleaf morningglory control (data not shown). Entireleaf morningglory was controlled 85 to 89% with 2,4-D alone, propanil combined with 2,4-D and quinclorac, and quinclorac combined with all herbicides, except bentazon and halosulfuron (data not shown).

Pennsylvania smartweed was controlled >90% by 2,4-D, acifluorfen, and carfentrazone applied alone or in combination with propanil or quinclorac at 4 WAT (Fig. 3). Additionally, halosulfuron with propanil and penoxsulam with quinclorac were effective on Pennsylvania smartweed. However, the addition of propanil reduced the efficacy of triclopyr against Pennsylvania smartweed, which represents an antagonistic interaction between these herbicides. Lowering the rate of propanil may reduce the burn (rapid necrosis) caused by this herbicide, in turn alleviating the observed antagonism.

Palmer amaranth was the weed most difficult to control, with a maximum of 78 and 73% control achieved with 2,4-D and acifluorfen applied with propanil at 4 WAT (Fig. 4). Overall, considering the diverse weed flora, including all of the above broadleaf weed species, 2,4-D alone or in combination with quinclorac, is the best option for rice levee weed control.

SIGNIFICANCE OF FINDINGS

As a result of this research, "weed control on rice levees" has been added to the rice section of the MP-44 (Recommended Chemicals For Weed and Brush Control). Application of 2,4-D alone or with quinclorac provided effective late-season control of most large-size broadleaf weeds. However, current restrictions in Arkansas prohibit the use of 2,4-D at certain times of the year (Slaton and Norman, 2001), meaning that other herbicides or herbicide mixtures must be used during the restricted period, with these providing less effective control of a broad spectrum of broadleaf weeds. Although propanil is commonly applied to rice levees in combination with other herbicides, it was observed that antagonism can occur when a full rate of propanil is applied with systemic herbicides. Future research efforts will include focusing on additional broadleaf weeds such as Northern jointvetch, eclipta, and cutleaf groundcherry and evaluating control options for late-season grass control on levees.

ACKNOWLEDGMENTS

The financial support provided by the Arkansas Rice Research and Promotion Board is thankfully acknowledged.

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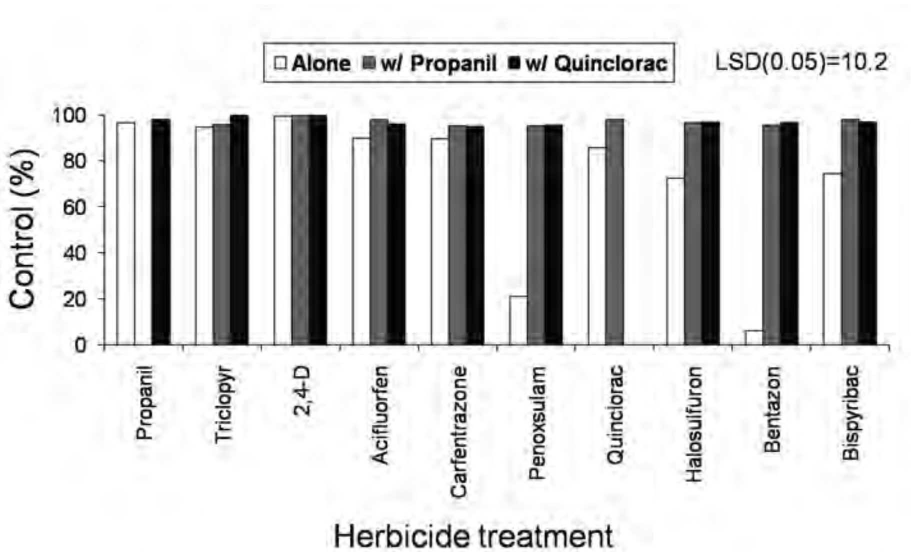

Fig. 1. Hemp sesbania control at Stuttgart and Lonoke at 4 wk after application as influenced by herbicide treatments.

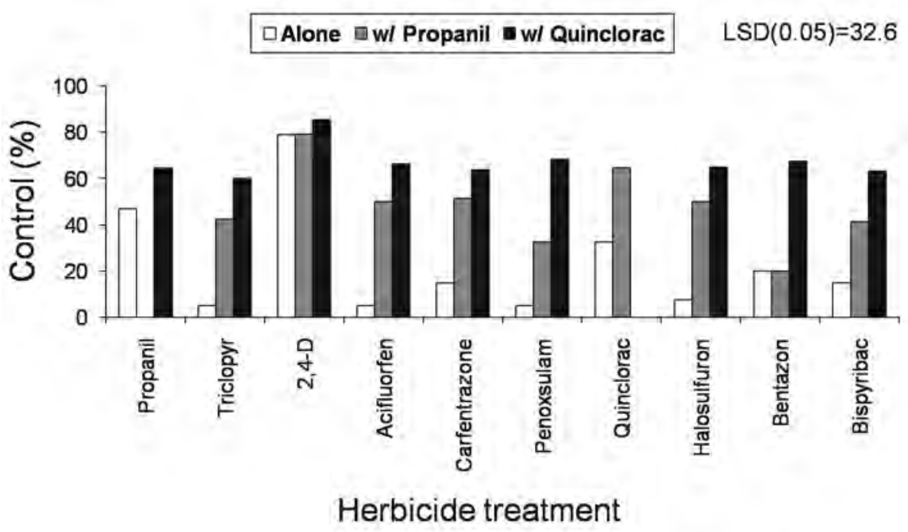

Fig. 2. Prickly sida control at Stuttgart and Lonoke at 4 wk after application as influenced by herbicide treatments.

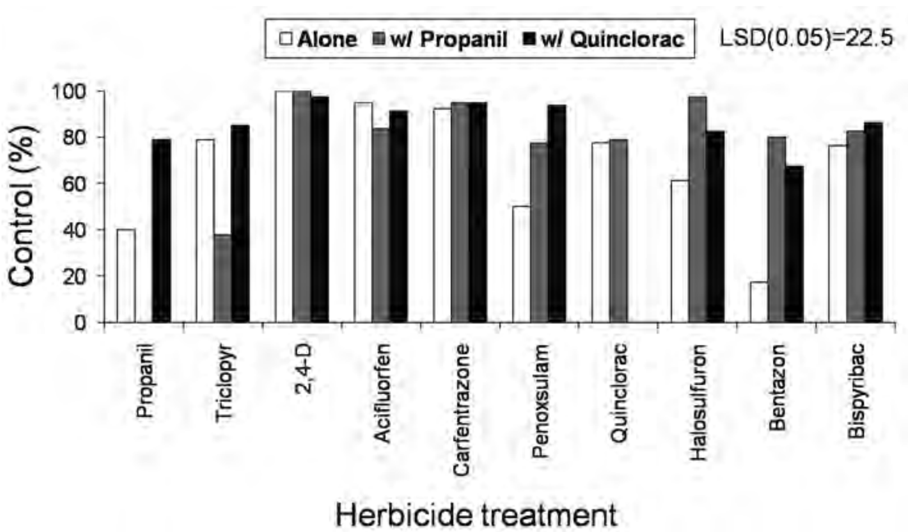

Fig. 3. Pennsylvania smartweed control at Stuttgart and Lonoke at 4 wk after application as influenced by herbicide treatments.

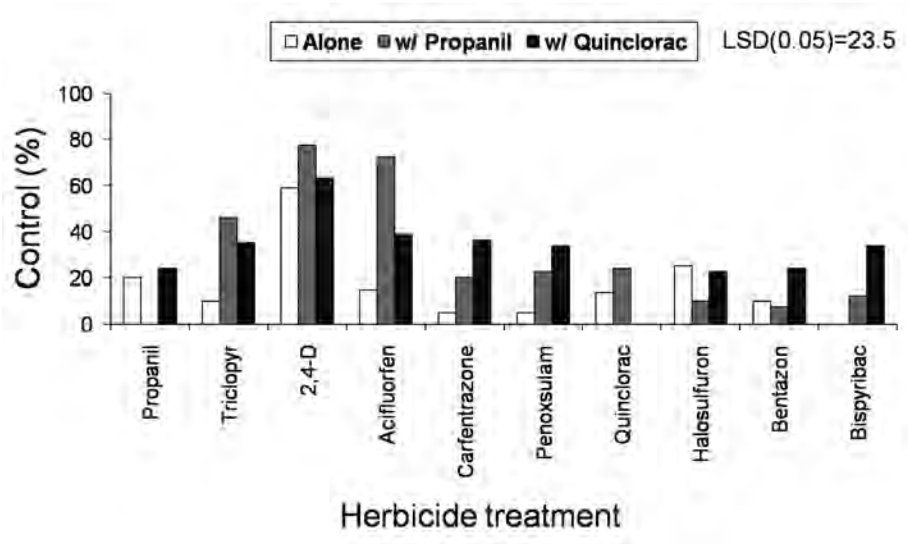

Fig. 4. Palmer amaranth control at Stuttgart and Lonoke at 4 wk after application as influenced by herbicide treatments.

Effects of Low Rates of Glyphosate and Glufosinate on Rice

B.M. Davis, R.C. Scott, N.D. Pearrow, and T.W. Dillon

ABSTRACT

The objective of this research was to evaluate the response of two rice cultivars to low rates of glyphosate and glufosinate. Treatment factors were herbicide, variety, and timing. Varieties 'XP723' and 'Wells' were drill-seeded at the appropriate rates in May of 2007. Glyphosate was applied at 0, 2.75, 5.5, andd 11 oz acid equivalent (ae)/acre. Glufosinate was applied at 0, 3.75, 7.5, and 15 oz active ingredient (ai)/acre. These treatments were applied to both cultivars at three timings, 3- to 4-lf, panicle initiation (PI), and late boot.

In this study glyphosate visual injury was minimal compared to glufosinate injury. Glyphosate injury ranged from 0 to 45% depending on rate and timing. Glufosinate injury on rice ranged from 0 to 85% depending on rate and timing. Injury increased as rate increased as previously documented by Kurtz et al. (2003) and Koger et al (2005). Yields in this study were reduced the greatest when glyphosate and glufosinate were applied at boot. In general, glufosinate caused more visual injury than glyphosate; however, yields were more negatively impacted by glyphosate.

INTRODUCTION

Glyphosate is the most popular non-selective burn-down herbicide on the market today. Over 95% of the soybean grown in Arkansas is glyphosate tolerant. As with most herbicides there is a risk of off target movement of glyphosate onto non-tolerant crops such as rice. In Arkansas, rice is one of the few crops not tolerant to glyphosate. In addition, 2009 will mark the introduction of LibertyLink soybean, which allows the use of glufosinate in over the top applications. Inevitably, there will also be an increase in the incidences of off target movement of glufosinate to rice.

PROCEDURES

A study was conducted to assess the injury caused by low rates of glufosinate and glyphosate on rice. The experiment was conducted near Lonoke, Ark., in 2007. Wells and XP723 varieties were grown using conventional tillage practices. Herbicide treatments consisted of glyphosate applied at 0, 2.75, 5.5, and 11 oz ae/acre. Glufosinate was applied at 0, 3.75, 7.5, and 15 oz ai/acre. These represent 0x, 1/2x, 1/4x, and 1/8x rates, respectively. Treatments were applied at the 3- to 4-lf, PI, and boot stages using Roundup Weathermax® (glyphosate) and Ignite280® (glufosinate). Applications were made using a pressurized-CO_2 backpack sprayer with a four-nozzle boom delivering a spray volume of 10 GPA. The study design was a randomized complete block with four replications. Visual injury, visual stunting, canopy heights (cm, taken at heading), heading dates, flag leaf length, and days to heading were recorded for all treatments. Yields were obtained using a small-plot combine and adjusted to 12.5% moisture.

RESULTS AND DISCUSSION

In general, both varieties responded similarly to glyphosate and glufosinate (Table 1). Visual injury from the 3- to 4-lf timing for glufosinate ranged from 0 to 83% depending on rate at 2 wk after treatment (WAT). Glyphosate injury at the 3- to 4-lf timing ranged from 0 to 45% injury. At the PI timing, glufosinate injury ranged from 16 to 78% and glyphosate injury ranged from 5 to 10% at 2 WAT. Injury at the boot timing for glufosinate ranged from 15 to 85%. Glyphosate at the boot timing did not show any increase in injury at any rate.

Canopy height was reduced the greatest when both herbicides were applied at the PI timing. Glyphosate reduced canopy height at the PI timing from 2 to 10.2 in. (data not shown). Glufosinate applied at the PI timing reduced canopy heights from 2.8 to 9.4 in.

Flag leaf length was not affected by either herbicide when applied at the 3- to 4-lf timing (data not shown). Glufosinate reduced flag leaf length from 4.7 to 11.8 in. when applied at PI. Glyphosate reduced flag leaf length from 1.2 to 8.3 in. when applied at PI. Both herbicides did not affect flag leaf length when applied at boot due to the emergence of the flag leaf prior to application.

Days to heading were not affected by either herbicide when applied at the 3- to 4-lf timing. However, days to heading was delayed by both herbicides when applied at the PI and boot timings. The greatest delay in heading occurred at the boot timing with glufosinate delaying heading from 34 to 44 days. Glyphosate delayed heading at the boot stage from 27 to 44 days. Meier et al. (2006) documented similar results in rice previously.

Glufosinate applied at 0.31 kg ai/ha reduced the yield of Wells by 37% and XP723 by 29% when applied at the 3- to 4-lf timing (Table 2). Glyphosate applied at 11 oz ae/acre reduced yields at the 3- to 4-lf timing of Wells by 65% and XP723 by 91%. When herbicides were applied at the PI timing yields were reduced from 9 to 70%. Glufosinate at 15 oz ai/acre reduced yield of Wells by 55% and XP723 by 39%. Glyphosate applied at 11 oz ae/acre reduced yields of both cultivars by 70%. Yields were reduced the greatest when herbicides were applied at the boot timing. Glufosinate applied at 15 oz ai/acre reduced yield of Wells by 93% and XP723 by 91%. When glyphosate was applied at 11 oz ae/acre yields were reduced by 93% for Wells and 95% for XP723.

SIGNIFICANCE OF FINDINGS

In general, glyphosate injury was minimal but yield reduction was greater than glufosinate and glufosinate caused greater visual injury but did not reduce yield as great as glyphosate.

ACKNOWLEDGMENTS

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Table 1. Rice injury response to glyphosate and glufosinate at 2 weeks after treatment at all timings.

		Application timing					
		3- to 4-lf		Panicle initiation		Boot	
Herbicide	Rates[z]	Wells	XP723	Wells	XP723	Wells	XP723
	(oz/acre)	(% injury)					
Check		0	0	0	0	0	0
Glufosinate	15.00	83	85	78	73	85	80
	7.50	15	14	38	31	55	43
	3.75	0	0	16	18	21	15
Glyphosate	11.00	45	34	10	8	0	0
	5.50	15	14	6	6	0	0
	2.75	0	0	5	5	0	0
LSD (p=0.05)		7					

[1] Glufosinate rates are active ingredient/acre; glyphosate rates are acid equivalent/acre.

Table 2. Rice yield response as percentage of check to glyphosate and glufosinate applied at 3- to 4-lf, panicle initiation, and boot.

		Application timing					
		3- to 4-lf		Panicle initiation		Boot	
Herbicide	Rates[1]	Wells	XP723	Wells	XP723	Wells	XP723
	(oz/acre)	[Yield (% of check)					
Glufosinate	15.00	62	72	45	62	7	9
	7.50	87	91	71	82	11	21
	3.75	94	94	99	86	21	28
Glyphosate	11.00	35	9	30	30	7	5
	5.50	77	72	64	59	6	11
	2.75	86	97	92	85	28	34
LSD (p=0.05)		11					

[1] Glufosinate rates are active ingredient/acre; glyphosate rates are acid equivalent/acre.

BAS 800 (Kixor) for Northern Jointvetch and Hemp Sesbania Control in Rice

J.W. Dickson, R.C. Scott, K.L. Smith, J.K. Norsworthy, and B.M. Davis

ABSTRACT

The objective of this research was to evaluate the performance of BAS 800, a new herbicide from BASF, on hemp sesbania and northern jointvetch in rice. The experiment was conducted at the Rice Research and Extension Center (RREC) at Stuttgart, and at the University of Arkansas at Pine Bluff Farm (UAPB) at Lonoke. The experimental design was a randomized complete block with four replications. 'CL 171' was the rice variety used at the Stuttgart location and 'Wells' was the variety used at the Lonoke location. Conventional cultivation and planting methods were used in planting the rice, and the entire study was over-seeded with hemp sesbania and northern jointvetch. A preemergence (PRE) application of Newpath was applied to the entire study at a rate of 6oz/acre on the Clearfield variety, and Clincher was applied to the entire study at the UAPB when grass weeds were at the 1- to 2-leaf (lf) stage at 15 oz/acre with a crop oil concentrate at 2.5% v/v in order to eliminate grass weeds. BAS 800 herbicide applications were made at the preemergence, 2-lf rice, and 4-lf rice timings at 1, 2, and 4 oz/acre at each timing. Aim herbicide was also applied at the same rice growth stages at the rate of 3.2 oz/acre for comparison. Agridex (non-ionic surfactant) at 1% v/v was included in all post-emergence treatments.

Neither herbicide displayed any significant amount of residual activity at the rates evaluated. BAS 800 controlled hemp sesbania from 90 to 100% by 35 and 85 days after application in both post-emergence application timings at both locations, while Aim controlled hemp sesbania 100% at both post-emergence timings at both locations. BAS 800 controlled northern jointvetch from 90 to 100% by 85 days after application in both post-emergence application timings at both locations. At 85 days after application, Aim, applied at 2-lf rice, controlled northern jointvetch 48% at the RREC and 58% at

the UAPB. At the 4-lf timing, however, Aim controlled northern jointvetch 100% at the RREC and 90% at the UAPB. Visual rice injury was never greater than 10% and no significant yield response was observed.

INTRODUCTION

BAS 800 is a new herbicide developed by BASF expected to be registered as Kixor in 2010 (Anonymous, 2009a). The active ingredient in BAS 800 is saflufenacil. Saflufenacil is a new PPO-inhibiting, peroxidizing herbicide (Grossman et al., 2009). The active ingredient of Aim, carfentrazone-ethyl, is also a PPO-inhibitor. Aim is effective at controlling hemp sesbania (*Sesbania exaltata*) (90%), but is a less effective northern jointvetch (*Aeschynomene virginica*) herbicide (60%) (Scott et al, 2009). The objectives of these studies was to evaluate crop tolerance and preemergence and postemergence hemp sesbania and northern jointvetch control using BAS 800 compared to Aim herbicide.

PROCEDURES

Two studies were conducted in 2008 to evaluate the performance of BAS 800 for control of northern jointvetch and hemp sesbania in rice. One study was conducted at the University of Arkansas at Pine Bluff Research Farm (UAPB) near Lonoke, Ark., and the other study was conducted at the Rice Research and Extension Center (RREC) near Stuttgart, Ark.

The study at UAPB was drill-seeded into 10-ft by 25-ft plots on 9 June 2008 using the variety Wells at 90 lb/acre. The study at RREC was drill-seeded into 7-ft by 20-ft plots on 12 May 2008 using the Clearfield variety CL 171 at 90 lb/acre. Treatments were arranged in a randomized complete block design with four replications in both studies. The study at RREC was treated with a preemergence application of Newpath at the rate of 6 oz/acre, and the study at UAPB was treated with an application of Clincher when grass weeds were at the 1- to 2-lf stage at a rate of 15 oz/acre with a crop oil concentrate at 2.5%v/v. Hemp sesbania and northern jointvetch were broadcasted over the entire study area to ensure even populations of these weeds. Standard University of Arkansas fertility recommendations and farming practices were followed for both studies. All treatments were applied at a spray volume of 10 gal/acre (GPA). Treatments at RREC were applied using a handheld boom and CO_2 as a propellant. Treatments at UAPB were applied using a MudMaster® or tractor equipped with a multi-boom sprayer and compressed air as a propellant.

Both studies consisted of 12 common treatments and an untreated check. The treatments were BAS 800 applied at 1, 2, and 4 oz/acre and Aim at 3.2 oz/acre applied at preemergence, 2-lf rice, and 4-lf rice stages. No weeds were present at the preemergence application. At the 2-lf rice application, hemp sesbania and northern jointvetch were approximately 3-in. in height at both locations, and at the 4-lf rice application, hemp sesbania was 4 to 7 in. in height while northern jointvetch was only 4 in. in height.

Weed control and crop-tolerance ratings were conducted multiple times throughout the season. Weed control was visually estimated using a scale of 0 to 100%, where 0 equals no control and 100 equals complete control or desiccation of weeds. Crop tolerance was visually estimated using the same scale where 0 equals no injury and 100 equals complete crop loss. Parameters evaluated on crop tolerance included: stunting, discoloration, and maturity. Harvest was conducted and yield data collected using a John Deere 4435 combine modified for plot harvesting.

Data were arranged and organized using Agriculture Research Manager (ARM) by Gylling Data Management (Brookings, S.D.). Data analysis was completed using the analysis of variance procedure (P=0.05), and treatment means were separated using the least significant difference (LSD) procedure in ARM.

RESULTS AND DISCUSSION

In both studies, evaluations of hemp sesbania control were made at 35 and 85 days after treatment, and evaluations of northern jointvetch control were made at 85 days after treatment. The preemergence applications of both BAS 800 and Aim failed to control hemp sesbania 35 days after application and northern jointvetch 85 days after application (Tables 1 and 2). When applied to 2-lf rice at the 1 oz/acre rate, BAS 800 controlled hemp sesbania >90% and northern jointvetch >90% in both studies. BAS 800 at the 2 and 4 oz/acre rates controlled hemp sesbania ≥99% in both studies. Aim applied at 2-lf rice controlled hemp sesbania ≥99%, but control of northern jointvetch was only 48% and 58% at RREC and UAPB, respectively. BAS 800 applied to 4-lf rice controlled hemp sesbania 100%, regardless of application rate. BAS 800 applied to 4-lf rice controlled northern jointvetch ≥94% with no significant difference between application rates. Aim applied to 4-lf rice controlled hemp sesbania 100% and northern jointvetch ≥90%.

Visual rice injury of no greater than 10% was observed in the plots that received herbicide applications at the 4-lf rice stage (Tables 1 and 2), but no significant yield loss was observed at harvest (data not shown).

SIGNIFICANCE OF FINDINGS

Data from these trials suggest that BAS 800 applied postemergence at 2 and 4 oz/acre is as effective as Aim at 3.2 oz/acre at controlling hemp sesbania in conventional and Clearfield rice cropping systems. BAS 800 applied postemergence proved effective at controlling northern jointvetch (≥91%), while these studies and prior research affirms that Aim is less effective (only rated at 60% control in the MP44) at controlling this weed (Scott et al., 2009).

Mode of action research with radiolabeled saflufenacil by Grossmann and others revealed that, due to it weak acid character, saflufenacil is distributed within the plant *via* xylem and phloem to the plant growing parts, which provides contact and additional systemic action of saflufenacil for more effective control of dicot weeds (Grossman et al., 2009). Symplastic phloem movement of carfentrazone-ethyl is assumed to be limited, based on rapid foliar desiccation (Senseman et al., 2007). The research of Grossman suggests that saflufenacil's translocation may be the reason better northern jointvetch control was achieved with BAS 800.

Neither BAS 800 nor Aim displayed any significant residual activity when applied preemergence.

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Table 1. Rice response and weed control with BAS 800 at the Rice Research and Extension Center, 2008.

				Control		
			Rice injury	Hemp sesbania		Northern jointvetch
Herbicide[z]	Rates	Timing[y]	35 DAT	35 DAT	85 DAT	85 DAT
	(oz/acre)		---------------------------- (%) ----------------------------			
Check			0	0	0	0
BAS 800	1.0	PRE	0	65	0	0
BAS 800	2.0	PRE	0	50	0	0
BAS 800	4.0	PRE	0	68	0	0
Aim	3.2	PRE	0	38	0	0
BAS 800	1.0	2-lf	0	91	99	100
BAS 800	2.0	2-lf	0	100	100	100
BAS 800	4.0	2-lf	0	100	99	100
Aim	3.2	2-lf	0	100	100	48
BAS 800	1.0	4-lf	5	100	100	100
BAS 800	2.0	4-lf	8	100	100	100
BAS 800	4.0	4-lf	10	100	100	97
Aim	3.2	4-lf	10	100	100	100
LSD (p=0.05)			1	6	1	3

[z] Post applications made with Agridex at a rate of 1% v/v

[y] PRE = preemergence; 2-lf = 2-leaf rice; and 4-lf = 4-leaf rice.

Table 2. Rice response and weed control with BAS 800 at the University of Arkansas Pine Bluff Farm, 2008.

				Control		
			Rice injury	Hemp sesbania		Northern jointvetch
Herbicide[z]	Rates	Timing[y]	35 DAT	35 DAT	85 DAT	85 DAT
	(oz/acre)		---------------------------- (%) ----------------------------			
Check			0	0	0	0
BAS 800	1.0	PRE	0	0	0	0
BAS 800	2.0	PRE	0	0	0	0
BAS 800	4.0	PRE	0	0	0	0
Aim	3.2	PRE	0	0	0	0
BAS 800	1.0	2-lf	0	99	99	91
BAS 800	2.0	2-lf	0	100	100	97
BAS 800	4.0	2-lf	0	100	100	99
Aim	3.2	2-lf	0	100	99	58
BAS 800	1.0	4-lf	5	100	100	94
BAS 800	2.0	4-lf	10	100	100	100
BAS 800	4.0	4-lf	10	100	100	100
Aim	3.2	4-lf	10	100	100	90
LSD (p=0.05)			0	1	1	8

[z] Post applications made with Agridex at a rate of 1% v/v

[y] PRE = preemergence; 2-lf = 2-leaf rice; and 4-lf = 4-leaf rice.

Environmental Implications of Pesticides in Rice Production

J.D. Mattice, B.W. Skulman, and R.J. Norman

ABSTRACT

For the past 6 years we have collected and analyzed water in Arkansas from four sites each on the Cache, L'Anguille, and St. Francis rivers from near Jonesboro in the north to near Marianna in the south and on La Grue Bayou from just below Peckerwood lake north of Stuttgart to near the mouth southeast of DeWitt. Since 2003, 56 to 93% of the detections over 2 ppb have been for quinclorac (Facet) and clomazone (Command). Each year, most (60 to 86%) of the detections that were over 2 ppb were less than 5 ppb, and 85 to 99% of the detections over 2 ppb were less than 10 ppb. The highest concentration in 2008 was 18.8 ppb for triclopyr. The Cache and the L'Anguille rivers consistently have the most detections over 2 ppb. There is no trend for the overall frequency of detections over 2 ppb (9.2% in 2000, 12.0% in 2001, 5.2% in 2002, 6.2% in 2003, 5.4% in 2004, 3.7% in 2005, 3.3% in 2006, 6.3% in 2007, and 5.2% in 2008).

INTRODUCTION

The goal of this project is to determine if any environmental problems are developing in Arkansas surface waters as a result of pesticides used in rice production. Monitoring for pesticides in water may allow us to detect a potential problem and address it before it becomes a major problem.

Small rivers in watersheds that are predominately in rice-growing country would be the most sensitive barometers of potential problems due to pesticide use, since most of the water in the rivers would come from areas growing rice.

PROCEDURE

Sampling Sites

Four sites on each of 4 rivers have been established (Fig. 1). Water samples were collected on the L'Anguille River where it crosses highways US 79 near Marianna, US 64 near Wynne, State 14 near Harrisburg, and near Claypool reservoir north of Harrisburg. They were collected on the St. Francis River where it crosses US 79 near Marianna, US 64 near Parkin, State 75 near Marked Tree, and State 18 east of Jonesboro. Samples were collected on La Grue Bayou at a county road approximately 0.5 km below Peckerwood Lake, the second bridge on Highway 146 west of the Highway 33 junction, near the town of La Grue at Highway 33 before the junction with Highway 153, and where the La Grue crosses Highway 1 outside of DeWitt. Four samples were also collected on the Cache River where it crosses State Highway 91 west of Jonesboro, a dirt road off County 37 at Algoa, State Highway 260 near Patterson, and US 70 south of I-40.

Sampling Procedure

A 500 mL aliquot of each sample was extracted onto C18 disks in the field with a mobile extractor using conventional C18 disk technology. The disks were stored on ice packs and eluted on return to the lab. Samples were then analyzed by gas chromatography mass spectrometry (GCMS) and high performance liquid chromatography (HPLC).

For quality control, at one site on each river four replicate subsamples were collected. Two subsamples were fortified with known amounts of the compounds and two were left unfortified. Analysis of these samples allowed us to verify recovery and reproducibility. Sampling was performed at 2-week intervals during the rice-production season from May through August until 2004. In 2004, we began collection in mid-April and stopped in mid-August.

The compounds chosen for analysis changed as their use in the field changed. Each year analysis is for approximately 10 to 13 compounds that we could reasonably expect to find. In 2008 analysis was for 10 pesticides and three pesticide degradation products. The compounds were Bolero (thiobencarb), Command (clomazone), 2,4-D, Facet (quinclorac), Garlon (triclopyr), Pursuit (imazethapyr), Quadris (azoxystrobin), Raptor (imazamox), Stam (propanil), Tilt (propiconazole); plus triclopyridinol (degradation product of triclopyr), and cyhalofop-acid and diacid (both degradation products of cyhalofop-butyl, trade name Clincher).

RESULTS AND DISCUSSION

Since the compounds require some water solubility to be active, and with the sensitive analytical equipment now available, it is not surprising to find low levels of pesticides in runoff water adjacent to fields when and where the compounds are used. Trying to find meaningful trends when looking at changes in small fractions of a part per billion concentration in water would be difficult. There will be variability, but not necessarily meaningful variability in the sense of identifying a developing problem. Since these are water samples from small rivers surrounded by rice fields, we have chosen a concentration of 2 ppb as the cutoff level for making comparisons.

Three different pesticides, one detection per pesticide, were detected in samples collected from each of the rivers on the first sampling trip on 25 and 26 April (Table 1). In 2007, only three different pesticides were detected on the first sampling trip, but there were a total of 12 detections on that trip.

As in previous years, clomazone and quinclorac were the two most frequently detected compounds in 2008 (Table 1). A total of 58 samples provided 86 detections of compounds at concentrations greater than 2 ppb compared to 73 samples and 102 detections in 2007. Quinclorac was detected in 57% of these 58 samples, and clomazone was detected in 43%. Both compounds were also detected most frequently when they were being used. All but one of the 25 detections of clomazone (96%) occurred prior to 3 July. The detections of quinclorac were slightly more spread out, but 27 out of the 33 detections (82%) were after 4 June. This was similar to 2007 when 90% of the detections of quinclorac occurred during a 6-week period covering four sampling trips from 6 June to 18 July.

The 86 detections over 2 ppb in 2008 is the second largest number of detections over the past 6 years and is a decrease from the 102 detections in 2007, which was the largest number of detections over the past 6 years (Table 2). Part of the reason for having more detections in 2007 and 2008 is because analysis was being conducted for 13 compounds in both years. In 2003, analysis was for 10 compounds, so although the 79 detections in 2003 was lower than in 2007, the percent detections was almost the same (6.2% in 2003 verses 6.3% in 2007) where 100% is equivalent to finding every compound in every sample. In 2008, the percent was 5.2%. In 2000, the percent detections was 12% (Mattice et al., 2000), in 2001 it was 9.2% (Mattice et al., 2001), and in 2002 it was 5.1% (Mattice et al., 2002). The percent detections between 5.1 to 6.3% in the years 2002, 2003, 2004, 2007, and 2008 may reflect the norm with the percent detections in 2005 and 2006 being unusually low and the percent detections in 2000 and 2001 being unusually high. Overall this may reflect the extremes and variability that can be expected.

The distribution of concentrations in the 2 to 5 ppb concentration range has varied between 60 and 86% over the past 6 years (Table 3). Small changes in concentrations near the dividing line between concentration ranges can produce large changes in percent distribution in those ranges. In 2005, there were seven values in the 5- to 6-ppb range and three values in the 10- to 11-ppb concentration range (Mattice et al., 2005). If these values had been 1 ppb lower, the percents for the 2- to 5-, 5- to 10-, and 10- to 40-ppb would have been 70%, 19%, and 10%. In 2008, there were seven values in the 5- to 6-ppb range and five in the 10- to 11-ppb range. If these had been 1 ppb lower, the percents for the ranges would have been 74% (2- to 5-ppb), 20% (5- to 10-ppb) and 6% (10- to 40-ppb). A slight change in concentrations of several samples would make the percent distribution of concentrations for 2005 and 2008 similar to the other years.

The L'Anguille and the Cache rivers routinely produce the largest number of detections (Table 4). Over the past 6 years, the L'Anguille has produced an average of

24.2 detections per year and the Cache produced 31.2 detections per year. Combined for the 6-year period they have accounted for 75% of the detections, although they have 50% of the sampling sites.

The upper portions of the L'Anguille and Cache are completely surrounded by rice fields, so virtually all the water is coming from areas under rice production. Farther downstream there could be a dilution effect if larger percentages of water flowing into these two rivers come from areas not under rice production. From 2003 to 2008 there were 126 detections from the uppermost sampling sites on the L'Anguille (site A) and the Cache (site Q) compared to only 52 at the lowest sites D and T consistent with a dilution effect (Table 4).

The reverse trend is observed for the St. Francis River and La Grue Bayou. The St. Francis River begins in southeast Missouri where rice production is not as prevalent as farther downstream in Arkansas, so the upstream sampling site E might have few detections and the downstream sampling site H, where there is more rice production, would have more detections (Table 4; Fig. 1). The first sampling site K on La Grue Bayou is approximately 0.5 km downstream from Peckerwood Lake. If the lake is a reservoir where pesticide degradation can occur, then the upstream site, which is essentially lake water, would be expected to provide a low detection frequency of pesticides. Farther downstream where there is more inflow from rice-producing areas we would expect to have increasing detections. The uppermost sites on the St. Francis (E) and La Grue (K) produced 15 detections over 6 years, and the two most downstream sites H (St.Francis) and N (La Grue) produced 32 detections, indicating this is the case. Both situations demonstrate the value of having multiple sampling sites on rivers if they are being used to measure effects of runoff water into these rivers.

Each river has 25% of the sampling sites, but from 2003 to 2005 most of the detections came from the Cache River (46% in 2003, 43% in 2004, and 40% in 2005; Table 4). In 2006, the L'Anguille and Cache rivers produced almost the same frequency of detections with 43% from the L'Anguille and 41% from the Cache, a difference of 1 detection. In 2007, the L'Anguille had 38 detections (37%) and the Cache had 34 detections (33%). In 2008, the L'Anguille had 28% of the detections, almost proportional to the number of sampling sites (25%). The Cache had 48% of the detections, still more than would be expected from the number of sampling sites and higher than in 2007, but similar to what was observed from 2003 to 2006.

Over the past 6 years, 60 to 86% of the samples that contained a compound at a concentration over 2 ppb contained only one compound (Table 5). In 2008, 40% of the samples containing a compound contained two or more. This is similar to 2007 when 37% contained two or more. In 2007, most of the increase, 34%, was for samples that contained only two compounds. Twelve of the samples that had two compounds had one compound with a concentration between 2.0 and 2.5 ppb (Mattice et al., 2007). A decrease in concentration of 0.5 ppb would have caused those samples to be listed in the one compound per sample category. In that case, 79% of the samples containing a compound at a concentration over 2 ppb would have had only one compound, and 18% would have had two compounds. This would be similar to years 2003 to 2006. The same treatment in 2008 would result in 67% of the samples containing only one compound, 29% having two compounds, 3% with three compounds, and none of the samples would have had four compounds. Similarly to the discussion showing how small changes in concentrations near the borderline of a category can have a large effect on distributions in concentration ranges, this illustrates that small changes in concentrations can have a large affect on how samples are distributed in categories showing the number of detections per sample.

Detection of the same compound at the same site on consecutive sampling periods could indicate that the compound is being continually introduced into the river, as opposed to a limited, intermittent introduction. Not surprisingly, clomazone and quinclorac, which were detected most often, were also the compounds which were detected most frequently on consecutive sampling dates (Table 6). Also, this occurred on the L'Anguille and the Cache rivers, which had the highest numbers of detections (Table 4). There is a period from late May through mid-June on the upper L'Anguille, especially site A, when we can expect to find both clomazone and quinclorac at concentrations over 2 ppb. On the Cache River we can expect to find both compounds from the end of May through early July throughout most of the river, but especially the upper to middle part.

EPA does not have guidelines on acceptable levels for most of these compounds in either the National Recommended Water Quality Criteria - Correction (USEPA 1999) or the 2002 Edition of the Drinking Water Standards and Health Advisories (USEPA 2002). There was a listing of 70 ppb for the Maximum Contaminant Level (MCL) for 2,4-D in their drinking water standards. The highest level we found in river water was 25.5 ppb in 2007.

As mentioned previously (Mattice et al., 2007), comparing our results to EPA ecotoxicity data in the Pesticide Action Network data base (PAN, 2007) indicates that on two occasions in the past 6 years concentrations of propanil (9.5 ppb in 2004) or 2,4-D (25.5 ppb in 2007) may have been high enough to cause an effect on some form of development of green algae or diatoms. These two compounds are rarely found, and when they are found they are at lower concentrations. None of the concentrations found in 2008 exceed these concentrations. They have been found infrequently in water because of their short environmental half-lives. The half-life of propanil is only 17 to 154 hr in environmental water (Anon 2008a), and the half life of 2,4-D in water ranges widely from 10 to >50 days depending on environmental conditions. The half life of 2,4-D in sediment and mud is less than 1 day (Anon 2008b).

The two compounds that are most frequently found, clomazone and quinclorac, require much higher concentrations to have a detrimental affect on a variety of test species listed in the PAN database, so unless there is a strong synergistic effect between these two compounds, they are not likely to be causing an environmental problem. We were not able to find any study in the literature investigating a possible synergism between these two compounds.

SIGNIFICANCE OF FINDINGS

Most of the detections have been of low level and sporadic. Exceptions for being sporadic would be for clomazone (Command) in the first part of the sampling season and for quinclorac (Facet) in the middle part of the season (Tables 1 and 6). These compounds were detected frequently but usually at low concentrations. These results are generally similar to those of previous years. Comparing our results to ecotoxicity data indicates no developing environmental problem unless there is a strong synergism between clomazone and quinclorac, the two most commonly found compounds. Individually they have low toxicity, and there are no data available regarding a synergistic affect.

ACKNOWLEDGMENTS

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Table 1. Results for the year 2008 water samples that contain at least one detection of a pesticide at a limit of quantitation of 2 ppb.

Date	River	Site[z]	Compounds and concentrations detected[y]								
			azo	clom	con	cy	ima	pro	qui	tri	triol
			(ppb corrected for recovery)								
4/25	LG	M	2.3				2.7				
4/26	CA	Q		2.9							
5/09	LA	A		11.4				5.2		18.8	
5/09	LA	B		5.9							
5/09	LA	D	3.9								
5/09	SF	F	2.0								
5/09	SF	H			3.5						
5/23	LA	A		10.7					4.4	2.9	
5/23	LA	B		4.5					2.6		
5/24	LA	C		3.0							
5/24	CA	Q		8.9					3.6		
5/24	CA	R		3.4							
5/24	CA	S		2.4							
6/04	LA	A		10.7					5.8		
6/04	LA	B		5.6							
6/04	LA	C		2.7							
6/04	LA	D		2.3							
6/04	SF	G					2.7				
6/04	SF	H			3.0						
6/04	LG	K									2.2
6/04	LG	L									2.4
6/04	LG	M	2.9								
6/05	CA	Q		10.4					7.0		
6/05	CA	R		10.1					9.3		
6/05	CA	S	2.2	5.1							
6/04	CA	T									3.1
6/20	LA	A		2.8					16.8		
6/20	SF	G	3.0						2.1		
6/20	LG	M							2.5		
6/21	CA	Q		6.9					7.8		
6/21	CA	R		6.9					6.2		
6/21	CA	S		8.3					4.1		
7/02	LA	A							12.6		
7/02	LA	B							3.1		
7/02	LG	L							3.2		
7/02	LG	M							2.0		
7/03	CA	Q		5.2					10.3		
7/03	CA	R		4.6					9.4		
7/03	CA	S		4.1					5.3		
7/02	CA	T		2.3							
7/18	LA	B							3.1		
7/18	LA	C							2.7		
7/18	SF	G							2.3		
7/18	SF	H							2.2		
7/18	LG	K			2.6						
7/18	LG	L							4.8		
7/18	LG	M									3.8

continued

Table 1. Continued.

Date	River	Site[z]	Compounds and concentrations detected[y]								
			azo	clom	con	cy	ima	pro	qui	tri	triol
			(ppb corrected for recovery)								
7/19	CA	Q			2.8				7.9	2.1	
7/19	CA	R	2.1						6.0		
7/19	CA	S							8.1		
7/18	CA	T		3.7	2.0		2.4		8.1		
7/31	LA	A	4.9			2.8					
7/31	SF	H							2.3		
7/31	LG	K					4.2				
8/01	CA	Q							3.6		
8/01	CA	R							4.5		
8/01	CA	S							4.4	2.8	
7/31	CA	T					3.0		5.0		
TOTAL			8	25	5	1	5	1	33	4	4
% in 58 samples			14	43	9	2	9	2	57	7	7
% of 86 detections			9	29	6	1	6	1	38	5	5

[z] A-D = L'Anguille upstream to downstream; D-H = St. Francis upstream to downstream; K-M = LaGrue upstream to down stream; and Q-T = Cache upstream to downstream.

[y] azo = azoxystrobin; clom = clomazone; con = propiconazole; cy = cyhalofop-butyl; ima = imazethapyr; pro = propanil; qui = quinclorac; tri = triclopyr; and triol= triclopyridinol.

Table 2. Frequency of detections over 2 ppb of pesticides in water by year.

Year	2003	2004	2005	2006	2007	2008
Number of rivers	4	4	4	4	4	4
Possible detections	1280	1440	1792	1792	1616	1664
Detections	79	77	67	59	102	86
Percent	6.2	5.4	3.7	3.3	6.3	5.2

Table 3. Concentration distribution of pesticides in water by year.

Concentration	Number of detections[z]					
range	2003	2004	2005	2006	2007	2008
	(ppb)					
2-5	68 (86%)	63 (82%)	40 (60%)	48 (81%)	76 (75%)	57 (66%)
5-10	10 (13%)	13 (17%)	17 (25%)	7 (12%)	19 (19%)	19 (22%)
10-40	1 (1%)	1 (1%)	10 (15%)	4 (7%)	7 (7%)	10 (12%)

[z] Percents may not total to 100 due to rounding to nearest percent.

Table 4. Detection frequency of pesticides in water over 2 ppb by river and site.

	Detection frequency					
River/Site	2003	2004	2005	2006	2007	2008
L'Anguille						
A[z]	8	9	4	10	14	13
B	6	5	2	4	10	6
C	3	9	4	10	9	3
D	4	2	2	1	5	2
Total	**21**	**25**	**12**	**25**	**38**	**24**
St. Francis						
E	0	0	0	2	1	0
F	2	3	0	1	3	1
G	3	3	2	0	6	4
H	4	3	1	2	6	4
Total	**9**	**9**	**3**	**5**	**16**	**9**
LaGrue						
K	5	2	0	0	2	3
L	2	3	1	1	5	3
M	4	1	2	2	3	6
N	2	4	0	2	4	0
Total	**13**	**10**	**3**	**5**	**14**	**12**
Cache						
Q	16	11	9	8	11	13
R	8	7	4	6	7	10
S	6	7	3	7	8	10
T	6	8	3	3	8	8
Total	**36**	**33**	**19**	**24**	**34**	**41**

[z] A-D = L'Anguille upstream to downstream; D-H = St. Francis upstream to downstream; K-M = LaGrue upstream to down stream; and Q-T = Cache upstream to downstream.

Table 5. Multiple detections of pesticides in river water over 2 ppb per sample.

No. of compounds	Number of samples[z]					
per sample	2003	2004	2005	2006	2007	2008
1	49 (80%)	63 (82%)	34 (69%)	44 (86%)	46 (63%)	35 (60%)
2	9 (15%)	14 (18%)	12 (24%)	6 (12%)	25 (34%)	19 (33%)
3	1 (2%)	0	3 (6%)	1 (2%)	2 (3%)	3 (5%)
4	1 (2%)	0	0	0	0	1 (2%)
5	1 (2%)	0	0	0	0	0

[z] Percents may not total to 100 due to rounding to nearest percent.

Table 6. Consecutive detections of selected pesticides by site in 2008.

Date	clomazone							quinclorac					
5/09	A[z]	B											
5/23	A	B	C	Q	R	S		A		Q			
6/04	A	B	C	Q	R	S		A		Q	R		
6/20	A			Q	R	S		A		Q	R	S	
7/02				Q	R	S	T	A	B	Q	R	S	
7/18							T		B	Q	R	S	T
8/01										Q	R	S	T

[z] A-D = L'Anguille upstream to downstream; D-H = St. Francis upstream to downstream; K-M = LaGrue upstream to down stream; and Q-T = Cache upstream to downstream.

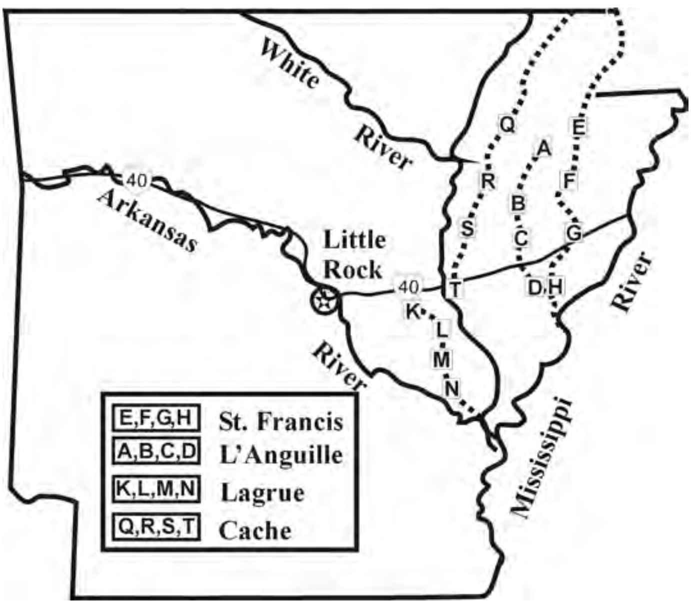

Fig. 1. Sampling sites for the 2008 water monitoring program.

Texasweed (*Caperonia palustris*) Response to Rice Herbicides in Greenhouse Screening

J.R. Meier, K.L. Smith, R.C. Scott, and J.K. Norsworthy

ABSTRACT

Texasweed (*Caperonia palustris*) has recently been identified in soybean and rice fields in southeast Arkansas. There is little data published on control of Texasweed, especially with herbicides labeled for use in rice. Two greenhouse experiments were conducted in 2008 at the University of Arkansas Southeast Research and Extension Center at Monticello, Ark., to examine control of Texasweed with herbicides labeled for use in rice. Texasweed and 'CL161' rice seed were planted 0.5-in. deep into pots containing Sharkey clay soil in both trials. Experiments were established in a randomized complete block design with four replications and applications were made with a CO_2 backpack sprayer calibrated to deliver 12 GPA. Triclopyr applied to 4- to 5-leaf (lf) Texasweed provided greater control than penoxsulam, bensulfuron, propanil, and acifluorfen. Combinations of triclopyr or bensulfuron with penoxsulam and acifluorfen or bensulfuron with propanil increased control over penoxsulam and propanil applied alone. Saflufenacil and aminopyralid both provided excellent control (>98%) of Texasweed at rates as low as 1 oz/acre.

INTRODUCTION

Texasweed is a dicotyledonous summer annual species in the Euphorbiaceae family that has recently been identified in soybean and rice fields in southeast Arkansas. It is an erect herb ranging in height from 1 to 10 ft, with coarsely pubescent stems and petioles. Leaves are alternate, range in length of 1 to 6 in., are broadly lanceolate, and serrated on the margins (SWSS ,1998). Texasweed prevails in clay soils, which are commonly used for rice and soybean rotations (Koger et al., 2004; Poston et al., 2007). Seed production occurs for an extended period of time throughout the growing season, with mature seed dehiscing while new seed are produced (Koger et al., 2004). Teaxasweed can germinate under a wide range of soil temperatures, pH levels, and various soil depths, and can produce an average of 893 seed/plant with 90% viability (Koger et al., 2004). Seed are also buoyant, which makes dispersal through drainage systems a possibility and a concern. In soybean, limited control has been reported with various rates and combinations of glyphosate, acifluorfen, bentazon, and fomesafen when Texasweed exceeded the 3-lf growth stage (Griffin et al., 2002). Poston et al. (2007) recently reported that control of Texasweed in soybean with postemergence herbicides primarily consisted of suppression of growth rather than plant mortality, and that plants in the field recovered from most treatments. Unfortunately, there is little data published on control of Texasweed with herbicides labeled for use in rice. The objectives of this research were to examine Texasweed and rice response to herbicides applied alone and in combinations.

PROCEDURES

Two greenhouse experiments were conducted in 2008 at the University of Arkansas Southeast Research and Extension Center at Monticello, Ark. Four CL161 rice and Texasweed seed were planted 1-in. deep into 4-in. square pots containing Sharkey clay soil (very-fine, smectitic, thermic Chromic Epiaquerts) in both trials. Rice and Texasweed plants were thinned to two plants per pot, and both experiments were established in a randomized complete block design with four replications. Applications were made with a CO_2 backpack sprayer calibrated to deliver 12 GPA. Treatments in the first experiment included a nontreated control; penoxsulam + halosulfuron at 2 + 1 oz ai/acre; penoxsulam + bensulfuron at 2 + 1 oz/acre; penoxsulam + triclopyr at 2 + 11 oz/acre; propanil + triclopyr at 128 + 11 oz/acre; propanil + acifluorfen at 128 + 16 oz/acre; orthosulfamuron + triclopyr at 2.1 + 11 oz/acre; orthosulfamuron + bensulfuron at 2.1 + 1 oz/acre; saflufenacil at 4 oz/acre; aminopyralid at 1 oz/acre; halosulfuron + GWN 3124 at 1 + 0.3 oz/acre; and carfentrazone + halosulfuron at 17 1 + 1 oz/acre applied to Texasweed at the 2- to 3-lf and 4- to 5-lf growth stage. After the completion of the first trial, the second trial was initiated in a similar manner to examine Texasweed and rice response to herbicides applied alone and in combinations. These treatments included a nontreated control; penoxsulam at 2 oz/acre; triclopyr at 11 oz/acre; propanil at 128 oz/acre; bensulfuron at 1 oz/acre; acifluorfen at 16 oz/acre; a, 2, and 4 oz/acre; aminopyralid at 1 and 2 oz/acre; penoxsulam + bensulfuron at 1 + 1 oz/acre; penoxsulam + triclopyr at 2 + 11 oz/acre; propanil + triclopyr at 128 + 11 oz/acre; propanil + acifluorfen at 128 + 16 oz/acre; and propanil + bensulfuron at 128 + 1 oz/acre were applied to Texasweed at the 4- to 5-lf growth stage. Adjuvants were added to treatments as recommended in both trials. Texasweed and rice response was evaluated on a percent basis (0 to 100), and data were subjected to ANOVA with means separated using Fisher's Protected LSD test (P=0.05).

RESULTS AND DISCUSSION

In the first experiment, propanil + triclopyr, propanil + acifluorfen, saflufenacil, and aminopyralid provided 100% control of Texasweed 21days after the 2- to 3-lf application, which was greater than control provided by penoxsulam + halosulfuron and halosulfuron + GWN 3124 but equal to all other treatments (Table 1). When applied to 4- to 5-lf Texasweed, saflufenacil again provided 100% control 21 days after application (DAA). Aminopyralid and propanil + acifluorfen provided 95% control at this time, and control with propanil + triclopyr was 83%. Control with penoxsulam + bensulfuron, orthosulfamuron + bensulfuron, propanil + triclopyr, and carfentrazone + halosulfuron decreased as plant size increased. From this trial it was evident that Texasweed response to some herbicide combinations was greater than others and that this response could be influenced by plant size.

In trial 2, saflufenacil and aminopyralid at all rates, and triclopyr provided 100% control of Texasweed 21 DAA, which was greater than penoxsulam, propanil, bensulfuron, and acifluorfen (Table 2). The addition of triclopyr to penoxsulam and propanil increased control to 90% and 98%, and when propanil and acifluorfen were combined, control increased to 98%. Control with propanil + bensulfuron increased; however, control with penoxsulam + bensulfuron was similar to bensulfuron alone. Injury to rice was minimal in both trials, and had dissipated by 21 DAA. Saflufenacil, aminopyralid, and triclopyr alone successfully controlled Texasweed in this trial; however, these herbicides have little to no activity on grass weed species. Therefore these herbicides must be incorporated into a program with a good preemergence residual for grass control or a tankmix partner will be needed for postemergence applications.

SIGNIFICANCE OF FINDINGS

Of the herbicides currently labeled for use in rice, triclopyr provided greater control over penoxsulam, bensulfuron, propanil, and acifluorfen. Combinations with triclopyr or propanil increased Texasweed control. Saflufenacil and aminopyralid provided excellent control (>98%) of Texasweed at rates as low as 1 oz/acre. Although the level of Texasweed control observed in these greenhouse trials may not be achievable in the field, these results indicate good activity with some herbicides and herbicide combinations that are currently labeled for use in rice. Texasweed may not be a major weed of rice in Arkansas at this time; however, it is a major problem for producers with infestations and more research is needed to improve recommendations for control.

ACKNOWLEDGMENTS

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Table 1. Texasweed control 21 days after application in Trial 1.

		Growth stage[z]			
		2- to 3-lf		4- to 5-lf	
Treatment	Rate[x]	Control	Injury[y]	Control	Injury
	(oz/acre)	(%)			
Penoxsulam + halosulfuron	2 + 1	66	0	59	0
Penoxsulam + bensulfuron	2 + 1	88	0	70	0
Penoxsulam + triclopyr	2 + 11	89	0	90	0
Propanil + triclopyr	128 + 11	100	1	83	0
Saflufenacil	4	100	1	100	0
Aminopyralid	1	100	0	95	0
Orthosulfamuron + triclopyr	2.1 + 11	94	0	84	0
Orthosulfamuron + bensulfuron	2.1 + 1	89	0	63	0
Halosulfuron + GWN 3124	1 + 0.3	85	0	69	0
Carfentrazone + halosulfuron	1 + 1	88	0	66	0
Propanil + acifluorfen	128 + 16	99	1	95	0
Nontreated	0	0	0	0	0
LSD (0.05)[w]		15	NS	20	NS

[z] Average growth stage of Texasweed when applications were made.
[y] Injury was evaluated on rice as leaf-tip burn and speckling.
[x] Herbicide rate expressed as oz ai/acre.
[w] LSD to compare means at different growth stages = 17.

Table 2. Texasweed control 21 days after application in Trial 2.[z]

Treatment	Rate[x]	Control	Injury[y]
	(oz/acre)	-------------(%)-----------	
Penoxsulam	2	51	0
Triclopyr	11	100	0
Propanil	128	74	0
Bensulfuron	1	71	0
Acifluorfen	16	85	0
Saflufenacil	1	98	0
Saflufenacil	2	100	0
Saflufenacil	4	100	0
Aminopyralid	1	100	0
Aminopyralid	2	100	0
Penoxsulam + bensulfuron	2 + 1	74	0
Penoxsulam + triclopyr	2 + 11	90	0
Propanil + triclopyr	128 + 11	91	0
Propanil + acifluorfen	128 + 16	98	0
Propanil + bensulfuron	128 + 1	93	0
Nontreated	0	0	0
LSD (0.05)		12	NS

[z] Average size of Texasweed at time of application was 4- to 5-lf.
[y] Injury was evaluated on rice as leaf-tip burn and speckling.
[x] Herbicide rate expressed as oz ai/acre.

Effect of Postflood Timing and Single versus Sequential Clincher Applications on Barnyardgrass Control in Rice

J.K. Norsworthy, S. Bangarwa, G. Griffith, M.J. Wilson, J. Still, and R.C. Scott

ABSTRACT

Barnyardgrass continues to be a common and difficult-to-control weed in rice fields throughout Arkansas. Clincher (cyhalofop) is often applied late in the growing season to control large barnyardgrass plants that have escaped control with earlier applied herbicides, and control is often inconsistent. Research was conducted in 2007 and 2008 to determine the influence of postflood timing and to compare single and sequential cyhalofop applications on barnyardgrass control. All single and sequential applications of cyhalofop were highly efficacious on barnyardgrass in 2007, with all treatments providing at least 90% end-of-season control. In 2008, barnyardgrass plants were more robust, and control was generally less than in the previous year. Sequential cyhalofop applications were often needed for consistent control, and delaying the initial application to 21 d postflooding resulted in poor barnyardgrass control, even when using sequential applications.

INTRODUCTION

Barnyardgrass is the most problematic and common weed in Arkansas rice (Norsworthy et al., 2007). Unmanaged barnyardgrass can cause up to 87% rice yield loss (Stauber et al., 1991). Clincher (cyhalofop) is often applied postflood in rice for control of barnyardgrass and to prevent yield-reducing interference. As a result of the postflood timing, weather, or application issues, single postflood applications of cyhalofop often provide inconsistent control. Furthermore, if cyhalofop application is used as a salvage treatment, barnyardgrass plants are usually large at application, resulting in failure of cyhalofop to provide consistent control. Therefore, research was conducted to determine the influence of postflood timing and compare single and sequential cyhalofop applications for barnyardgrass control.

PROCEDURES

Experiments were conducted in 2007 and 2008 at the Rice Research and Extension Center in Stuttgart, Ark. 'Wells' rice was drill-seeded at 24 seed/ft of row on 18 April 2007, and 1 May 2008, in 7.5-in.-wide rows. The test site contained a natural infestation of barnyardgrass and was flooded both years at the 5- to 6-leaf (lf) stage of rice. Herbicide treatments included cyhalofop at 0.28 lb ai/acre applied 1 d prior to flooding (PREFL), and 7, 14, and 21 d postflooding (PFL). Additional treatments included the previous timings followed by a second application of cyhalofop at 0.19 lb/acre at 14 d after the initial treatment. All cyhalofop treatments contained crop oil concentrate at 1% v/v and were applied at 10 gal/acre. A nontreated control was included. Crop injury and barnyardgrass control were rated weekly beginning 2 wk after the PREFL application. All data were subjected to analysis of variance, and means were separated using Fisher's protected Least Significance Difference test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

End-of-season control of barnyardgrass in 2007 was similar between single and sequential applications for all timings, except the single 14-d PFL application (Fig. 1). Excluding the 14-d PFL application, barnyardgrass control in all cyhalofop treatments was at least 98% in 2007. Conversely in 2008, due in part to the later planting of rice, barnyardgrass exhibited more robust early-season growth and was more difficult to control with cyhalofop. Cyhalofop applied PREFL controlled barnyardgrass only 68% at 2 WAT (data not shown). Control further declined throughout the season, and end-of-season control was only 28% when a single cyhalofop application was made before flooding. Delaying the single application of cyhalofop to 7 d POSTFL improved barnyardgrass control, with end-of-season control averaging 91%. Barnyardgrass control declined with further delays in application timing, with end-of-season control averaging 78 and 10% when cyhalofop was applied at 14 and 21 d PFL. Following the PREFL with a PFL application improved late-season control to 89% in 2008, which was comparable to other sequential applications that were made 7 and 14 d PFL (90% control). Sequential applications that began 21 d POSTFL were not effective in controlling barnyardgrass, which averaged 46% control late in the season.

No rice injury was observed in either year (data not shown). Due to the high level of control in 2007 (Fig. 1), rice yields were comparable among herbicide treatments, ranging from 152 to 169 bu/acre (data not shown). Delaying cyhalofop applications in 2008, including sequential applications, to 14 or 21 d PFL reduced rice yield, and single and sequential applications, with the first application made PREFL or 7 d PFL, resulted in comparable yields in 2008.

SIGNIFICANCE OF FINDINGS

This research shows that a single late-season cyhalofop application will not provide consistent barnyardgrass control across growing seasons. Under typical rice-growing conditions, it is advisable to make the first cyhalofop application as close to 7 d PFL as possible, which will offer the best single application control. However, sequential applications are needed for consistent control, and even then, delaying the initial application to 21 d PFL followed by an additional application may not result in acceptable barnyardgrass control.

ACKNOWLEDGMENTS

The continued support of weed management research in rice by the Arkansas Rice Research and Promotion Board is gratefully appreciated.

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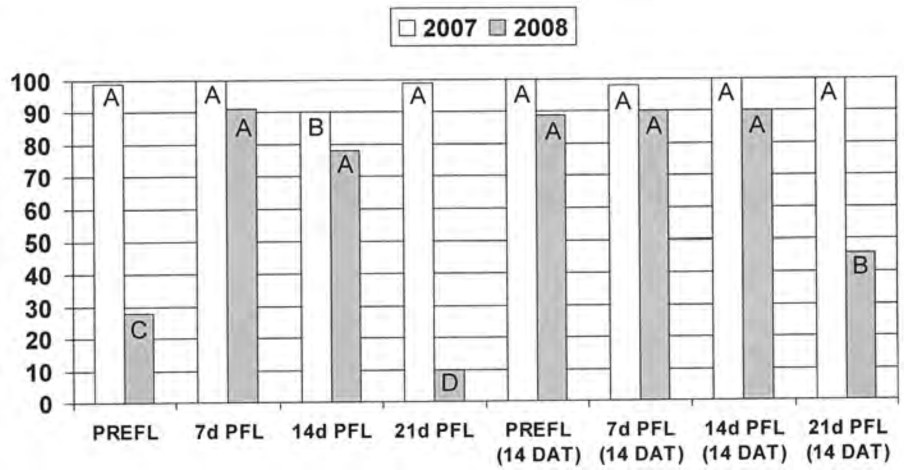

Fig. 1. End-of-season barnyardgrass control following single and sequential applications (14 d after initial treatment) of cyhalofop in 2007 and 2008. The first application of cyhalofop was applied at 0.28 lb/acre and the second application at 0.19 lb/acre. Means within a year followed by the same letter are not statistically different. Abbreviations: PREFL, preflood; PFL, postflood; DAT, days after initial treatment.

RicePyr LC® for Broadleaf Weed Control on Levees

J.K. Norsworthy, S. Bangarwa, G. Griffith, M.J. Wilson, J. Still, and R.C. Scott

ABSTRACT

RicePyr LC® is a product mixture of propanil and triclopyr that will be marketed in 2009 for weed control on rice levees. Research was conducted at three locations in Arkansas in 2008 to determine the rate of RicePyr LC® needed for effective broadleaf weed control. Two rates of RicePyr LC® were compared to a standard treatment of SuperWham (propanil) at 2 qt/acre plus Grandstand (triclopyr) at 0.67 pt/acre. RicePyr LC® at 3 qt/acre, the highest rate evaluated, provided effective control of hemp sesbania, Pennsylvania smartweed, entireleaf morningglory, ivyleaf morningglory, pitted morning-glory, and Palmer amaranth when applied to weeds no more than 12 in. tall or 12-in. runners. Weed control with RicePyr LC® at 3 qt/acre was comparable to the standard treatment for all species evaluated, except eclipta which was not adequately controlled as well with Superwham plus Grandstand. Neither rate of RicePyr LC® injured the rice growing on the treated levees. Hence, RicePyr LC® appears to be effective option for broadleaf weed control on rice levees when weeds are small at application.

INTRODUCTION

Weed control on rice levees is one of the most daunting tasks rice producers face each year (Norsworthy et al., 2007). Saturated soil on levees is conducive for continual weed emergence, even after establishment of the permanent flood within bays. Often, two or more herbicides applied jointly are needed to maintain a high level of weed control on levees. RicePyr LC®, a mixture of propanil (3 lb ai/gal) and triclopyr (0.33 lb ai/gal), will be marketed in rice in 2009 for economical, broad-spectrum control of broadleaf weeds on levees.

An experiment was conducted at three sites in 2008 to evaluate the effectiveness of RicePyr LC® for broadleaf weed control on rice levees.

PROCEDURES

Experiments were conducted at the Arkansas Pine Bluff Farm (APBF) near Lonoke, the Pine Tree Branch Station (PTBS) near Colt, and the Rice Research and Extension Center (RREC), near Stuttgart, Ark. 'Wells' rice was broadcast-seeded on 2-ft tall levees at 120 lb/acre, with 10 ft between levees. Plots were 30 ft in length and replicated four times. Herbicide treatments evaluated were RicePyr LC® at 2 qt/acre (propanil at 1.5 lb ai/acre plus triclopyr at 0.165 lb ai/acre), RicePyr LC® at 3 qt/acre (propanil at 2.25 lb/acre plus triclopyr at 0.25 lb/acre), and a standard treatment of SuperWham at 2 qt/acre plus Grandstand at 0.67 pt/acre (propanil at 2.0 lb/acre plus triclopyr at 0.25 lb/acre). Crop oil concentrate was added to all herbicide treatments at 1% (v/v), and herbicides were applied at 15 or 20 gal/acre. A nontreated control was included. Treatments were applied when the largest weed was 6- to 12-in. tall or had 6- to 12-in. runners (morningglories). Weed control and crop injury were rated at 2 and 4 weeks after treatment (WAT). All data were subjected to analysis of variance, and means were separated using Fisher's protected Least Significance Difference test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Hemp sesbania, eclipta, Pennsylvania smartweed, and pitted morningglory were present at APBF. At ABPF the low rate of RicePyr LC® was not as effective at 4 WAT as the standard treatment for control of pitted morningglory, eclipta, and hemp sesbania (Table 1). The high rate of RicePyr LC® provided weed control at 4 WAT comparable to the standard treatment, except for eclipta control was lower than the standard treatment. Control of all weeds with the high rate of RicePyr LC® was >80% at APBF at 4 WAT.

At RREC, hemp sesbania and ivyleaf morningglory were evaluated. Control of both weeds was comparable between the high rate of RicePyr LC® and the standard treatment at 4 WAT, with RicePyr LC® providing at least 89% control (Table 1).

Weeds present at PTBS included hemp sesbania, entireleaf morningglory, eclipta, and Palmer amaranth. Control of all weeds with the highest rate of RicePyr LC® was comparable to the standard treatment at 4 WAT (Table 1). The high rate of RicePyr LC® controlled hemp sesbania 89%, entireleaf morningglory 75%, eclipta 68%, and Palmer amaranth 81% at 4 WAT. No rice injury was observed at any site. In summary, RicePyr LC® at 3 qt/acre generally provided equivalent weed control to our selected standard treatment, but weed control with RicePyr LC at 2 qt/acre was often less than the standard treatment.

SIGNIFICANCE OF FINDINGS

Price for RicePyr LC® at 3 qt/acre is anticipated to be comparable to SuperWham at 2 qt/acre plus Grandstand at 0.67 pt/acre in 2009. RicePyr LC® will simplify weed control on rice levees because propanil and triclopyr, the two active ingredients in RicePyr LC®, will be a premixed product. Although RicePyr LC® at 3 qt/acre did provide control of a range of broadleaf weeds on levees, it must be noted that applications were made when weeds were ≤12-in. tall or ≤12-in. runners. Applications on larger weeds will probably result in a lower level of weed control than observed in these trials.

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The continued support of weed management research in rice by the Arkansas Rice Research and Promotion Board is gratefully appreciated. Partial support for this research was provided by RiceCo.

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Table 1. Weed control on rice levees at 4 weeks after
the Arkansas Pine Bluff Research Farm, and the

		PTBS			
Treatment[z]	Rate	Hemp sesbania	Entireleaf morningglory	Eclipta	Palmer amaranth
		--			
RicePyr LC®	2 qt/acre	90	61	59	81
RicePyr LC®	3 qt/acre	89	75	68	81
SuperWham + Grandstand	2 qt/acre + 0.67 pt/acre	88	83	69	83
LSD (0.05)		NS[y]	21	NS	17

[z] All herbicide treatments were applied with crop oil concentrate at 1% v/v.
[y] NS = nonsignificant.

treatment at the Pine Tree Branch Station (PTBS),
Rice Research and Extension Center (RREC) in 2008.

APBF				RREC	
Hemp sesbania	Pitted morningglory	Eclipta	Pennsylvania smartweed	Hemp sesbania	Ivyleaf morningglory
------------(% control)------------					
83	75	74	93	90	89
95	83	81	94	92	89
92	91	96	91	91	92
8	13	10	NS	NS	NS

Control of Clomazone-Resistant Barnyardgrass in Rice with Preemergence Herbicides

J.K. Norsworthy, R.C. Scott S. Bangarwa, G. Griffith, M.J. Wilson, and J. Still

ABSTRACT

A second clomazone-resistant barnyardgrass biotype was confirmed in fall 2007 from a field near Delaplaine, Ark. A field trial was conducted in 2008 to determine the effectiveness of preemergence-applied clomazone with and without other residual rice herbicides for control clomazone-resistant and -susceptible barnyardgrass. Rainfall within 2 days of planting activated the preemergence herbicides. Rice injury from clomazone (Command 3ME) at 0.45 lb ai/acre was up to 44% at 2 weeks after treatment (WAT). The labeled rate of clomazone for the soil texture at the site (0.3 lb ai/acre) controlled the clomazone-resistant barnyardgrass 70% at 2 WAT compared with 100% control of two susceptible biotypes through 7 WAT. Quinclorac (Facet 75 DF), imazethapyr (Newpath), and halosulfuron (Permit) provided effective, extended residual control of the resistant biotype through 7 WAT. Hence, herbicide options at planting are still available for controlling this resistant biotype.

INTRODUCTION

Clomazone is applied to most of the Arkansas rice acreage for grass weed control, especially barnyardgrass, the most troublesome weed of rice (Norsworthy et al., 2007). Soil-applied clomazone use rates range from 0.3 to 0.6 lb ai/acre, depending on soil type. In 2007, a barnyardgrass biotype from Delaplaine, Ark., was not controlled with a labeled-use rate of clomazone. The field in which failure occurred had been in continuous rice production and had been treated solely with clomazone for at least 6 years. In fall 2007, the barnyardgrass sample from this field was confirmed resistant to clomazone, making it the second clomazone-resistant barnyardgrass biotype confirmed in Arkansas (Norsworthy et al., 2008). Therefore, field research was initiated to determine the effectiveness of preemergence-applied clomazone with and without other residual rice herbicides for control of clomazone-resistant and -susceptible barnyardgrass.

PROCEDURES

A field experiment was conducted at the University of Arkansas Pine Bluff research farm near Lonoke, Ark., in 2008. The soil texture at the test site was a silt loam with a pH of 4.8. 'CL-161' rice was drill-seeded at 100 lb/acre in 10- by 40-ft plots on 21 May. One clomazone-resistant and two clomazone-susceptible biotypes were sown in rows perpendicular to the drilled rows immediately after rice planting. Herbicide treatments evaluated included clomazone (Command 3ME) at 0.3 and 0.45 lb ai/acre, quinclorac (Facet) at 0.375 lb ai/acre, imazethapyr (Newpath) at 0.06 lb ai/acre, halosulfuron (Permit) at 0.06 lb ai/acre, clomazone at 0.3 and 0.45 lb ai/acre plus quinclorac at 0.375 lb ai/acre, clomazone at 0.3 and 0.45 lb ai/acre plus imazethapyr at 0.06 lb ai/acre, clomazone at 0.3 lb ai/acre plus halosulfuron at 0.06 lb ai/acre, halosulfuron at 0.06 lb ai/acre plus quinclorac at 0.375 lb ai/acre, and halosulfuron at 0.06 lb ai/acre plus quinclorac at 0.375 lb ai/acre. A nontreated control was included. All herbicides were applied at 20 gal/acre. Barnyardgrass control and rice injury were evaluated at 2, 4, 6, and 7 WAT on a scale of 0 to 100%, with 0 equal to no control or rice injury and 100 equal to complete control or rice death. All data were subjected to analysis of variance, and means were separated using Fisher's protected Least Significance Difference test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Injury to rice in the form of bleaching and stand thinning from clomazone at 2 WAT ranged from 10 to 44% (Fig. 1), and injury persisted through 7 WAT, averaging 6% in several treatments containing clomazone at 0.45 lb ai/acre (data not shown). The extensive injury to rice was a result of approximately 2 in. of rainfall at the test site within 2 days of application, resulting in excellent activation of all herbicides. Phytotoxicity in the form of bleaching by clomazone commonly occurs when rainfall occurs soon after application (R.C. Scott, personal communication). Rice injury from all other herbicides applied alone was <10% on all rating dates.

Both susceptible barnyardgrass biotypes were completely controlled (100%) at 2 WAT (Fig. 2), and complete control persisted through 7 WAT, regardless of clomazone rate (data not shown). These results are in agreement with previous findings where soil-applied clomazone controlled barnyardgrass (Zhang et al., 2005). However, control of the resistant biotype with clomazone at 0.3 lb ai/acre ranged from 65 to 71% at 2 to 7 WAT. Clomazone applied at 0.45 lb ai/acre completely controlled the resistant biotype; however, the injury associated with this rate of clomazone would be unacceptable to growers. Quinclorac, halosulfuron, and imazethapyr alone provided at least 95% control of all biotypes, evidence that alternative preemergence herbicides are available for control of the resistant biotype. Efforts are underway to evaluate the effectiveness of postemergence-applied herbicides alone and the success of season-long programs for control of the resistant biotype. Additionally, laboratory experiments have been initiated to determine the resistance mechanism.

SIGNIFICANCE OF FINDINGS

This is the second clomazone-resistant barnyardgrass biotype documented in Arkansas rice. Fortunately, imazethapyr and quinclorac, which are currently labeled for barnyardgrass in rice, provided effective control of the resistant biotype. Additionally, soil-applied halosulfuron at the rate evaluated in this experiment was effective in controlling the resistant and susceptible biotypes and further research should be conducted to evaluate the utility of halosulfuron for soil-residual barnyardgrass control under a wider range of environments and soils. Due to widespread propanil and quinclorac resistance (resistance to post-applied quinclorac) in Arkansas rice, clomazone needs to be applied in conjunction with an additional residual herbicide to reduce the risk of further resistance evolution and spread.

ACKNOWLEDGMENTS

The continued support of weed management research in rice by the Arkansas Rice Research and Promotion Board is gratefully appreciated.

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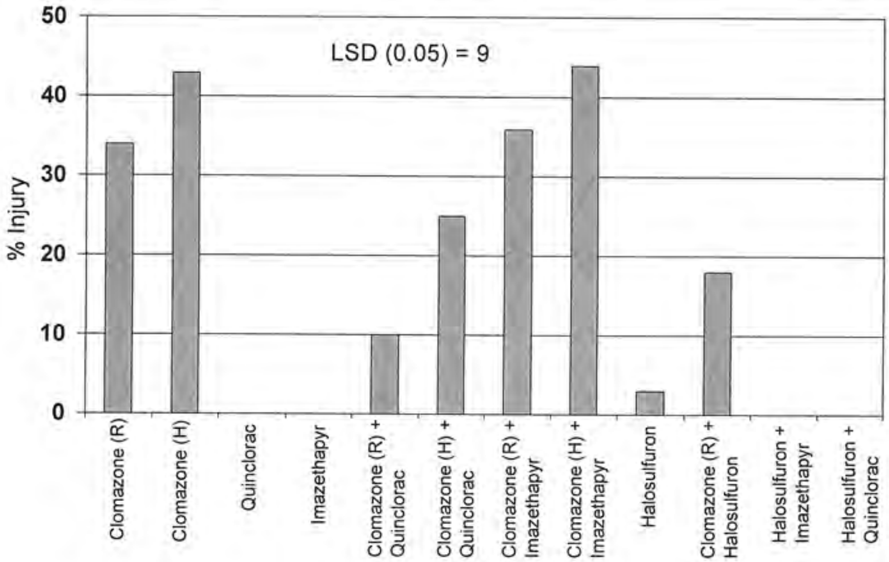

Fig. 1. Rice injury at 2 WAT with preemergence-applied herbicides evaluated for control of clomazone-resistant barnyardgrass (R = recommended rate, 0.3 lb ai/acre; H = high rate, 0.45 lb ai/acre).

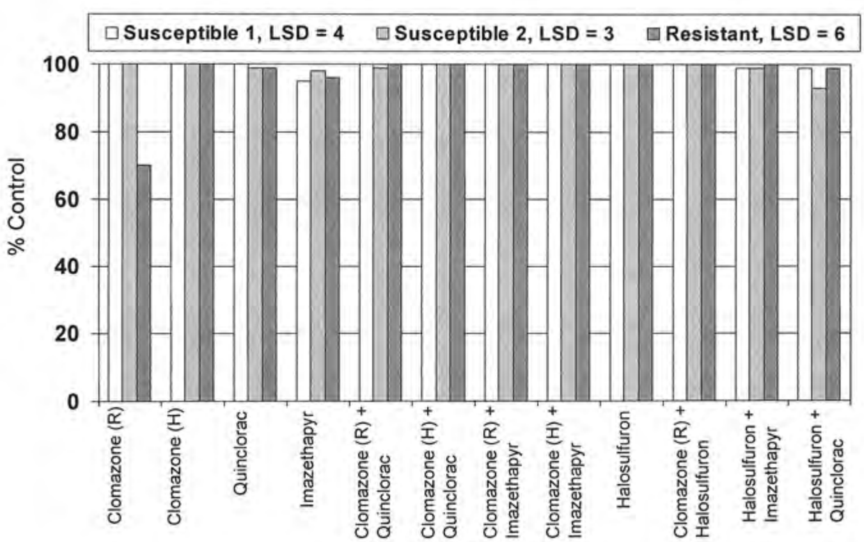

Fig. 2. Control of clomazone-resistant and susceptible barnyardgrass (2 susceptible biotypes) at 2 weeks after application of preemergence herbicides (R = recommended rate, 0.3 lb ai/acre; H = high rate, 0.45 lb ai/acre).

A Model to Predict Safe Stages of Development for Draining Rice Fields

P.A. Counce, K.B. Watkins and T.J. Siebenmorgen

ABSTRACT

A computer program has been developed to predict the stage of development for draining rice at which the risk of reduced grain yield or milling quality from insufficient water is considered to be near zero. An experiment to test program predictions was conducted in 2008 at the Rice Research and Extension Center near Stuttgart, Ark. The model predicted the safe stage for draining as R7 (one kernel on the main stem panicle is yellow) for both locations. Yields were not reduced by draining at the R7 stage of development compared to draining at 28 days after 50% heading (DAH). Draining at R7 allows a minimum water savings of one irrigation. Budget analysis indicates water savings from one less 3-inch irrigation to be between $4.46 to $24.79/acre depending on water table depth of the well. Consequently, our test in 2008 showed that the program predictions allowed earlier draining, water savings, and no losses of grain yield or milling quality. The 2008 results are consistent with results from three previous years of experiments on draining rice by the rice growth staging program.

INTRODUCTION

A rice growth-staging system has been developed to allow clear communication among farmers, researchers, extension personnel, and others as to the physiological stage of a rice crop (Counce et al., 2000). Research on growth staging has allowed us to time the intervals between different reproductive growth stages after heading (Watson et al., 2005; Clements et al, 2003). This is partially because of the objective features of the staging system, which allows clear determination of each growth stage.

Generally, rice yield is sensitive to water stress through the R9 (all kernels that reached R6 have a brown hull) growth stage. As is true for corn and grain sorghum, the crop is sensitive to drought stress until the kernels are filled. Thus, it is generally accepted that any water deficit prior to crop maturity is likely to lead to reductions in both rough rice yield and milling quality. With this caveat in mind, it is worthwhile to know when to drain rice without reducing rough rice yield or milling quality and yet maximize water usage by avoiding unnecessary irrigations.

Consequently, we are faced with the prospect that rice can in some cases be drained at 2 weeks after 50% heading without reducing yield or quality and the other fact that the plant is sensitive to drought stress until the kernels have filled. It is apparent that the soil profile contains significant water after draining and this water can prevent drought stress. Within the root zone of a DeWitt silt loam soil with 4 to 8 in. to the impervious layer, there are 2.6 to 4.0 in. of water available to the rice crop after draining [0.44 inches of water/inch of soil (Davis, 2002)]. The crop uses between 0.25 in./day at the R3 growth stage (heading or emergence of the main stem panicle) and 0.05 in./day at the R8 growth stage (one or more brown kernels on the head) (Lage et al., 2003). Therefore water use by the rice crop is great as heads emerge, progressively lessens as the grain develops, and reaches very low levels towards harvest.

With these three elements – intervals between growth stages in DD50 units, water use at different growth stages, and soil water content at draining – an Excel computer program has been developed to predict the safe growth stage for draining rice. Data needed for input are soil type, rooting zone depth, and the projected (or actual) date of 50% heading. The program incorporates data sets relating reproductive stages to DD50 units for different cultivars (Watson et al., 2005; Clements et al., 2003). The outputs from the program are a predicted growth stage and date of that stage for safely draining a rice field without reducing grain yield or milling quality. Results of field experiments to test the model are reported herein.

PROCEDURES

The experiment at the Rice Research and Extension Center near Stuttgart, Ark., was conducted on a DeWitt silt loam soil with field plots 34 ft wide by 120 ft long. Each plot was bounded by its own normal earth levees. The control treatment was drained 31 days after heading (DAH) (Table 1). There were four replications in the experiment. The cultivar was 'Wells'.

The computer program has three components: (1) prediction of reproductive growth stage intervals with DD50 units; (2) prediction of maximum water use for each growth stage interval; and (3) prediction of plant available water for a given soil at draining. The timing between reproductive stages of development was noted in the field for selected plants of twelve rice cultivars. Subsequently, calculations of DD50 intervals were made (Watson et al., 2005; Clements et al., 2002). Maximum water use values per day were derived from Lage et al. (2003) and were multiplied by the number of days for a given site and growth stage. The length of specific developmental periods at a given location was determined from the number of DD50 units required for a given stage of development and historical maximum and minimum temperatures at the site for that calendar period. Soil water available after draining was determined by multiplying the depth of the effective root zone by the inches of water available per inch of soil. Soil water-supplying properties can be estimated (among other sources) from Davis (2002). Beyrouty et al. (1996) determined that, although some roots extend to 16 in., greater than 90% of the roots are in the upper 8 in. Beginning at R9 and working backward, the amount of water to reach each previous stage of development was summed. First, the water use from R9 to R8 was calculated, then the amount of water used from R9 to R7, then R9 to R6, etc. At a given reproductive growth stage, if the amount of water in the cumulative water use column was less than or equal to the amount of soil water available at draining, it was deemed to be a safe stage of development to drain the rice field.

Plots were harvested by hand with a sickle and threshed with a stationary thresher. Rough rice harvest moisture content and rough rice yield were determined shortly after harvest for each plot. Subsequently, grain was partially dried in shallow metal pans at room temperature for one to 12 hours and stored in two plastic bags within each other at approximately 45°F until transporting to Fayetteville for controlled drying, and for determination of brown, milled, and head rice yield determination. Data were subjected to analysis of variance.

The goal of the program is to allow growers to save money by draining rice without reducing rice grain yield or milling quality. Consequently, the predictions are to be conservative: we wish to have ample water available so that yield and quality are not reduced. To minimize risk, three assumptions are made: (1) no rainfall will occur after draining the rice field; (2) the maximum water use by the crop is assumed at each growth stage; and (3) no water will be extracted below 8 in. even if the pervious soil layer extends beyond 8 in. Some rice roots, even with an impervious soil layer, do penetrate below this depth (Sharma et al., 1994; Beyrouty et al., 1996). We know that some of these three assumptions are overly conservative and, consequently, they add a measure of safety into the model's predictions.

RESULTS AND DISCUSSION

Water use predictions cumulative to R9 backward indicated that the safe stage of growth for draining rice was R7 (Table 2). Neither grain yields nor head rice yields differed between the control and plots drained by growth stage predictions (Table 3). Given the results of these experiments, it is reasonable to expect a minimum savings of one irrigation could be realized. Given this savings, cost savings of $4.46 to $24.79/acre could be realized by employing the program (Table 4). These results are consistent with the results of experiments conducted to test the model's projections in the past two years.

SIGNIFICANCE OF FINDINGS

Water pumping costs are a significant part of the costs of producing rice. The goal is to provide all the water needed to produce the maximum rough rice yield and head rice yields. The earlier draining permitted by using the output from the computer draining program resulted in no reductions in either rice grain yield or milling quality. In addition, budget analysis revealed water savings from $4.46 to $24.79/acre depending upon water depth. These results are consistent with the previous research in 2005 and 2006 (Counce et al., 2009) and in 2007 (Counce et al., 2008).

ACKNOWLEDGMENTS

The authors thank Arkansas rice producers for support of this project through check-off funds in previous years.

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Table 1. Dates of draining treatments for an experiment on draining rice conducted on the Arkansas Grand Prairie in 2008.

Draining treatments	Stuttgart
Drain at R7[z]	August 20 (12 DAH)
31 DAH[y]	September 8

[z] Date (growth stage) at which one grain on main stem panicle is yellow.
[y] DAH, days after heading

Table 2. Projections for crop water use by Wells rice grown in randomized complete block design experiments conducted at the Rice Research and Extension Center near Stuttgart Ark., in 2008.

Rice growth stage[z] (RGS) interval	Maximum water use/day	Cumulative water use
	(in.)	
R3-R4	0.256	5.00
R4-R5	0.236	4.18
R5-R6	0.209	3.22
R6-R7	0.189	2.60
R7-R8	0.118	1.60
R8-R9	0.079	0.98
Available soil moisture	--	1.72
Predicted safe RGS	--	R7

[z] Rice Growth Stage (RGS) morphological markers:
R3 - Panicle exertion from boot, tip of panicle is above collar of flag leaf on main stem.
R4 - One or more floret on main stem panicle has reached anthesis.
R5 - At least one caryopsis on the main stem panicle is elongating to the end of the hull.
R6 - At least one caryopsis on the main stem panicle has elongated to the end of the hull.
R7 - At least one grain on the main stem panicle has a yellow hull.
R8 - At least one grain on the main stem panicle has a brown hull.
R9 - All grains which reached R6 have brown hulls.

Table 3. Rough rice and head rice yields from a draining experiment conducted at the Rice Research and Extension Center near Stuttgart, Ark., with Wells rice in 2008.

	Grain yield	
Treatment	Head rice yield	Rice grain yield
	(%)	(bu/acre)
Drained by program predictions at Rice Growth Stage R7[z]	67.6	189.9
Control[y]	67.0	181.6
CV (%)	0.61	3.12
Significance	NS[x]	NS

[z] Rice Growth Stage R7 is when one grain on the main stem panicle has turned yellow.
[y] Controls were drained 28 days after 50% heading.
[x] NS = not significant.

Table 4. Variable cost savings associated with a 3 acre-in. reduction in applied water for varying pump lifts.

	Pump lift (ft)					
Variable cost item	50	100	150	200	250	300
Diesel consumption (gallons per acre-in)[z]	0.49	0.99	1.48	1.98	2.47	2.97
Fuel & lubrication cost ($/acre)[y]	3.75	7.58	11.34	15.16	18.92	22.75
Repairs & maintenance cost ($/acre)[x]	0.35	0.35	0.50	0.50	1.69	1.69
Labor cost ($/acre)[w]	0.35	0.35	0.35	0.35	0.35	0.35
Total cost savings ($/acre)	4.46	8.29	12.19	16.02	20.96	24.79

[z] Diesel consumption was varied by pump lift using an engineering formula supplied by Dr. Phil Tacker (University of Arkansas Extension Agricultural engineer).
[y] Fuel consumption for 3 acre-in. multiplied by $2.20/gal for on-farm diesel (2007 Arkansas rice budgets) plus $0.33/gal for engine oil.
[x] Derived from 2007 Arkansas rice budgets. Values for deeper pump lifts were adjusted upward to reflect greater repair expenditures for larger wells.
[w] Derived from 2007 Arkansas rice budgets. Assumes a labor wage of $8.12/hour.

Nitrogen Content in Floodwater of Drill-Seeded, Delayed Flood Rice Following Urea Fertilization

A.J. Enochs, T.L. Roberts, N.A. Slaton, R.J. Norman,
C.E. Wilson Jr., D.L. Frizzell, and J.D. Branson

ABSTRACT

Nitrogen (N) fertilizer has the potential to enter streams, rivers, and lakes via irrigation return flow from rice [*Oryza sativa* (L.)] fields. This study was conducted to determine the days after urea fertilization that floodwater should be held to minimize N loss via irrigation return flow. The effects of planting date, fertilizer N rate, and fertilizer N application timing (preflood vs. midseason) on the extent and persistence of N in rice floodwater were investigated with a dry-seeded, delayed flood cultural system at the Rice Research and Extension Center near Stuttgart, Ark., on a Dewitt silt loam (fine, smectic, thermic Typic Albaqualf). Floodwater N concentrations (18.9 mg N/L maximum) from preflood N rates of 60 and 120 lb N/acre to a dry soil surface decreased to control levels (0 lb N/acre) within 6 days of application. Application of 180 lb N/acre caused floodwater N concentrations to remain above control levels for up to 11 days after fertilization. Midseason N fertilizer applications (i.e., 30 and 60 lb N/acre) increased floodwater N concentrations (32.5 mg N/L maximum) greater than preflood N applications, but also decreased to background levels within 5 days after application. Results from this study indicate a prudent recommendation would be to retain floodwater on rice fields for at least 6 days after application of typical preflood and midseason N rates and up to 11 days after atypically large preflood N application rates.

INTRODUCTION

In the drill-seeded, delayed-flood rice production system, preflood and midseason are the two common times for nitrogen (N) fertilizer application (Norman et al., 2003).

The preflood N fertilizer generally represents 2/3 of the total N fertilizer used and is applied aerially as urea onto dry soil at the 4- to 5-leaf stage to provide sufficient N for rapid plant growth during maximum tillering. Fields are quickly flooded to incorporate urea into the soil. Urea fertilizer which has been incorporated into the soil is less likely to be lost via ammonia volatilization or nitrification/ denitrification as long as the flood is maintained. Rice uptake of N fertilizer applied preflood reaches a maximum by 21 days after application (Wilson et al., 1989). Therefore, proper water management is needed for at least 3 weeks after preflood N fertilization to achieve maximum N fertilizer uptake.

The midseason N fertilizer is applied between panicle initiation and 0.5-in. internode elongation. If applied at the proper time, midseason N fertilizer reaches maximum uptake 3 days after application (Wilson et al., 1989). By this point into the season the rice plant has an extensive root system that can take up the midseason N quickly and the rice canopy has grown to shade the floodwater and create a microclimate that may reduce ammonia escape.

Based on previous studies (Moore et al., 1992; Turner et al., 1980), holding the floodwater for 1 week after the preflood and midseason N fertilizer applications should result in maximum plant uptake and minimize any N loss via runoff. This seems suitable for midseason N fertilizer applications, which are rapidly taken up by rice. However, the preflood N fertilizer does not reach maximum uptake until 21 days after fertilization suggesting that floodwater N content could be elevated for more than 1 week following fertilizer application. The objective of this study was to determine the days after urea fertilization at preflood and midseason that floodwater should be held to minimize N loss via irrigation return flow.

MATERIAL AND METHODS

Microplot studies were conducted in 2007 and 2008 at the Rice Research and Extension Center (RREC) near Stuttgart, Ark., on a Dewitt silt loam (Typic Albaqualf). ‘Wells’ rice was chosen for this study because it is one of the principal cultivars grown in Arkansas. Rice was seeded at 100 lb/acre and grown upland until the 4- to 5-leaf stage at which time the microplots were established, treatments were initiated, and the permanent flood was established. Metal squares (30 in. x 30 in. microplots) were placed into the soil to a sufficient depth (~5 in.) that would prevent water movement into or out of the squares.

Samples were collected by submerging 125 mL plastic bottles into the floodwater of each microplot. The water depth for each microplot was measured every sampling day to allow calculation of total water volume. The floodwater samples were analyzed for pH and then frozen for later analysis. Samples of floodwater were analyzed for nitrate-N using the Gries-Ilosvay procedure and for ammonium-N using the salicylate hypochlorite procedure (Mulvaney, 1996), both by automated colorimetric analysis on a Sans-plus segmented-flow autoanalyzer (Skalar Inc., Norcross, Ga.). The diacetyl monoxime microscale colorimetric procedure was used to analyze for urea-N (Greenan et al., 1995). Total N in this report refers to the sum of the nitrate-N, ammonium-N, and urea-N.

Preflood N Fertilizer Study

The preflood N study had two planting times (emergence dates 28 April 2007 / 26 April 2008, and 30 May 2007 / 24 May 2008) and the preflood N fertilizer was applied to a dry soil surface by hand as urea at three N rates (60, 120, and 180 lb N/acre) plus a control (0 lb N/acre). The early planting date was fertilized on 4 June 2007 and 11 June 2008 and flooded (4-in. flood depth) the same day and the late planting date was fertilized and flooded on 27 June 2007 and 30 June 2008. Water samples were collected 1, 3, 4, 6, 8, 11, and 14 days after N fertilization and flooding, and then weekly for the duration of the growing season.

Midseason N Fertilizer Study

The midseason N study had two preflood N rates (60 and 120 lb N/acre) and midseason treatments that consisted of two single application rates (60 and 120 lb N/acre), a control (0 lb N/acre), and a plot with no rice receiving a single 60 lb N/acre application. The midseason N was applied by hand as urea directly into the floodwater on 27 June 2007 and 30 June 2008. Samples were collected 1, 2, 3, 4, 5, 6, and 8 days after N fertilization and then weekly for the duration of the growing season.

Statistical Analysis

The preflood study was a split-plot design with N rate arranged in a randomized complete block as the whole plot and sampling date as the split plot with four replications. The midseason study was a split-strip plot with preflood N rate arranged in a randomized complete block as the whole plot, midseason N rate striped across preflood N rate, and sampling date as the split plot with four replications. Analysis was conducted using Fisher's protected LSD at α=0.05.

RESULTS AND DISCUSSION

Preflood N Fertilizer Study

The urea-N concentrations in the rice floodwater peaked 1 day after fertilization and decreased to control levels within 8 days (Fig. 1). The ammonium-N concentrations peaked about 4 days after fertilization and decreased to background levels within 2 weeks. The nitrate-N concentrations in the rice floodwater remained at control levels. For the remainder of this report the three components will be combined and referred to as total N.

The early and late planting dates both had an average floodwater temperature of 82°F for the first 2 weeks after preflood fertilizer application (data not shown). There was a significant two-way interaction between planting date and sampling date, but only 1 day had significantly different mean total N floodwater concentrations (Fig. 2). The late planted rice would be expected to have a faster growth rate than the early planted rice and therefore remove the N from the floodwater at a faster rate, but our results did not display this effect. This anomaly could be caused by averaging over all preflood N rates and 2 years of field work.

Increased N fertilizer rate increased the concentration and extended the time of the N in the floodwater (Fig. 3). The low preflood N rate (60 lb N/acre) reached a maximum total N floodwater concentration 1 day after fertilization around 7 mg N/L and decreased to control levels within 3 days. The normal preflood N rate (120 lb N/acre) reached a mean maximum 1 day after fertilization at 15 mg N/L and decreased to control levels within 6 days. The higher preflood N rate (180 lb N/acre) reached a mean maximum 1 day after fertilization near 19 mg N/L and decreased to control levels within 11 days after fertilization.

Midseason N Fertilizer Study

Floodwater total N concentrations after midseason fertilizer application were not significantly related to preflood N fertilizer rate. Midseason fertilizer applications had higher floodwater total N concentrations than preflood fertilizer applications (Fig. 4). The 30 lb N/acre midseason rate reached a mean maximum 1 day after fertilization near 14 mg N/L and decreased to control levels within 4 days after fertilization. The 60 lb N/acre rate with and without rice behaved similarly. When no rice was present the mean floodwater total N concentration 1 day after fertilization was higher than when rice was present (32 and 26 mg N/L, respectively). Floodwater when rice was present reached control levels within 5 days after fertilization while the floodwater when rice was absent reached control levels within 6 days after fertilization. The 60 lb N/acre in the presence of rice was expected to have lower floodwater total N concentrations than when rice was absent due to N uptake by the rice plants. The similarity in that floodwater total N concentrations in the presence and absence of rice may be explained by the elevated pH of the floodwater in the absence of rice which would increase N loss due to ammonia volatilization.

SIGNIFICANCE OF FINDINGS

The length of time that rice field floodwater should be held after N fertilization appears to depend on N rate, N application timing (preflood or midseason), and perhaps planting date (or emergence date). This report recommends a 6-day holding time of floodwater after either a preflood or midseason N fertilizer application for most N rates. Higher preflood N rates (i.e., on clay soils) will extend the time to hold the floodwater after preflood application up to 11 days after fertilization and flooding.

ACKNOWLEDGMENTS

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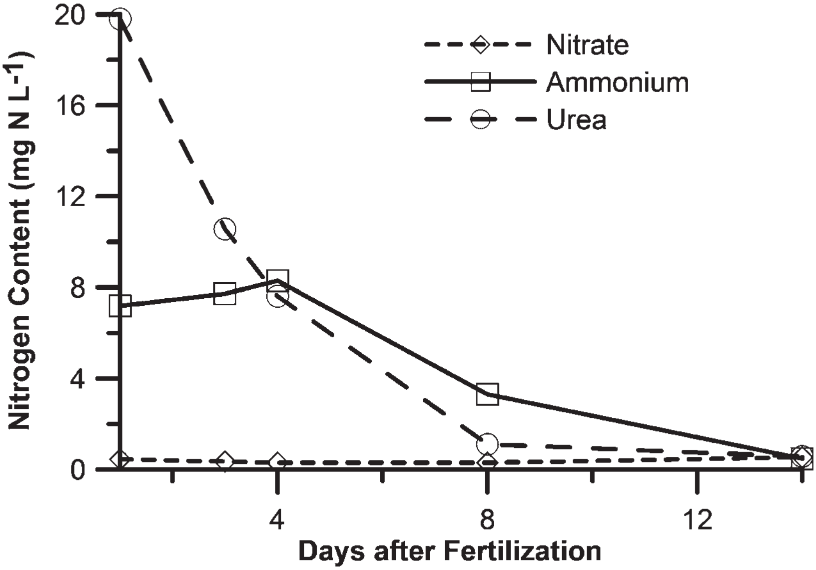

Fig. 1. Trends in the nitrate, ammonium, and urea concentrations of the floodwater after preflood fertilization.

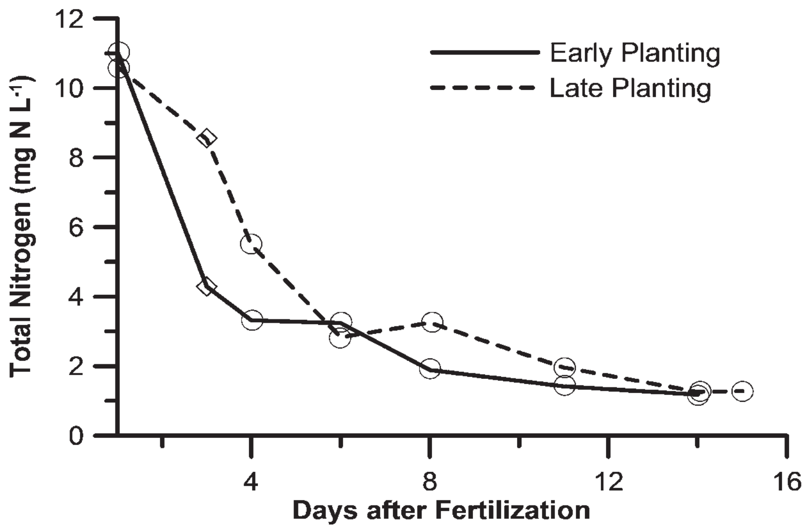

Fig. 2. Influence of planting date on the mean floodwater total N concentrations after preflood N application. Analysis was conducted with Fisher's LSD (α=0.05). Significantly different means on the same day after N fertilization are represented by the symbol ◇ and those that are the same are represented by the symbol ○.

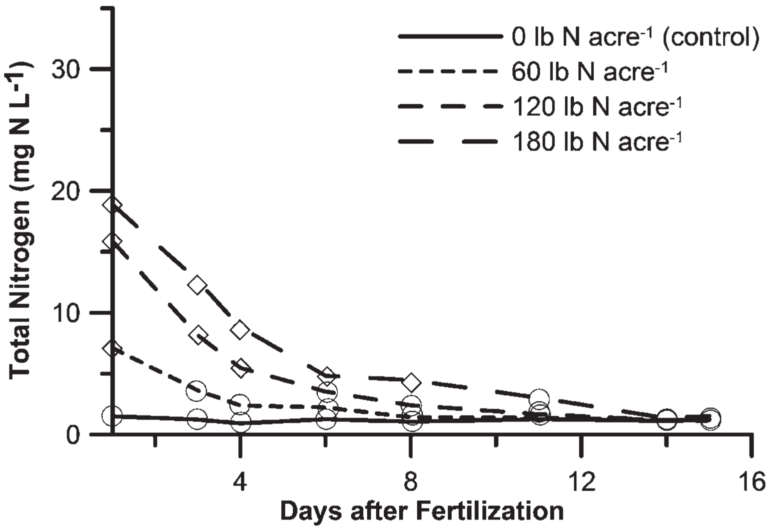

Fig. 3. Influence of nitrogen rate on mean floodwater total N concentrations after preflood N application. Analysis was conducted with Fisher's LSD (α=0.05). Means significantly different from the control are represented by the symbol ◇ and those that are the same as the control are represented by the symbol ○.

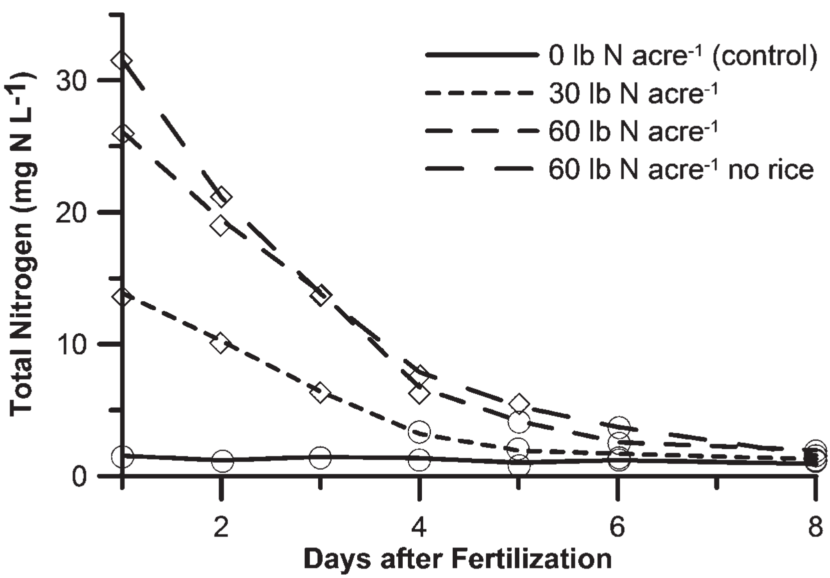

Fig. 4. Influence of nitrogen rate on mean floodwater total N concentrations after midseason N application. Analysis was conducted with Fisher's LSD (α=0.05). Means significantly different from the control are represented by the symbol ◇ and those that are the same as the control are represented by the symbol ○.

Development of Degree Day 50 Thermal Unit Thresholds for New Rice Cultivars

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ABSTRACT

The DD50 computer program has been one of the most successful programs developed by the University of Arkansas Division of Agriculture. The Degree-Day 50 (DD50) computer program must be continually updated as new conventional and hybrid rice cultivars are released. To accomplish this objective, DD50 thermal unit thresholds must be established in a controlled research environment. The DD50 thermal unit accumulations and grain yield performance of each new rice cultivar were evaluated over four seeding dates in the dry-seeded, delayed-flood management system most commonly used in the southern United States. Rice cultivars evaluated in 2008 were as follows: i) conventional rice cultivars 'Bowman', 'Catahoula', 'Cheniere', 'JES', 'Jupiter', 'Neptune', 'RU0801076', 'Taggart', 'Templeton', 'Trenasse', and 'Wells'; ii) Horizon Ag Clearfield cultivars 'CL 131', 'CL 151', 'CL 161', and 'CL 171 AR'; iii) Bayer Cropscience hybrid 'Arize 1003'; and iv) Rice Tec hybrid cultivars 'CL XL729', 'CL XL 730', 'CL XL745', and 'CL XP 746'.

INTRODUCTION

The DD50 computer program has been one of the most successful programs developed by the University of Arkansas Division of Agriculture. Approximately 50% of Arkansas rice farmers utilize this program as a production management tool and other rice-producing states have developed similar programs based on this model. The program utilizes cultivar-specific data to predict plant development based on the accumulation of DD50 thermal units from the date of seedling emergence. These data are acquired from annual studies of promising experimental lines and all newly released conventional and hybrid rice cultivars. Each new cultivar remains in the study for a minimum of 3 years. When a new cultivar is released, the data from these studies are used to provide threshold DD50 thermal units in the DD50 computer program to enable predictions of dates when plant development stages will occur and dates when specific management practices should be performed. Therefore, the objectives of this study are to develop a database for promising new rice cultivars, to verify the database for existing cultivars, and to assess the effect of seeding date on DD50 thermal unit accumulations. In addition to these objectives, the influence of seeding date on a cultivar's grain and milling yield performance was considered to determine optimal seeding date for new cultivars.

PROCEDURES

The study was conducted during 2008 at the University of Arkansas Rice Research and Extension Center (RREC) near Stuttgart, Ark., on a DeWitt silt loam soil. Eleven conventional rice cultivars (Bowman, Catahoula, Cheniere, JES, Jupiter, Neptune, RU0801076, Taggart, Templeton, Trenasse, and Wells), four Horizon Ag Clearfield cultivars (CL 131, CL 151, CL 161, and CL 171 AR), one Bayer Cropscience Hybrid (Arize 1003), and four Rice Tec hybrid cultivars (CL XL729, CL XL 730, CL XL745, and CL XP 746) were drill-seeded at a rate of 40 seeds/ft^2 in nine-row (7-in. spacing) wide plots, 15 ft in length, except the Rice Tec hybrids which were sown at 16 seeds/ft^2 according to RiceTec hybrid seeding recommendations. General seeding, seedling emergence, and flood dates are shown in Table 1. Seeding dates were 26 March, 17 April, 19 May, and 12, June 2008. The normal cultural practices for dry-seeded delayed flood rice were followed. All plots received 120 lb N/acre as a single preflood application of urea at the 4- to 5-lf growth stage. The permanent flood was applied and maintained until the rice reached maturity. Data collected included: maximum and minimum daily temperatures, seedling emergence, and the number of days and DD50 thermal units required to reach 0.5-in. internode elongation (IE), 50% heading, and maturity. At maturity, 12 ft of the center five rows of each plot was harvested, the moisture content and weight of the grain were determined, and a subsample of harvested grain saved for milling purposes. Grain yields were adjusted to 12% moisture and reported on a bushels-per-acre basis. A 125-g sample of the dried rice was milled for 30 sec. with a McGill No. 2 rice mill to obtain percent total white rice and percent head rice. Each seeding date was arranged as a randomized complete block with three replications. Statistical analyses were conducted with SAS and mean separations were conducted based upon Fisher's protected LSD (α= 0.05) where appropriate.

RESULTS AND DISCUSSION

The time between seeding and emergence ranged from 5 to 24 days (Table 1). Emergence for the 26 March seeding date occurred 24 days after seeding. Time between seeding and emergence of subsequent seeding dates normally decreased as seeding date was delayed except for the 12 June seeding date. Also, as the seeding date was delayed, the time between seeding and flooding was generally shorter, ranging from 76 days for the 26 March seeding date and decreased with each subsequent seeding date down to 34 days for the 12 June seeding date. Also, the number of days between emergence and flooding was greatest for the 26 March seeding date and became shorter as seeding was delayed. The time from emergence to flooding was 52 days for the 26 March seeding date, increased to 59 days for the 17 April seeding date, and then decreased to 38 and 26 days for the 19 May and 12 June seeding dates, respectively. The longer time period between emergence and flooding for the two early seeding dates was due to abnormally cool temperatures during April and an apparent herbicide carryover from the previous soybean crop. The day in development was observed throughout the year and adjustments were necessary to obtain accurate DD50 thresholds.

The delay in crop development for the early seeded rice was also observed in the time required from emergence to 0.5-in. IE (Table 2). The time required for the 26 March seeding date to reach 0.5-in. IE averaged 84 days (1910 DD50 thermal units) which is typical for an early maturing cultivar to reach 50% heading. The accumulations observed for the May and June seeded rice were more typical, averaging 55 and 47 days, respectively. Catahoula required the least amount of days and heat units to reach 0.5-in. IE (59 days, 1532 DD50 thermal units) while the experimental cultivar RU0801076 required the most days and units (70 days, 1835 DD50 thermal units).

The time required for development between emergence and 50% heading averaged 97 days (2638 DD50 thermal units) across all cultivars and seeding dates (Table 3). While many of the commonly produced cultivars were close to the average, a few were notably longer. Arize 1003 was 10 days later than the mean, while RU0801076 was 8 days later than the mean. CL XL 745, CL 151 and CL 131 were among the earliest to reach 50% heading. Note that although Catahoula reached 0.5-in. IE the quickest, it was not the earliest to reach 50% heading. The time required to reach 50% heading for these cultivars ranged from 6 to 15 days earlier than Wells, depending on seeding date.

When averaged across seeding dates, the cultivars with the highest yields during 2008 included the RiceTec hybrids CL XL746, CL XL729, and XP745 (Table 4). The highest yielding conventional cultivars were Neptune and Jupiter, both medium-grain cultivars. The highest yielding conventional long-grain cultivars included RU0801076, Wells, and Templeton. During this study year, most cultivars obtained maximum grain yield when seeding either 26 March or 17 April.

Cultivars demonstrating greatest consistent milling yield potential when averaged across seeding dates include Neptune, Jupiter, CL 161, and Catahoula (Table 5). The cultivars with the least milling yields were CL 151, Taggart, and Trenasse. The earliest seeding dates tended to have lower head rice yields. This is presumably due to the abnormal weather conditions during August and September. The cool weather observed during 2008 in these two months delayed the crop and resulted in an abnormally long dry-down period.

SIGNIFICANCE OF FINDINGS

The data from 2008 will be used to refine the DD50 thermal unit thresholds for the new cultivars and hybrids in this study. The grain and milling yield data will be used to help producers make decisions regarding rice cultivar selection, particularly for early and late seeding situations.

ACKNOWLEDGMENTS

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Table 1. General seeding, seedling emergence, and flooding date information for the DD50 seeding date study conducted in 2008 at the Rice Research and Extension Center near Stuttgart, Ark.

	Seeding date			
Parameter	26 March	17 April	19 May	12 June
Emergence date	19 April	26 April	24 May	20 June
Flood date	10 June	24 June	1 July	16 July
Days from seeding to emergence	24	9	5	8
Days from seeding to flooding	76	68	43	34
Days from emergence to flooding	52	59	38	26

Table 2. Influence of seeding date on DD50 accumulations and days from emergence to 0.5-in. IE of selected rice varieties in the DD50 seeding date study conducted at the Rice Research and Extension Center in 2008.

	0.5-in IE									
	26 March		17 April		19 May		12 June		Average	
Cultivar	Days	DD50 units	Days	DD50 units	Days	DD50 units	Days	DD50 units	Days	DD50 units
Arize1003	81	1852	74	1818	53	1563	43	1320	63	1638
Bowman	87	2057	80	1998	60	1794	53	1588	70	1859
Catahoula	78	1775	69	1667	47	1386	43	1299	59	1532
Cheniere	80	1831	71	1733	52	1525	48	1455	63	1636
CL131	78	1782	72	1744	52	1544	46	1405	62	1618
CL151	78	1774	69	1667	51	1507	44	1341	61	1572
CL171AR	83	1921	74	1818	55	1635	48	1467	65	1710
CLXL729	81	1862	.	.	53	1562	45	1362	60	1595
CLXL730	78	1782	.	.	53	1553	43	1310	58	1548
CLXL745	78	1783	73	1775	52	1524	44	1331	62	1603
CLXP746	81	1852	72	1765	50	1469	43	1299	61	1596
JES	85	1974	76	1881	57	1677	46	1405	66	1734
Jupiter	83	1932	77	1902	59	1763	50	1531	67	1782
Neptune	86	2006	76	1881	62	1837	53	1586	69	1828
RU0801076	90	2134	79	1969	59	1752	50	1524	70	1845
Taggart	87	2048	78	1948	60	1784	50	1524	69	1826
Templeton	87	2048	80	1998	56	1667	49	1496	68	1802
Trenasse	83	1911	73	1775	52	1527	44	1352	63	1641
Wells	84	1964	77	1899	55	1635	50	1531	67	1757
Mean	83	1910	75	1837	55	1616	47	1428	64	1691

Table 3. Influence of seeding date on DD50 accumulations and days from emergence to 50% heading of selected rice varieties in the DD50 seeding date study conducted at the Rice Research and Extension Center in 2008.

	50% Heading									
	26 March		17 April		19 May		12 June		Average	
Cultivar	Days	DD50 units	Days	DD50 units	Days	DD50 units	Days	DD50 units	Days	DD50 units
Arize1003	81	1852	74	1818	53	1563	43	1320	63	1638
Arize1003	123	3124	116	3060	100	2939	86	2474	107	2899
Bowman	115	2917	107	2827	95	2769	80	2318	99	2708
Catahoula	113	2866	102	2700	86	2549	79	2274	95	2597
Cheniere	113	2856	102	2701	87	2565	80	2309	96	2608
CL131	107	2669	99	2598	86	2549	77	2227	92	2511
CL151	108	2712	99	2598	85	2515	74	2176	92	2500
CL161	114	2887	106	2813	92	2697	84	2422	99	2705
CL171AR	115	2926	105	2754	90	2654	84	2404	99	2685
CLXL729	109	2733	102	2691	86	2549	78	2251	94	2556
CLXL730	109	2723	101	2660	87	2556	80	2300	94	2560
CLXL745	107	2659	99	2587	83	2474	73	2148	91	2467
CLXP746	109	2723	104	2739	86	2548	77	2227	94	2559
JES	116	2951	111	2933	94	2751	81	2343	101	2744
Jupiter	106	2648	101	2659	87	2564	74	2176	92	2512
Neptune	109	2723	103	2729	91	2670	77	2243	95	2591
RU0801076	120	3046	115	3027	94	2752	86	2468	104	2823
Taggart	121	3056	117	3071	96	2808	85	2432	105	2842
Templeton	118	2982	113	2979	93	2724	82	2350	101	2759
Trenasse	106	2648	99	2587	81	2410	71	2088	89	2433
Wells	115	2916	108	2863	91	2660	82	2350	99	2697
Mean	113	2838	105	2779	90	2635	80	2299	97	2638

Table 4. Influence of seeding date on the grain yield of selected rice varieties in the DD50 seeding date study conducted at the Rice Research and Extension Center in 2008.

Cultivar	Grain yields				
	26 March	17 April	19 May	12 June	Average
	(bu/acre)				
Arize1003	232.1	174.8	153.5	138.4	174.7
Bowman	210.8	175.4	147.3	123.5	164.3
Catahoula	181.5	186.4	89.4	127.4	146.1
Cheniere	195.7	174.8	133.2	138.1	160.4
CL131	186.8	168.9	141.7	142.5	160.0
CL151	215.2	176.3	118.7	143.6	163.4
CL161	164.0	155.6	157.4	91.8	142.2
CL171AR	190.6	140.5	115.5	109.1	138.9
CLXL729	225.6	186.5	182.0	180.2	193.6
CLXL730	199.7	192.1	173.7	166.6	183.0
CLXL745	207.6	212.9	169.6	173.2	190.8
CLXP746	246.5	210.8	184.2	176.2	204.4
JES	193.8	162.5	126.9	112.8	149.0
Jupiter	223.8	199.3	161.5	154.1	184.7
Neptune	194.3	206.5	179.6	161.5	185.4
RU0801076	213.7	183.0	155.4	131.2	170.8
Taggart	189.7	147.7	153.8	140.4	157.9
Templeton	207.2	174.7	151.7	126.7	165.1
Trenasse	178.7	158.7	150.2	117.5	151.3
Wells	185.3	189.8	171.6	128.1	168.7
Mean	202.1	178.8	150.8	139.1	167.7
LSD	24.5	32.3	29.6	14.3	
C.V.	7.4	10.7	12.0	6.2	

Table 5. Influence of seeding date on milling yield of selected rice varieties in the DD50 seeding date study conducted at the Rice Research and Extension Center in 2008.

Cultivar	Milling yield				
	26 March	17 April	19 May	12 June	Average
	------------------- [head rice (%) – milled rice (%)] -----------------				
Arize1003	---	---	59-69	59-71	35-69
Bowman	61-69	59-68	58-68	59-70	59-69
Catahoula	62-69	65-70	58-72	63-73	62-71
Cheniere	61-69	62-69	61-70	57-72	60-70
CL131	64-68	64-68	59-68	60-70	62-69
CL151	59-67	61-68	55-67	58-71	58-68
CL161	63-68	65-70	58-70	65-73	63-70
CL171AR	63-70	61-68	52-70	62-72	60-70
CLXL729	60-68	61-68	58-69	61-72	60-69
CLXL730	60-68	60-68	58-68	58-70	59-69
CLXL745	58-68	58-69	57-70	59-71	58-69
CLXP746	59-68	59-67	57-69	61-72	59-69
JES	62-67	59-65	55-67	60-68	59-67
Jupiter	67-71	67-71	66-72	66-74	67-72
Neptune	69-72	69-72	63-74	69-75	68-73
RU0801076	---	---	59-68	58-68	41-69
Taggart	57-68	54-66	57-70	60-70	57-69
Templeton	61-67	61-68	50-70	62-72	59-69
Trenasse	57-66	57-65	54-66	61-67	57-66
Wells	61-69	60-68	52-70	59-71	58-69
Mean	57-69	58-68	57-69	61-71	58-69

Nitrification Inhibitors Influence on Rice Grain Yield and Soil Inorganic Nitrogen Fractions

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ABSTRACT

Nitrogen source and application time recommendations for rice are currently limited to applying an NH_4-forming N source to a dry soil surface at the 5-lf growth stage for producers utilizing the delayed-flood production system. Fertilization trials were conducted at the Rice Research and Extension Center (RREC) and the Pine Tree Branch Station (PTBS) to investigate the use of urea amended with nitrification inhibitors for N fertilization from preplant to preflood application times. Laboratory incubations were conducted to determine the nitrification rate. Rice grain yields were not affected by N source at the RREC, however grain yields were greater from N applied preplant than N applied preflood. At the PTBS, the greatest rice grain yields were produced with N applied preflood and were uniform among N fertilizers. Yields were significantly lower for each N fertilizer applied 7 days before flooding and varied among N fertilizers. Laboratory incubations results showed that nitrification was very rapid in the Calhoun soil, intermediate for the Henry, and slowest for the Dewitt soil. Furthermore, nitrification inhibitor rate or product (DCD) was not effective in slowing nitrification on the Calhoun soil. Additional research is needed to examine the utility of nitrification inhibitors in N management for rice.

INTRODUCTION

The majority of rice (*Oryza sativa* L.) cultivated in Arkansas (96%) is produced utilizing a direct-seeded, delayed-flood production system (Wilson and Runsick, 2008). Nitrogen management in this system is limited to applying an ammonium (NH_4)-forming N source around the 5-lf growth stage and incorporating the N immediately with floodwater. This recommended N-management strategy, if performed correctly, is very efficient with fertilizer-N recovery ranging from 65 to 75% of the applied N (Norman et al., 2003). If N applications are mistimed, irrigation capacity is inadequate, floodwater management is poor, or the soil surface is moist at application N recovery can be very poor resulting in reduced yields and/or increased fertilizer and application expenses (Griggs et al., 2007). Nitrogen losses from the preflood N application are generally believed to occur through gaseous emissions of NH_3 and denitrification of NO_3. Ammonia volatilization losses can be as much as 30% or greater of the applied N if urea is applied to moist soil surfaces, into the floodwater, or if irrigation capacity is insufficient to achieve a permanent flood in <5 days of fertilizer application. Denitrification losses generally occur when N is applied far in advance of flood establishment, and fertilizer and/or soil NH_4-N undergoes nitrification to NO_3-N prior to flooding, resulting in rapid N loss via denitrification when the soil becomes saturated. If nitrification of NH_4-N could be limited, NH_4-forming fertilizers treated with a nitrification inhibitor might allow the preflood N-fertilizer to be applied weeks in advance of flooding allowing for the possibility that N applications could be made with ground-based equipment. Also, the dependency of N application to dry soil near the 5-lf stage would no longer exist, enabling producers more flexibility in establishing the permanent flood, controlling escape weeds, and capturing rain as an aid in flooding fields. The primary research objectives were to evaluate rice yield response to N sources and application times and examine the nitrification rate of selected silt loam soils commonly used for rice cultivation. The ultimate goal was to determine if urea amended with a nitrification inhibitor could slow nitrification and allow rice growers greater flexibility and perhaps enhance N-fertilizer recovery.

PROCEDURES

Field Studies

In 2008, N-fertilization trials with nitrification inhibitors were established at the Rice Research and Extension Center (RREC, Dewitt silt loam) and the Pine Tree Branch Station (PTBS, Calhoun silt loam). Selected agronomic information for each site is listed in Table 1. Soybean was the previous crop grown in rotation at the RREC, but rice followed rice at the PTBS. At each site, prior to fertilizer application, composite soil samples (0- to 4-in. depth), one from each replicate, were taken to characterize soil chemical properties. Soil samples were oven-dried, crushed to pass through a 2-mm sieve, and analyzed for nutrient availability (Mehlich-3), water pH (1:2), and total C and N by combustion (Table 2).

'Francis' rice was drill-seeded into conventionally tilled seedbeds at both sites. The trial at PTBS was initially planted in April, but had to be replanted (Table 1) at a different site due to non-uniform stand. Individual plots, measuring 6.5-ft wide and 16-ft long were flagged to establish plot boundaries. Each plot was surrounded by an alley measuring 1- to 2.5-ft wide that contained no rice. Phosphorus (46 lb P_2O_5/acre as triple superphosphate), K (60 lb K_2O/acre as muriate of potash) and Zn (10 lb Zn/acre as $ZnSO_4$) fertilizers were broadcast before seeding at each site. Rice management with respect to stand establishment, irrigation, weed control, and other practices closely followed the University of Arkansas Cooperative Extension Service guidelines for rice cultivated in the direct-seeded, delayed-flood production system.

Field trials evaluated three N sources including urea (46% N) and two urea-based products supplemented with nitrification inhibitors, Super-U [urea+DCD (dicyandiamide)+ NBPT; 46% N] and Entec [DMPP (3,4-dimethylpyrazole phosphate); 46% N). Each N source was applied at 0, 80, or 120 lb N/acre in single applications at two or three times before flooding. At the RREC, N was applied preplant (41 days before flooding, DBF), 3- to 4-leaf (13 DBF), and preflood (1 DBF). At the PTBS, N was applied at the 3- to 4-lf stage (7 DBF) and preflood (2 DBF). At both sites, the research area was flushed within 24 hours after N was applied at the 3- to 4-lf stage to minimize NH_3 volatilization. At maturity, the middle rows from each plot were harvested with a small-plot combine for determination of grain yield. Grain moisture content and harvest weight were determined and yields were adjusted to 12% moisture for statistical analysis.

At RREC, the experiment was arranged as a randomized complete block with three replications and a 3 (N source) by 2 (N rate) by 3 (N timing) factorial arrangement of treatments. At the PTBS, the experiment was also arranged as a randomized complete block with four replications with a 3 (N source) by 2 (N rate) by 2 (N timing) factorial treatment arrangement. Site data were analyzed separately. Yield data from rice receiving no N were not included in the statistical analysis, but are given as reference values. Means were separated using Fisher's Protected LSD at the 0.05 level of significance.

Laboratory Incubations

Soil was collected from the PTBS (Calhoun silt loam), RREC (Dewitt silt loam), and from a producer field in Poinsett County (Henry silt loam) and transported to the laboratory in plastic tubs. Soil was air-dried, crushed, and subsamples (*n*=3) were analyzed for nutrient content similarly to that described for the field experiment (Table 2). Soil was stored in an air-dry condition for several months before use.

Subsamples of each soil (100 g) were weighed into 4-oz incubation vessels and brought to a uniform soil moisture content (25% w/w) which was maintained throughout the incubation process. Incubation vessels were covered loosely with plastic wrap and incubated at room temperature for at least 10 days prior to the addition of each fertilizer.

After pre-incubation, 2 prills of urea, urea+NBPT (Agrotain), or urea+NBPT+DCD (Super-U) fertilizer were weighed on an analytical balance and placed 1-in. below the soil surface and covered with soil. Soil with no N fertilizer was also incubated to account for mineralized organic-N. The fertilizer application rate approximated adding 100 ppm N to the soil. Vessels containing soil and/or fertilizer were incubated at 25°C for a total of 20 d with sampling times of 10 and 20 d after fertilizer addition.

At each sampling time, incubation vessels of each treatment were quantitatively transferred into a 1 L bottle, 500 mL of 2 *M* KCl was added, and bottles were allowed to shake on a reciprocal shaker for 1 hour. A portion of the supernatant was filtered and collected for analysis of NO_3- and NH_4-N at each sampling time. Nitrogen analysis was conducted with an auto analyzer. Inorganic N recovered from soil receiving no N was subtracted from the inorganic N recovered from the soil receiving each N source to account for organic-N mineralization and estimate the percentage of fertilizer-N recovery [(Net inorganic-N ÷ total N added) × 100]. The proportion of fertilizer-N recovered as NO_3- and NH_4-N was calculated and expressed as a percent of the fertilizer-N recovered.

The study was analyzed as a randomized complete block with a 3 (N source) by 3 (soils) by 2 (sample time) factorial arrangement of treatments and included two replications. Means were separated using Fisher's Protected LSD at the 0.05 level of significance. All statistical analyses were performed with the general linear model procedure in SAS version 9.1.

RESULTS AND DISCUSSION

RREC Trials

At the RREC, the interactions between N application time, N rate, and N source were not significant (Table 3). The main effects of both N rate (P=0.0438) and application time (P=0.0408) were significant. Rice grain yield, averaged across application times and sources, increased from 195 bu/acre for rice receiving 80 lb N/acre to 203 bu/acre for rice fertilized with 120 lb N/acre (LSD 0.05 = 7). The main effect of application time also significantly influenced grain yield when averaged across N rates and N sources. Grains yields, as affected by N application time, followed the numerical order of preplant (205 bu/acre) > 3- to 4-lf stage (200 bu/acre) ≥ preflood (193 bu/acre, LSD 0.05 = 8 bu/acre). Rice receiving no N fertilizer produced 131 bu/acre, indicating the Dewitt soil had a high amount of N mineralized during the growing season.

PTBS Trials

At the PTBS, grain yield was affected by the significant N source by application time interaction (P=0.0004). Within each N source, grain yields were always statistically greater when N was applied preflood rather than the 3- to 4-lf stage (Table 4). For N applied at the 3- to 4-lf stage, rice receiving Entec-N fertilizer produced greater yields than rice fertilized with Super-U and urea which produced similar grain yields. When N was applied preflood, there were no statistical yield differences among N sources. The main effect of N rate, averaged across N sources and application times, was also significant (P<0.0001) and showed that rice receiving 120 lb N/acre produced greater yields (118 bu/acre) than rice fertilized with 80 lb N/acre (91 bu/acre). Rice receiving no N produced 32 bu/acre, indicating low soil N availability.

In general, grain yields were lower at the PTBS for all N sources and application times, when compared to RREC. At both the RREC and PTBS, 120 lb N/acre produced the greatest rice grain yields when averaged over N sources and application times, which was expected. However, the difference in grain yield between N rates was nominal. At the RREC, preplant N application produced greater grain yields than those produced with preflood applied N fertilizer which was unexpected and suggests the possibility of a low soil nitrification rate. Urease activity at the RREC could also have been low, which would limit the rate of NH_4 formation in the soil from the added urea. In contrast, N sources applied preflood at the PTBS produced the greatest grain yields. Previous research suggests that maximum grain yields are produced when N is applied preflood (Norman et al., 2003). Entec-N fertilizer applied at the 3- to 4-lf stage produced significantly greater grain yields at PTBS than Super-U and urea, which were similar. The differences in the nitrification inhibitors performance at the PTBS may be due to the different chemistries of each product, and the way each compound inhibits nitrification. The differences observed between RREC and PTBS, with respect to N sources suggest that soil at the PTBS has a greater potential for nitrification of added NH_4-N than the soil at the RREC that may be explained or at least verified by laboratory incubation data.

Laboratory Incubations

The laboratory incubation evaluated the percent of N-fertilizer recovered as soil inorganic N and the percent of recovered fertilizer N present as NO_3- and -NH_4-N. For all three variables the two-way interactions consisting of soil by sample time (Table 5) and N source by soil (Table 6) were significant. The percent recovery of N fertilizer, averaged across N fertilizers, was similar between sample times on the Dewitt and Henry soils, but differed for the Calhoun soil (Table 5). Averaged across sample times, fertilizer N recovery was >77% for all soils and N sources, and was fairly uniform among fertilizers and soils (Table 6). Fertilizer-N recovery means for each soil averaged 84% for the Dewitt, 81% of the Henry, and 83% for the Calhoun indicating that soil microbial biomass assimilated 15 to 20% of the N fertilizer.

Only N fertilizer recovered as NO_3-N will be discussed since the sum of NO_3- and NH_4-N equal total recovery. Within each sample time, averaged across N sources, the percent of fertilizer-N recovered as NO_3-N was greatest for the Calhoun, intermediate for the Henry, and lowest for the Dewitt (Table 5). These results suggest the rate of nitrification differs among these soils with the Calhoun having the most rapid nitrification rate. The percentage of fertilizer N recovered as soil NO_3-N increased significantly from 10 to 20 days only for the Dewitt soil. The N source by soil interaction (Table 6) also showed the percent of fertilizer N recovered as NO_3-N, averaged across sample times, within each N source was numerically greatest for the Calhoun soil. For urea and urea treated with Agrotain, the Henry and Calhoun soils had similar percentages of fertilizer N recovered as NO_3-N which were greater than those of the Dewitt soil. The Henry and Dewitt soils amended with Super-U contained significantly lower amounts of NO_3-N than soil amended with urea and urea treated with Agrotain. These results indicate that the nitrification inhibitor, DCD, slowed or delayed nitrification in both of these soils, but was more effective in the Dewitt soil. In contrast, the percentage of fertilizer N recovered as NO_3-N was similar for all three N-fertilizers in the Calhoun soil indicating that nitrification was not inhibited by the DCD.

Results suggest that the rate of nitrification was greatest for the Calhoun soil, intermediate for the Henry soil, and least for the Dewitt soil. The effectiveness of the DCD on these soils appeared to diminish as the rate of nitrification increased. Based on the laboratory incubation results, DCD would not be effective on the Calhoun soil which agrees with the yield results from the PTBS field trial. Determining the specific reasons why nitrification rate and DCD effectiveness differed among soils was beyond the scope of this study.

SIGNIFICANCE OF FINDINGS

The laboratory and field trial results show that nitrification rate varies among soils in Arkansas and has direct implications for N-fertilizer management. The apparent rapid nitrification rate of the Calhoun soil suggests that urea-N applied preflood may first be lost via NH_3 volatilization and additional losses may occur via nitrification followed by denitrification if the flood is not established immediately. Flooding the soil rapidly not only reduces potential N loss from NH_3 volatilization, but also prevents nitrification which is a microbial process that requires oxygen. The nitrification inhibitor, DCD, failed to slow the nitrification rate of fertilizer N following urea application on the Calhoun soil. Although nitrification inhibitors (i.e., DCD and/or others) may eventually be a useful tool for N management in rice, additional research is needed to determine the nitrification inhibitor products and application rates that produce consistent results among soils.

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Table 1. Dates of agronomic importance in two trials evaluating various N fertilizers and application times for rice production on silt loam soils at the Rice Research and Extension Center (RREC) and the Pine Tree Branch Station (PTBS) during 2008.

Event	RREC	PTBS
	----------- (Month - day) -----------	
Preplant N application	7 May	--
Planting date	7 May	21 May
Rice emergence date	15 May	29 May
3- to 4-lf[z] application date	4 June	11 June
Flush irrigation date	5 June	12 June
Preflood N application date	16 June	16 June
Flood established date	17 June	18 June

[z] lf - leaf.

Table 2. Selected chemical property means of soils used in field and laboratory incubation trials.

	Soil	Total	Total	Mehlich-3-extractable soil nutrients								
Site	pH	C	N	P	K	Ca	Mg	Na	S	Mn	Cu	Zn
		-----(%)-----		------------------------------- (mg/kg) -------------------------------								
Dewitt	5.9	0.76	0.09	23	107	1006	116	63	11.0	371	0.6	6.3
Calhoun	7.8	1.04	0.10	25	144	2030	371	46	12.0	406	1.6	1.2
Henry[z]	7.3	1.02	0.10	25	76	1259	211	67	52.0	85	0.9	17.4
Dewitt[z]	6.1	1.03	0.10	14	152	928	143	66	11.4	223	1.1	0.7
Calhoun[z]	7.6	1.03	0.10	26	80	2362	336	69	20.4	146	1.4	3.8

[z] Incubation soil.

Table 3. Effect of N source, N application time, and N rate interaction and the main effects of application time and N rate on rice grain yield at the Rice Research and Extension Center in 2008. Note: The no N control and polymer coated urea (43%) N yields given as reference values - i.e., not included in statistical analysis.

	80 lb N/acre			120 lb N/acre		
N source	Preplant	2-lf[z] stage	Preflood	Preplant	2-lf stage	Preflood
	-- (bu/acre) --					
None	131[y]					
Polymer 43%	197	--	--	213	--	--
Entec	198	192	197	222	209	195
Super Urea	196	198	190	208	200	192
Urea	200	198	191	202	201	194
LSD(0.05)	------------------------------ NS (*P*=0.4784, C.V. = 5.9%) ------------------------------					

[z] lf - leaf.

[y] Reference yield only - not included in statistical analysis.

Table 4. Effect of N source, N application time, and N rate interaction and the main effects of application time and N rate on rice grain yield at the Pine Tree Brance Experiment Station in 2008. Note: The no N control N yield is given as a reference value - i.e., not included in statistical analysis.[z]

	80 lb N/acre		120 lb N/acre	
N source	3- to 4-lf[y] stage	Preflood	3- to 4-lf stage	Preflood
	(bu/acre)			
None	32 (reference only)			
Entec	95	111	119	133
Super Urea	61	125	83	133
Urea	51	112	94	140
LSD(0.05)	NS (P=0.7641)			

N Source	3- to 4-lf stage	Preflood
Entec	107	122
Super Urea	70	130
Urea	73	126
LSD(0.05)	14 (P=0.0004, averaged across N rates)	

[z] Randomized complete block with 3 replications with a 2 application time by 3 N source by 2 N rate factorial treatment arrangement.

[y] lf - leaf.

Table 5. Fertilizer N recovery and the percentage of fertilizer N recovered as NO_3-N as affected by soil and sample time, averaged across N fertilizer sources, for three silt loam soils incubated at 25°C and 25% (w/w) soil moisture.

	Incubation soil		
Days after application	Dewitt	Henry	Calhoun
	(% Recovery of added N)		
10	87	80	93
20	81	82	80
LSD(0.05)	6 (P=0.0133)		
	(% NO_3-N recovered of added N)		
10	50	77	97
20	74	82	100
LSD(0.05)	6 (P<0.0001)		

Table 6. Fertilizer N recovery and the percentage of fertilizer N recovered as NO_3-N as affected by soil and N source, averaged across sample times, for three silt loam soils incubated at 25°C and 25% (w/w) soil moisture.

	Incubation soil		
Days after application	Dewitt	Henry	Calhoun
	--------------(% Recovery of added N)---------------		
Urea	84	77	86
Agrotain	80	87	83
Super-U	88	79	91
LSD(0.05)		8 (*P*=0.0377)	
	---------(% NO_3-N recovered of added N)----------		
Urea	80	94	100
Agrotain	79	97	100
Super-U	29	48	96
LSD(0.05)		8 (*P*<0.0001)	

Grain Yield Response of Thirteen New Rice Cultivars to Nitrogen Fertilization

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ABSTRACT

The Variety x Nitrogen (N) Fertilizer Rate Study determines the proper N fertilizer rates for the new rice cultivars across the array of soil and climatic conditions which exist in the Arkansas rice-growing region. The thirteen rice cultivars studied in 2008 were: 'Bowman'; 'Catahoula'; 'Neptune'; Horizon AG's 'CL151' and 'CL171'; Bayer Crop Science's 'Arize1003'; RiceTec's 'CLXL729', 'CLXL745', and 'CLXP746'; and the Arkansas experimental varieties 'RU0401182', 'RU0601188', 'RU0701124', and 'KDM08'. All of the varieties tested in 2008 reached maximum yield on silt loam soils when 120 to 150 lb N/acre was applied, except CL151, CL171, Arize1003, and KDM08. The RiceTec hybrids studied in 2008 usually required 30 lb N/acre more at preflood to obtain maximum yield compared to RiceTec hybrids previously studied. Clearfield CL151 and CL171 as well as KDM08 performed best on silt loam soils when 90 lb N/acre was applied and Arize1003 obtained maximum yield on silt loam soils when 60 to 90 lb N/acre was applied. All of the aforementioned varieties typically required 30 lb N/acre more at preflood when grown on clay soils compared to silt loam soils to achieve maximum yield.

INTRODUCTION

The Variety x Nitrogen (N) Fertilizer Rate Study measures the grain yield performance of the new rice cultivars over a range of N fertilizer rates on clay and silt loam soils and determines the proper N fertilizer rates for these soils under the climatic conditions that exist in Arkansas. Promising new rice selections from breeding programs in Arkansas, Louisiana, Mississippi, and Texas as well as those from private industry are evaluated in this study. Thirteen cultivars were studied in 2008 at one to three locations, depending on seed supply. Louisiana had the two new semidwarf varieties in the study, a medium- and a long-grain, named Neptune and Catahoula, respectively. Mississippi recently released and entered in the study the new semidwarf, long-grain named Bowman. Horizon AG entered two Clearfield, long-grain varieties in cooperation with Louisiana and Arkansas named CL151 and CL171, respectively. Clearfield rice varieties are tolerant to the broad spectrum herbicide imazethapyr (Newpath). Bayer Crop Science entered a long-grain, hybrid rice variety named Arize1003. RiceTec entered three hybrid rice varieties in the study named CLXL729, CLXL745, and CLXP746, which are long-grains tolerant to Newpath. There were four experimental lines in the study in 2008. The four experimental varieties entered by Arkansas were RU0401182, RU0601188, RU0701124, and KDM08.

PROCEDURES

Locations where the Variety x N Fertilizer Rate Study were conducted and corresponding soil series are as follows: Lake Hogue Research Farm (LHRF), in Poinsett County near Weiner, Ark. on a Hillemann silt loam (Thermic, Albic, Glossic Natraqualfs); Northeast Research and Extension Center (NEREC), Keiser, Ark., on a Sharkey clay (Vertic Haplaquepts); and the Rice Research and Extension Center (RREC), near Stuttgart, Ark., on a DeWitt silt loam (Typic Albaqualfs). The experimental design utilized was a randomized complete block with four replications at all locations for all the rice cultivars studied. A single preflood N fertilizer application was utilized for all cultivars, except the hybrids from Bayer Crop Science and RiceTec. The preflood N fertilizer was applied as urea on to a dry soil surface at 4- to 5-lf stage. The preflood N rates were: 0, 60, 90, 120, 150, 180, and 210 lb N/acre. The Bayer hybrid Arize1003 had the N fertilizer applied in a two-way split application scheme at preflood and late-boot (BT) in the following total N (preflood N + BT N) rate splits: 0 (0+0), 60 (30+30), 90 (60+30), 120 (90+30), 150 (120+30), 180 (150+30), and 210 (180+30) lb N/acre. The studies on the two silt loam soils at the LHRF and the RREC received the 0 to 180 lb N/acre fertilizer rates and the studies on the clay soil at the NEREC received the 0 to 210 lb N/acre N rates with the 60 lb N/acre rate omitted. The reasoning behind this is that rice usually requires about 30 lb N/acre more N fertilizer to maximize grain yield when grown on clay soils compared to the silt loams. The RiceTec hybrids had N fertilizer rates ranging from 0 to 210 lb N/acre applied in an assortment of split applications at preflood, beginning internode elongation (BIE), and BT. The rice was drill-seeded in plots nine-rows wide (row spacing of 7 in.), 15 ft. in length at a rate of 100 lb/acre on the silt loam soils and 130 lb/acre on the clay soil, except the hybrids. The Bayer hybrid Arize 1003 was seeded at 45 lb/acre and the RiceTec hybrids which were seeded at a rate of 30 lb/acre on the silt loam soil at the RREC and 40 lb/acre on the clay soil at NEREC. Rice was seeded on 16 April at the RREC, on 21 May at the NEREC and on 6 May at the LHRF. The studies were flooded at each location when the rice was at the 4- to 5-lf stage and within 2 days of preflood N fertilization. The studies remained flooded until the rice was mature. At maturity, 12 ft of the center four rows of each plot were harvested, the moisture content and weight of the grain were determined, and yields were calculated as bu/acre at 12% moisture. A bushel (bu) of rice weighs 45 pounds (lb). Statistical analyses were conducted with SAS and mean separations were based upon protected LSD (p=0.05) where appropriate.

RESULTS AND DISCUSSION

A single preflood N application method was adopted in 2008 in all Variety x N studies due to the rising cost of N fertilizer and the preference of the short stature and semidwarf rice plant types currently being grown. The currently grown rice varieties reach a maximum yield with less N when the N is applied in a single preflood application compared to a two-way split. The rice varieties typically require 20 to 30 lb N/acre less when the N is applied in a single preflood application compared to two-split applications where the second split is applied between beginning internode elongation and 0.5-in. internode elongation. Thus, if 150 lb N/acre is recommended for a two-way split application then 120 to 130 lb N/acre is recommended for a single preflood N application. With the rising costs of N fertilizer growers should consider the single preflood N application.

Bowman did not significantly increase in grain yield when more than 90 lb N/acre was applied on the silt loam soils at LHRF and RREC (Table 1). Bowman had maximum grain yields of 149 and 190 bu/acre on the silt loam soils at LHRF and RREC, respectively. The high native soil N at LHRF and RREC coupled with the single preflood N application method used in 2008 is why Bowman did not significantly increase in yield when only 90 lb N/acre was applied to the silt loam soils. The variability of native soil N among silt loam soils is why a soil test for N is needed to accurately recommend an N rate for the different rice varieties. Bowman displayed a significant decrease in yield at LHRF, but not at RREC, once the N rate required to reach the peak grain yield was exceeded on the silt loam soils. When Bowman was studied on the clay soil at the NEREC, 150 lb N/acre was required to maximize grain yield, but grain yield did not significantly increase when more than 120 lb N/acre was applied. It is typical for rice to require 30 to 60 lb N/acre more to reach maximum yield potential when grown on clay soils compared to silt loam soils. The 2008 results for Bowman in the Variety x N Rate Study are similar to those obtained in 2007 (Norman et al., 2008) and suggest Bowman will probably require around 100 lb N/acre in a single preflood N application and 125 lb N/acre in a two-way split application when grown on silt loam soils. Bowman will require 130 lb N/acre in a single preflood application and about 150 lb N/acre in a two-way split application when grown on clay soils to obtain maximum yield.

Catahoula achieved maximum grain yields of 168 and 190 bu/acre when 180 lb N/acre was applied to the silt loam soils at LHRF and RREC, respectively (Table 2). Catahoula, however, did not significantly increase in grain yield on the silt loam soils at LHRF and RREC when more than 150 lb N/acre was applied. Catahoula only obtained a peak grain yield of 128 bu/acre when grown on the clay soil at NEREC. Catahoula did not significantly increase in yield when more than 90 lb N/acre was applied to the clay soil at NEREC. It is very unusual for a variety to requires less N to achieve peak grain yields on a clay soil compared to a silt loam soil. The combination of NEREC being the northern most location coupled with the late planting is probably the reason for Catahoula not yielding well at this location and may indicate Catahoula does not yield well when planted late. This was the first year Catahoula was in the Variety x N Rate Study and more years of study have to be conducted before a judgement can be made on the proper N rate and late planting implications for Catahoula.

Neptune was able to achieve a maximum grain yield of 212 bu/acre on the silt loam soil at RREC when 150 lb N/acre was applied, but did not significantly increase at RREC when more than 120 lb N/acre was applied (Table 3). Neptune only achieved a maximum yield of 159 bu/acre on the silt loam soil at LHRF when 120 lb N/acre was applied. Lodging was a problem for Neptune at LHRF and is most certainly the cause for the low yields. Neptune broke the 200 bu/acre barrier on the clay soil at NEREC when only 60 lb N/acre was applied. Maximum yield was achieved by Neptune when 180 lb N/acre was applied to the clay soil at NEREC, although grain yield did not significantly increase at NEREC when more than 150 lb N/acre was applied. Neptune did have some lodging problems at NEREC similar to those measured at LHRF, but yields did not appear to suffer at NEREC like at LHRF. This was the first year Neptune was in the Variety x N Rate Study and 1 or 2 more years of study will be required to accurately determine the proper N rate for Neptune to achieve maximum yield.

CL151 did not significantly increase in grain yield at any of the three locations in 2008 when more than 90 lb N/acre was applied (Table 4). The new Rice Soil N Test indicated high native soil N fertility at the silt loam locations in 2008. CL151 had a maximum grain yield of 175 bu/acre on the silt loam soil at LHRF when 90 lb N/acre was applied and displayed no significant grain yield increase at this location when more than 60 lb N/acre was applied. When the N fertilizer rate was increased to 120 lb N/acre, CL151 began to lodge, but the combine did not have any trouble harvesting the grain. However, when 150 and 180 lb N/acre was applied at LHRF, CL151 steadily increased in the percent lodging which resulted in a nonsignificant grain yield decrease due at least partially to trouble harvesting the crop. CL151 obtained a top yield of 200 bu/acre at RREC when 120 lb N/acre was applied and showed no significant grain yield increase when more than 90 lb N/acre was applied. CL151 displayed a significant grain yield decrease from the 200 bu/acre high and slight lodging at RREC when 150 and 180 lb N/acre was applied. CL151 essentially peaked in grain yield at around 180 bu/acre when 90 lb N/acre was applied to the clay soil at NEREC. When the N rate was increased to 120 lb N/acre at NEREC, CL151 obtained a grain yield of 185 bu/acre, but began to lodge. Lodging increased to the 80 and 90% range when 150 to 210 lb N/acre was applied and the combine had trouble harvesting the rice and this resulted in a grain yield decrease of 13 to 22 bu/acre. Overall, CL151 definitely has raised the bar on Clearfield grain yield potential. The 2008 data indicates that CL151 should maximize grain yield on silt loam soils when 100 lb N/acre is applied in a single preflood N application or when 125 lb N/acre is applied in a two-way split application. This would translate to around a 130 to 150 lb N/acre in a single preflood and two-way split application, respectively, when grown on clay soils.

CL171 did not significantly increase in grain yield at any of the three locations in 2008 when more than 90 lb N/acre was applied (Table 5). This was due to the high native N fertility and the single preflood N method used in 2008. CL171 obtained a maximum grain yield of 167 bu/acre at LHRF when 150 lb N/acre was applied, 161 bu/acre at NEREC when 90 lb N/acre was applied, and 164 bu/acre at RREC when 150 lb N/acre was applied. CL171 displayed stable grain yields at all locations when up to 180 lb N/acre was applied and this was partially due to the lack of lodging. CL171 appears to have stronger straw strength compared to CL151. In summary, after three years of study (Norman et al., 2007, 2008), the six location/years of data on silt loam soils indicates CL171 when grown on silt loam soils should achieve maximum grain yield potential when 90 lb N/acre is applied in a single preflood N application and when 120 lb N/acre is applied in a two-way split application. The four location/years of data on clay soils is a little less clear, but appears to indicate CL171AR should achieve maximum grain yield potential when 120 lb N/acre is applied in a single preflood N application and when 150 lb N/acre is applied in a two-way split application. In addition, the overall ten location/years of data indicates that CL171AR has a stable grain yield with no noticeable lodging when 30 lb N/acre and perhaps 60 lb N/acre more than the optimum N fertilizer rate are applied to silt loam and clay soils.

Bayer Crop Science hybrid Arize1003 reached a maximum grain yield of 189 bu/acre at LHRF when only 30 lb N/acre was applied at preflood (Table 6). Arize1003 had lodging percentages in the 90% range when as little at 30 lb N/acre was applied preflood. The lodging caused the data to be quite variable. The grain yield of 131 bu/acre when no N was applied indicates Arize1003 is a hybrid that can acquire nutrients from the soil similar to the RiceTec hybrids and in much greater amounts compared to conventional in-bred varieties. Similar to at LHRF, Arize1003 also had a high grain yield of 128 bu/acre on the clay soil at NEREC when no N fertilizer was applied. Arize1003 reached a grain yield of 164 bu/acre when 60 lb N/acre was applied preflood at NEREC and did not significantly increase in grain yield when more than 60 lb N/acre was applied. Lodging was not as bad at NEREC compared to at LHRF, but similar to LHRF, lodging was a problem even when no N fertilizer was applied. Arize1003 produced the highest yield of the three locations at RREC with a maximum yield of 218 bu/acre when 90 lb N/acre was applied preflood. Amazingly, Arize1003 produced a grain yield of 182 bu/acre on the silt loam soil at RREC when no N fertilizer was applied. Grain yield of Arize1003 did not significantly increase above the 207 bu/acre at RREC when more than 60 lb N/acre was applied. Lodging was a problem at RREC for Arize1003 with lodging being not quite as bad as at LHRF, but a little worst than at NEREC. As with the other two locations, lodging may be partially to blame for the yields not significantly increasing when more than 30 to 60 lb N/acre were applied preflood. This was the first year Arize1003 was in the Variety x N Rate Study and one or two more years of study will be required to accurately determine the proper N rate for Arize to achieve maximum yield. In summary, Arize1003 indicated at RREC that it had good yield potential and the high grain yields when no N was applied indicates this hybrid can acquire or scavenge nutrients from the soil similar to other hybrids. Arize1003 has potential to be a commercially grown variety if the lodging problem can be solved.

RiceTec hybrid CLXL729 obtained a top yield of 226 bu/acre on the silt loam soil at RREC with no lodging when 120 lb N/acre was applied preflood followed by 30 lb N/acre at BIE and BT (Table 7). The grain yield of CLXL729 at RREC did not significantly increase above the 212 bu/acre achieved when 120 lb N/acre was applied in a single preflood N application or when 90 lb N/acre was applied preflood followed by 30 lb N/acre at BIE or BT. CLXL729 did not lodge at all on the silt loam soil at RREC, except when 150 and 180 lb N/acre was applied preflood without the 30 lb N/acre applied at BT. There was some lodging of CLXL729 on the clay soil at NEREC, but the BT N application minimized the lodging in most cases. CLXL729 produced the highest yield of 240 bu/acre on the clay soil at NEREC with no lodging when 150 lb N/acre was applied preflood followed by 30 lb N/acre at BT. This in agreement with the 2007 data for CLXL729 which indicated it required a preflood N rate of 150 lb N/acre as opposed to 120 lb N/acre when grown on clay soils (Norman et al., 2008). The grain yield of CLXL729 did not significantly increase when more than 120 lb N/acre was applied in a single preflood N application, however, there was an obvious numerical grain yield increase when the preflood N rate was increased to 150 lb N/acre or 180 lb N/acre and when 120 lb N/acre was applied preflood with 30 lb N/acre applied at BT. The BT application minimized lodging at NEREC and appeared to help some with yield, but this may be because the combine was better able to harvest the rice due to minimal lodging. The N application at BIE did not appear to increase grain yield, but did appear to aggravate lodging similar to preflood applied N. The 2007 and 2008 results for CLXL729 indicate it requires a preflood N rate of at least 90 lb N/acre and in some cases 120 lb N/acre preflood when grown on silt loam soils. When CLXL729 is grown on clay soils a preflood N rate of 150 lb N/acre will be required. CLXL729 appears to require a higher preflood N rate than previously release hybrids. The BT N application helps minimize lodging of CLXL729 and helps with yield.

There was minimal lodging of CLXL745 at RREC in 2008 and it only occurred when too high of a preflood N application of 150 or 180 lb N/acre was applied (Table 8). CLXL745 achieved a peak grain yield of 225 bu/acre on the silt loam soil at RREC when 90 lb N/acre was applied preflood followed by 30 lb N/acre at BIE and at BT. The grain yield of CLXL745 did not significantly increase above the 216 to 218 bu/acre achieved when 90 lb N/acre was applied preflood followed by 30 lb N/acre at BIE or at BT, respectively. Increasing the preflood N rate from 90 to 120 lb N/acre did not have a positive numerical influence on grain yield, even if 30 lb N/acre was applied at BIE. However, the 30 lb N/acre application at BT did have a positive influence, although nonsignificant, on grain yield when 120 lb N/acre was applied preflood. CLXL745 obtained a peak grain yield of 211 bu/acre on the clay soil at NEREC when 120 lb N/acre was applied preflood followed by 30 lb N/acre at BIE and at BT. However, CLXL745 did not significantly increase in grain yield on the clay soil above the 200 bu/acre achieved when 90 lb N/acre was applied in a single preflood N application. CLXL745 did experience minimal lodging at NEREC when the preflood N rate was increased from 90 to 120 lb N/acre and the BT application did lessen the lodging at this preflood N rate if no N was applied at BIE. The most severe lodging of 50% or more was only measured when the preflood N rate was increased to 150 lb N/acre and then the BT application did not influence lodging as it usually does with the hybrids. Thus, the 2008 data indicates CLXL745 should have no more than 120 lb N/acre applied preflood when grown on clay soils and the BT N application appeared to minimize lodging even though it was small at this preflood N rate. CLXL745 in 2007 (Norman et al., 2008) and 2008 appeared to do the best on the silt loam soils when 90 lb N/acre was applied preflood followed by 30 lb N/acre at BIE and/or BT. When CLXL745 was grown on the clay soil 120 lb N/acre at preflood followed by 30 lb N/acre at BIE and/or BT achieved maximum yield with minimal lodging.

CLXP746 obtained a peak grain yield of 225 bu/acre on the silt loam soil at RREC when 150 lb N/acre was applied in a single preflood N application (Table 9). CLXP746, however, did not significantly increase in grain yield on the silt loam soil when more than 120 lb N/acre was applied preflood with or without an additional 30 lb N/acre applied at BIE and/or BT. The only exception being when 218 bu/acre was achieved when 90 lb N/acre was applied preflood followed by 30 lb N/acre at BIE and at BT. However, the results appear to indicate that 120 lb N/acre at preflood was required for CLXP746 to consistently get in the 220 bu/acre range or more. Nitrogen applied at BIE did not appear to help the grain yield of CLXP746, except when 90 lb N/acre (too little N) was applied preflood. The only lodging CLXP746 experienced at RREC in 2008 was when way too much N, 180 lb N/acre, was applied in a single preflood application. The grain yield of CLXP746 did not significantly increase above the 224 bu/acre achieved when 90 lb N/acre was applied in a single preflood N application on the clay soil at NEREC. However, CLXP746 required at least 105 to 120 lb N/acre at preflood to consistently obtain 230 bu/acre or more. Increasing the preflood N rate above 120 lb N/acre or application of N at BIE and/or BT appeared to have minimal influence on the yield of CLXP746 at NEREC which is surprising since the same preflood N rate was required on the silt loam soil at RREC to maximize yield. CLXP746 appears to be less prone to lodging compared to CLXL729 and CLXL745.

The Arkansas experimental variety KDM08 maximized grain yield on the silt loam soils at LHRF and RREC when 90 lb N/acre was applied (Table 10). KDM08 obtained an excellent yield of 200 bu/acre at RREC, but began to lodge and lodging increased and yield decreased with each incremental increase in N above 90 lb N/acre. The lower yields for KDM08 at LHRF and NEREC are probably due to late planting, especially at NEREC. KDM08 only obtained a peak yield of 155 bu/acre on the silt loam soil at LHRF and displayed sporadic lodging when 90 lb N/acre or greater was applied. When KDM08 was grown on the clay soil at NEREC a top grain yield of 163 bu/acre was achieved when 120 lb N/acre was applied. However, KDM08 did not significantly increase in yield when more than 90 lb N/acre was applied at NEREC. KDM08 did not lodge at NEREC like at the two other locations, but did steadily decrease in yield similar to the other two locations when the N rate to achieve maximum yield was exceeded.

A preliminary N fertilizer rate study was conducted on the silt loam soil at the RREC with the Arkansas experimental rice variety RU0701124 (Table 11). RU0701124 achieved a maximum yield of 177 bu/acre when 120 lb N/acre was applied, but did not significantly increase in yield above the 168 bu/acre obtained when 90 lb N/acre was applied. Lodging was a problem for RU0701124 when the N rate to achieve maximum yield was exceeded, although yield was not affected as much as the lodging percentage would indicate.

Arkansas experimental variety RU0401182 achieved top yields in the 170 bu/acre range when 90 and 120 lb N/acre was applied to the silt loam soil at LHRF (Table 12). Yield did not significantly decline below the maximum yield when 150 and 180 lb N/acre was applied. Lodging was a problem for RU0401182 at LHRF even when no N fertilizer was applied. RU0401182 maximized yield at 176 bu/acre when 90 lb N/acre was applied to the clay soil at NEREC and maintained a yield of 167 bu/acre or more when up to 180 lb N/acre was applied with no lodging. Yield did decrease significantly below the maximum yield when 210 lb N/acre was applied. The best yield of 201 bu/acre was obtained by RU0401182 on the silt loam soil at the RREC when 150 lb N/acre was applied. RU0401182 got in to the 180 bu/acre plus range when as little as 90 lb N/acre was applied at RREC. Minimal lodging of RU0401182 was measured at RREC when the N rate (i.e., 150 lb N/acre) to achieve maximum yield was applied or exceeded.

Arkansas experimental variety RU0601188 achieved a maximum yield of 182 bu/acre when 120 lb N/acre was applied to the silt loam soil at LHRF (Table 13). Yield did not significantly decline below the maximum yield when 150 and 180 lb N/acre was applied. Lodging was not a problem for RU0601188 at LHRF or at any of the other locations. RU0601188 maximized yield at 177 bu/acre when 150 lb N/acre was applied to the clay soil at NEREC and did not significantly decrease in yield below this maximum when up to 210 lb N/acre was applied. RU0601188 did not significantly increase in yield at NEREC when greater than 90 lb N/acre was applied. RU0601188 had a very stable yield of 169 to 177 bu/acre at the NEREC over a wide N rate application range from 90 to 210 lb N/acre. Similarly, when RU0601188 was grown on the silt loam soil at RREC a yield of 181 bu/acre or more was obtained when 90 to 180 lb N/acre was applied with no lodging. RU0601188 obtained a maximum yield of 196 bu/acre when 180 lb N/acre was applied, but obtained a similar yield of 194 bu/acre when 150 lb N/acre was applied at RREC. This variety, RU0601188, displays a remarkably stable yield over a very wide N application range with no lodging. This was also observed in 2007 (Norman et al., 2008) and should make it much easier to obtain top yields when grown commercially.

SIGNIFICANCE OF FINDINGS

The Variety x N Fertilizer Rate Study examines the grain yield performance of a new rice variety across a range of N fertilizer rates on representative soils and under climatic conditions that exist in the Arkansas rice-growing region. Thus, this study is able to determine the proper N fertilizer rate for a variety to achieve maximum yield when grown commercially in the Arkansas rice-growing region. Thirteen rice cultivars were studied in 2008: Bowman; Catahoula; Neptune; Horizon AG's CL151 and CL171; Bayer Crop Science's Arize1003; RiceTec's CLXL729, CLXL745, and CLXP746; and the Arkansas experimental varieties RU0401182, RU0601188, RU0701124, and KDM08. The data generated from multiple years of testing of each variety will be used to determine the proper N fertilizer rate for a variety to achieve maximum yield when grown commercially on silt loam and clay soils in Arkansas.

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Table 1. Influence of nitrogen (N) fertilizer rate on the grain yield of 'Bowman' rice at three locations during 2008.

N Fertilizer rate	Grain yield		
	LHRF[z]	NEREC	RREC
(lb N/acre)	(bu/acre[y])		
0	94	85	125
60	137	---	174
90	143	155	180
120	149	167	190
150	135	176	186
180	139	155	180
210	---	152	---
$LSD_{(0.05)}$	9	14	12

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.

[y] A bushel of rice weighs 45 lb.

Table 2. Influence of nitrogen (N) fertilizer rate on the grain yield of 'Catahoula' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	(bu/acre[y])		
0	57	56	72
60	137	---	119
90	159	125	156
120	159	126	173
150	167	128	186
180	168	125	190
210	---	113	---
$LSD_{(0.05)}$	9	14	13

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.

[y] A bushel of rice weighs 45 lb.

Table 3. Influence of nitrogen (N) fertilizer rate on the grain yield of 'Neptune' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	(bu/acre[y])		
0	66	103	115
60	113 [10x]	-----	175
90	145 [18]	202	186
120	159 [20]	211 [13]	203
150	158 [25]	218 [8]	212
180	153 [35]	219 [20]	212
210	-----	194 [25]	-----
$LSD_{(0.05)}$	11	19	12

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.

[y] A bushel of rice weighs 45 lb.

[x] Numbers in superscript to side of the yield are lodging percentages.

Table 4. Influence of nitrogen (N) fertilizer rate on the grain yield of 'Clearfield CL151' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	(bu/acre[y])		
0	89	83	120
60	163	-----	181
90	175	181	192
120	172 [35x]	185 [58]	200
150	156 [58]	174 [83]	181 [13]
180	164 [70]	162 [80]	171 [10]
210	-----	173 [93]	-----
$LSD_{(0.05)}$	14	17	15

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; RREC = Rice Research and Extension Center, Stuttgart, Ark..
[y] A bushel of rice weighs 45 lb.
[x] Numbers in superscript to side of the yield are lodging percentages.

Table 5. Influence of nitrogen (N) fertilizer rate on the grain yield of 'Clearfield CL171' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	(bu/acre[y])		
0	97 [18x]	90	92
60	151	-----	129
90	161	161	156
120	166	160	159
150	167	161	164
180	166	157	164
210	-----	145	-----
$LSD_{(0.05)}$	8	21	10

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[y] A bushel of rice weighs 45 lb.
[x] Numbers in superscript to side of the yield are lodging percentages.

Table 6. Influence of nitrogen (N) fertilizer rate on the grain yield of Bayer Crop Science hybrid Arize1003 rice at three locations in Arkansas during 2008.

N fertilizer rate			Grain yield		
Total N	N timing[z]				
rate	PF	BT	LHRF[y]	NEREC	RREC
-------------(lb N/acre) ----------			------------------------(bu/acre[x]) ------------------------		
0	0	0	131 ^{73w}	128 ^{25}	182 ^{55}
60	30	30	189 ^{93}	-----	202 ^{58}
90	60	30	168 ^{90}	164 ^{50}	207 ^{70}
120	90	30	163 ^{93}	130 ^{25}	218 ^{50}
150	120	30	158 ^{93}	134 ^{25}	204 ^{18}
180	150	30	146 ^{80}	167 ^{50}	184 ^{60}
210	180	30	-----	154 ^{25}	-----
$LSD_{(0.05)}$			32	37	14

[z] PF=preflood; BT= late boot.
[y] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[x] A bushel of rice weighs 45 lb.
[w] Numbers in superscript to the right of yield weight are lodging percentage.

Table 7. Influence of nitrogen (N) fertilizer rate and timing on the grain yield of RiceTec hybrid 'CLXL729' rice at two locations in Arkansas during 2008.

N fertilizer rate				Grain yield	
Total N	N timing[z]				
rate	PF	BIE	BT	NEREC[y]	RREC
------------------------(lb N/acre) -----------------------				------------ (bu/acre[x])-----------	
0	0	0		103	132
60	60	0	0	---	184
90	90	0	0	214	215
120	120	0	0	219 ^{35w}	212
120	90	30	0	-----	212
120	90	0	30	-----	212
150	150	0	0	229 ^{20}	211 ^{18}
150	120	30	0	220 ^{15}	219
150	120	0	30	228	219
150	90	30	30	-----	222
180	180	0	0	231 ^{23}	212 ^{20}
180	150	30	0	234 ^{43}	-----
180	150	0	30	241	-----
180	120	30	30	223 ^{28}	226
210	150	30	30	229 ^{33}	-----
105	105	0	0	213 ^{18}	-----
135	135	0	0	239 ^{20}	223 ^{5}
$LSD_{(0.05)}$				21	16

[z] PF=preflood; BIE = beginning internode elongation; BT= late boot.
[y] NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[x] A bushel of rice weighs 45 lb.
[w] Numbers in superscript to the right of yield weight are lodging percentage.

Table 8. Influence of nitrogen (N) fertilizer rate and timing on the grain yield of RiceTec hybrid 'CLXL745' rice at two locations in Arkansas during 2008.

N fertilizer rate				Grain yield	
Total N	N timing^{z}				
rate	PF	BIE	BT	NEREC^{y}	RREC
------------------------(lb N/acre) -----------------------				------------ (bu/acre^{x})-----------	
0	0	0		121 ^{10w}	159
60	60	0	0	-----	201
90	90	0	0	200	206
120	120	0	0	193 ^{8}	209
120	90	30	0	-----	216
120	90	0	30	-----	218
150	150	0	0	207 ^{55}	209 ^{8}
150	120	30	0	207 ^{8}	208
150	120	0	30	206	221
150	90	30	30	-----	224
180	180	0	0	195 ^{13}	211 ^{28}
180	150	30	0	197 ^{50}	-----
180	150	0	30	209 ^{55}	-----
180	120	30	30	211 ^{13}	224
210	150	30	30	174 ^{55}	-----
105	105	0	0	201	-----
135	135	0	0	200 ^{18}	211
$LSD_{(0.05)}$				27	13

^{z} PF=preflood; BIE = beginning internode elongation; BT= late boot.
^{y} NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
^{x} A bushel of rice weighs 45 lb.
^{w} Numbers in superscript to the right of yield weight are lodging percentage.

Table 9. Influence of nitrogen (N) fertilizer rate and timing on the grain yield of RiceTec hybrid 'CLXP746' rice at two locations in Arkansas during 2008.

N fertilizer rate				Grain yield	
Total N	N timing[z]				
rate	PF	BIE	BT	NEREC[y]	RREC
(lb N/acre)				(bu/acre[x])	
0	0	0		115	149
60	60	0	0	-----	177
90	90	0	0	223	196
120	120	0	0	230	223
120	90	30	0	-----	213
120	90	0	30	-----	209
150	150	0	0	230	225
150	120	30	0	226	217
150	120	0	30	231	222
150	90	30	30	-----	218
180	180	0	0	235	219 [35w]
180	150	30	0	237	-----
180	150	0	30	231	-----
180	120	30	30	234	223
210	150	30	30	236	-----
105	105	0	0	231	-----
135	135	0	0	231	220
$LSD_{(0.05)}$				19	12

[z] PF=preflood; BIE = beginning internode elongation; BT= late boot.
[y] NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[x] A bushel of rice weighs 45 lb.
[w] Numbers in superscript to the right of yield weight are lodging percentage.

Table 10. Influence of nitrogen (N) fertilizer rate on the grain yield of experimental variety 'KDM08' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	(bu/acre[y])		
0	100	99	145
60	142	-----	186
90	155 [18x]	160	200 [10]
120	150 [13]	163	188 [23]
150	143 [53]	142	178 [35]
180	138 [13]	137	151 [65]
210	-----	129	-----
$LSD_{(0.05)}$	17	14	25

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[y] A bushel of rice weighs 45 lb.
[x] Numbers in superscript to side of the yield are lodging percentages.

Table 11. Influence of nitrogen (N) fertilizer rate on the grain yield of Arkansas experimental rice variety 'RU0701124' at the Rice Research and Extension Center near Stuttgart, Ark., during 2008.

N fertilizer rate	Grain yield
(lb N/acre)	(bu/acre[z])
0	95
60	148
90	168
120	177
150	169 [48y]
180	160 [70]
$LSD_{(0.05)}$	13

[z] A bushel of rice weighs 45 lb.
[y] Numbers in superscript to the right of yield weight are lodging percentage.

Table 12. Influence of nitrogen (N) fertilizer rate on the grain yield of Arkansas experimental rice variety 'RU0401182' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	------------------------------ (bu/acre[y])	------------------------------	
0	100 [55x]	82	97
60	153	----	154
90	171 [13]	176	182
120	173 [35]	168	187
150	159 [30]	167	201 [5]
180	165 [20]	174	193 [15]
210	----	151	----
$LSD_{(0.05)}$	18	17	14

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[y] A bushel of rice weighs 45 lb.
[x] Numbers in superscript to side of the yield are lodging percentages.

Table 13. Influence of nitrogen (N) fertilizer rate on the grain yield of Arkansas experimental rice variety 'RU0401182' rice at three locations during 2008.

N Fertilizer	Grain yield		
rate	LHRF[z]	NEREC	RREC
(lb N/acre)	------------------------------- (bu/acre[y]) -------------------------------		
0	77	82	104
60	134	----	152
90	163	171	181
120	182	176	183
150	178	177	194
180	171	173	196
210	----	169	----
$LSD_{(0.05)}$	14	18	12

[z] LHRF = Lake Hogue Research Farm, Wiener, Ark.; NEREC = Northeast Research and Extension Center, Keiser, Ark.; and RREC = Rice Research and Extension Center, Stuttgart, Ark.
[y] A bushel of rice weighs 45 lb.

Variable Rates of Agrotain® on Ammonia Volatilization Loss of Urea Applied to a Dewitt Silt Loam

C.R. Roth, T.L. Roberts, and R.J. Norman

ABSTRACT

One of the many problems associated with delayed-flood rice production is the ability of producers to flood fields in a timely manner following preflood nitrogen (N) fertilization. Producers which are unable to flood fields within 3 days can lose a significant portion of the urea-N due to ammonia volatilization. The use of Agrotain with the urea has been shown to improve yields for fields that require greater than 3 days to flood. As the cost of urea continues to increase, the need for alternative management techniques to ensure N fertilizer remains in the field are also needed. Laboratory incubations were conducted to determine if different rates of Agrotain can be used while significantly reducing N losses due to ammonia volatilization.

Three different rates of Agrotain coated on urea were analyzed to determine the resulting influence on ammonia volatilization of the urea over a 15-day aerobic incubation. Increasing rates of Agrotain significantly lowered the cumulative ammonia volatilization of urea at day 15, but at day 7 all rates of Agrotain were not significantly different from one another. These results indicate that fields flooded in less than 7 days can potentially use a lower rate of Agrotain (3 qt/ton of urea) while effectively suppressing ammonia volatilization similar to the standard recommendation of 4 qt/ton of urea. Fields requiring greater than 11 days to flood may benefit from a higher rate of Agrotain (5 qt/ton of urea) as higher rates of Agrotain significantly reduced ammonia volatilization at times greater than 11 days. These results coupled with field experiments identify the need to use Agrotain treated-urea on fields that cannot be flooded in less than 3 days. For fields that require much longer time periods to flood, more than 11 days, producers can benefit from using a higher than recommended rate of Agrotain to further suppress ammonia volatilization.

INTRODUCTION

Nitrogen is an essential component of modern rice production systems and has been likened to the fuel that makes the racecar run. Most producers in the mid-South utilize a system known as direct-seeded, delayed-flood rice production. In this system, rice is grown upland until the 4- to 5-lf stage when N is broadcast as urea over the entire field. Following N fertilization with urea the field should be flooded as soon as possible to reduce the potential loss of N due to ammonia volatilization. Flooding a field incorporates N into the soil and lowers the potential for losses due to ammonia volatilization, nitrification and/or denitrification (Savin et al., 2007). Ammonia volatilization can be an issue of concern for producers that require more than 3 days to flood a field as studies have shown N losses of 15 to 20% after 5 days (Norman et al., 2004). Significant losses of N due to ammonia volatilization have led to the development of urea stabilization products to help reduce volatilization. Agrotain is a urea stabilizer which contains the urease inhibitor NBPT. Urease inhibitors reduce ammonia volatilization by slowing the conversion of urea to ammonium and therefore lowering the potential for ammonia volatilization (Norman et al., 2007).

A laboratory study was initiated to determine the influence of Agrotain rate on ammonia volatilization of urea and identify the potential of specific rates to improve N management in direct-seeded, delayed-flood rice production.

MATERIALS AND METHODS

An aerobic incubation study to quantify ammonia volatilization of urea was conducted in the Rice Nitrogen Fertility Lab at the University of Arkansas, Fayetteville, Ark. The study was initiated on 21 January 2008 and concluded on 4 February 2008. The study was designed to evaluate the influence of various rates of the product known as Agrotain on ammonia volatilization of urea. The study included four fertilizer treatments: 1) urea with no Agrotain added (control); 2) 3 qt of Agrotain/ton of urea; 3) 4 qt of Agrotain/ton of urea (standard recommendation); and 4) 5 qt of Agrotain/ton of urea. Ammonia volatilization was measured at five sample times: 0, 3, 7, 11, and 15 days after application to the soil and was replicated four times.

The soil utilized in this study was a Dewitt silt loam (Albaqualf) that was collected at the Rice Research and Extension Center near Stuttgart, Ark. Soil was taken from the top 4 inches of the soil profile and returned to the lab where it was dried and ground to pass through a 2 mm sieve. Prior to incubation the volumetric water content of the soil was adjusted to 20% v/v and 50 g of soil were added to each diffusion chamber modified according to Khan et al. (2001). Fertilizer treatments were added to the surface of the soil within the diffusion chambers to equal a rate of 150 lb N/acre on an area basis. Petri dishes were placed within the diffusion chamber lids and 5 ml of 4% boric acid indicator solution was added. Immediately following fertilizer application the modified lids containing the petri dishes with boric acid were used to seal the diffusion chambers. Samples were incubated at 76°Fahrenheit (±1.6°) within the laboratory. After 3 days, the lids were removed and the petri dishes containing boric acid were replaced with a new petri dishes containing boric acid and resealed within 30 seconds. Following removal from the diffusion chambers, 5 ml of deionized water was added to each petri dish and the sample was titrated to a predetermined endpoint using an autotitrator. The volume of acid required to titrate the sample was used to determine the mass of N that volatilized during the sample period. This process was repeated for each of the sampling periods following 7, 11, and 15 days of incubation. Cumulative ammonia volatilization loss for day 3 was calculated by adding the volatilization for day 3 to the ammonia loss from the previous period. This was repeated for each of the sample times and reported as cumulative ammonia volatilization over time. Upon completion of the 15 day incubation period, the data were analyzed and presented graphically.

RESULTS AND DISCUSSION

Urea is the most commonly used form of N fertilizer in today's delayed-flood rice culture. Nitrogen applied as urea can be the most logical and cost effective form of N fertilizer if it is applied and soil incorporated in a timely manner. When urea is added and a flood is applied within 2 days of application, it results in the highest yield per pound of N added (Norman et al., 2008). Previous studies have shown that rice yields will be higher when urea is applied 1 day prior to flooding rather than 5 days and subsequently flooding at 5 days will result in higher yields than flooding at 10 days (Norman et al., 2004). Other studies have shown that urea used in combination with Agrotain can still provide excellent yields even if the urea is not immediately incorporated into the soil (Norman et al., 2008).

The results presented in this paper further support the evidence that Agrotain slows the volatilization of urea and can be used on fields that require longer than ideal to flood (>3 days). In this experiment Agrotain was applied to urea at three different rates to determine its influence on ammonia volatilization. There was an inversely proportional relationship between Agrotain rate and ammonia volatilization (Fig. 1). The highest rate of Agrotain resulted in the lowest cumulative ammonia volatilization following the 15-day incubation period. Ammonia volatilization was highest in the control, where urea was applied without the addition of Agrotain. Each rate of Agrotain had an influence on ammonia volatilization and all three rates were significantly lower than the control at day 15.

Cumulative ammonia volatilization of urea at day 3 showed no differences between treatments (Fig. 1). At this sampling time very little ammonia was volatilized from any of the treatments and there was no significant difference in cumulative ammonia volatilization between urea that received Agrotain and urea that did not receive Agrotain. These results support previous findings that suggest there is no benefit from the addition of Agrotain to urea for fields that can be flooded in less than 3 days. The first significant difference in cumulative ammonia volatilization was measured at day 7 where urea without Agrotain was significantly higher than urea with Agrotain, regardless of rate. Nitrogen loss from urea without Agrotain at day 7 was nearly 25%, but the ammonia volatilization recorded from urea receiving Agrotain was not significantly different than zero.

The first rate of Agrotain (3 qt/ton) utilized in this study was lower than the rate that is recommended for standard use on urea fertilizer. At day 11 this treatment resulted in a 20% loss of the applied urea, which was roughly half of the control treatment where no Agrotain was applied. Although a rate of 3 qt/ton of urea was effective at lowering ammonia volatilization compared to the urea without Agrotain, the 3 qt/ton rate still resulted in N loss significantly higher than the other two rates of Agrotain at samplings later than 7 days. By day 15, the N loss from the 3 qt/ton treatment was almost 35% of the total N applied and was significantly lower than the control, but significantly higher than both the 4 and 5 qt/ton treatments. The 3 qt/ton rate of Agrotain appears to be sufficient at reducing ammonia volatilization losses from urea as long as the field can be flooded within 7 days after application. There is no benefit from using this rate on fields requiring more than 7 days to flood.

Four quarts of Agrotain per ton of urea is the standard recommendation for use on urea fertilizer. This was utilized as the second treatment of this study and was significantly better than the 3 qt/ton rate at days 11 and 15, but did not perform as well as the 5 qt/ton rate at these same time periods. Although ammonia volatilization for the 4 and 5 qt/ton rates were statistically different at day 11, they were both below 10% of the total N applied and less than half of the 3 qt/ton rate and less than one fourth of the control where no Agrotain was used. At day 15, the 4 qt/ton rate had lost ~20% of the applied urea and outperformed the 3 qt/ton rate, but was 8% higher than the 5 qt/ton rate. Fields requiring 11 days to flood would benefit from using a 4 qt/ton rate rather than the 3 qt/ton rate, and even though the 4 qt/ton rate was slightly higher in ammonia volatilization than the 5 qt/ton rate a producer would not benefit from the additional cost.

The highest rate of Agrotain used in the study was 5 qt/ton of urea and this rate is slightly higher than the standard recommendation of 4 qt/ton and only did better than the standard recommendation at the last sampling time, day 15. During the first 7 days of this experiment the 4 qt/ton rate was very similar to the 3 qt/ton rate and the only real differences were seen at days 11 and 15 where the 4 qt/ton rate resulted in a significantly lower cumulative ammonia volatilization. A higher rate of Agrotain appears to increase the product's ability to slow ammonia volatilization. Higher rates of Agrotain such as the 5 qt/ton rate may prove beneficial to areas that require several weeks to flood.

Following this experiment it is apparent that the rate of Agrotain applied to urea has a significant influence on the resulting rate of ammonia volatilization. At day 15 each rate of Agrotain was significantly different than one another and all were significantly lower than the control. It appears that ammonia volatilization is inversely proportional to the rate of Agrotain that is applied, at least within the confines of this experiment. Producers that require more than 1 week to flood fields have the flexibility to use variable rates of Agotain to help curb N losses via ammonia volatilization.

SIGNIFICANCE OF FINDINGS

Ammonia volatilization losses of urea applied preflood to delayed-flood rice can be devastating both in terms of yield reduction and profitability. Agrotain is a urea stabilizer that reduces ammonia volatilization and provides producers with a fertilizer management tool on fields that require more than 1 week to flood. Lower rates of Agrotain (3 qt/ton) can be utilized on fields that require less than 1 week to flood without any significant losses of N. Fields requiring >7 days to flood would benefit from using the standard recommendation of 4 qt of Agrotain/ton of urea. In the event that a producer is unable to flood their field within 2 weeks of urea fertilizer application there is a potential benefit of utilizing a higher rate of 5 qt/ton of Agrotain as this will significantly lower the ammonia volatilization losses. These findings will grant producers more preflood fertilizer management options to help increase profitability and yields, by reducing ammonia volatilization through variable rate Agrotain application based on the time required to flood a field.

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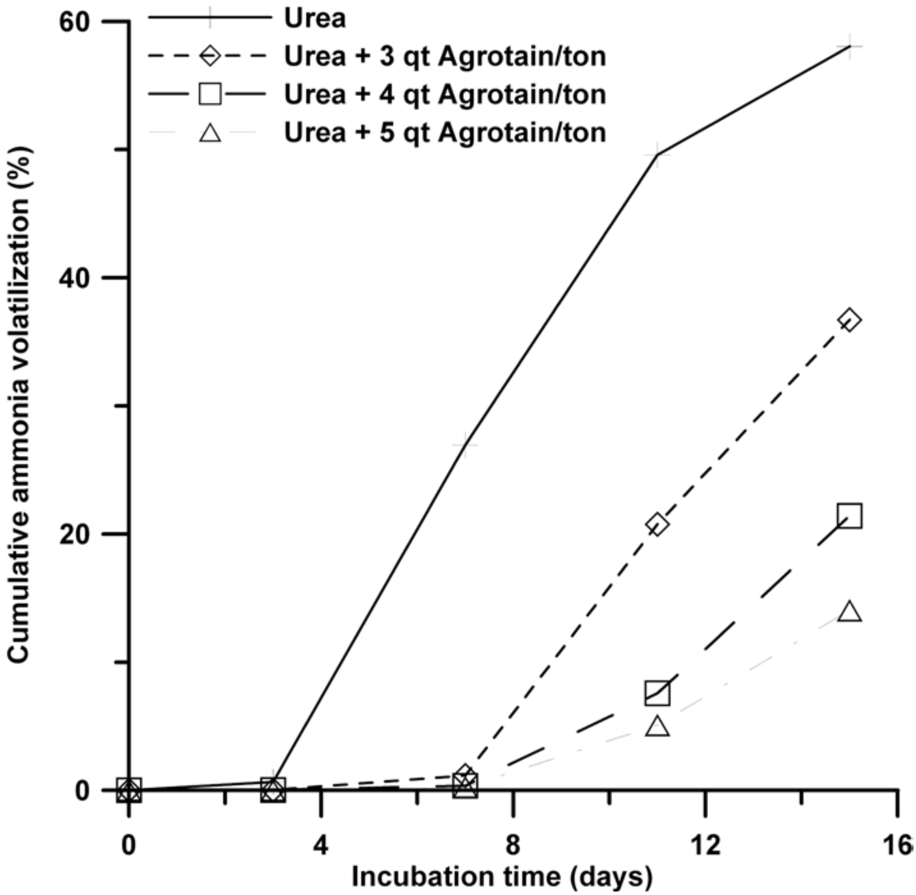

Fig. 1. The influence of Agrotain rate on cumulative ammonia volatilization loss following a 15 day aerobic incubation.

Rice Yield and Stem Rot Response to Potassium Fertilization

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ABSTRACT

Potassium (K) is known to influence crop yield potential and plant susceptibility to various diseases. This research evaluated the long-term effects of annual K-fertilization on grain yield and stem rot of rice and the short-term effects of K-fertilization and fungicide application rate on rice grain yield and stem rot severity of rice grown on silt loam soils. Soil receiving the same annual K application rates (0-160 lb K_2O/acre) since 2000 showed rice yields in 2006 and 2008 were increased by as much as 19 and 72%, respectively, above soil receiving no K. Stem rot severity increased as long-term K-fertilizer rate decreased with annual K rates of 120 lb K_2O/acre/yr needed to minimize stem rot. The results of six short-term trials conducted in 2007 and 2008, showed rice yields were maximized and stem rot was minimized by application of 120 lb K_2O/acre with maximum benefits from K applied preflood. Fungicide application also increased rice grain yield and reduced stem rot index. Application of no K with fungicide produced yields that were similar to rice that received no fungicide and K applied preflood. These yield data suggest that yield loss from K deficiency is affected by the essential functions K performs in plant nutrition as well as from increased disease pressure. However, rice yields were maximized only when K and fungicide were applied together. Diligent attention to K fertilization can increase rice yields and possibly reduce the severity of some diseases as well as the need for fungicide.

INTRODUCTION

Potassium (K) is sometimes referred to as the crop health nutrient because K deficiency is often accompanied by increased disease incidence and severity. Potassium deficiency has been recognized as one of the more common nutrient deficiencies of rice (*Oryza sativa* L.) grown on silt and sandy loam soils in Arkansas since the early 1990's. Silt loam soils that have <100 ppm soil-test K (Mehlich-3) require K fertilizer to produce near maximum yield potential. About 50 to 64% of the rice and irrigated-soybean acreage in Arkansas contains <131 ppm soil-test K and requires K fertilization to maintain a medium soil K level and/or prevent yield loss from K deficiency (DeLong et al., 2008). Soil-test based, K-fertilization recommendations for rice have been researched vigorously and modified in recent years, but we lack knowledge of whether mid- to late-season application of K fertilizer to K-deficient rice is of direct benefit to grain yield or reducing the incidence and severity of diseases associated with K deficiency.

Stem rot (*Sclerotium oryzae* Catt.) is one of the most common diseases in Arkansas rice fields and is often more severe in rice that is low or deficient in K. Stem rot infects rice sheaths and stems and moves inward which may decrease stalk strength, increase lodging, cause premature death of lower leaves, and decrease rice yield by an estimated 10 to 75% (Cralley, 1936). Application of sufficient K-fertilizer has the potential to reduce stem rot severity and increase grain yields of rice grown on K-deficient soil (Williams and Smith, 2001). Because other diseases in addition to stem rot may be more severe on K-deficient rice, application of fungicide may help reduce a portion of the yield loss associated with disease. Thus, the research objectives were to evaluate 1) the long-term effects of annual K-fertilizer rate on grain yield and stem rot of rice and 2) the short-term effects of K-fertilizer application rate and time and fungicide application rate on rice grain yield and stem rot severity of rice grown on silt loam soils having medium or lower soil-test K levels.

PROCEDURES

Long-Term Effect of K-Fertilization Trials

A long-term K-fertilization trial was established on a Calhoun silt loam at the Pine Tree Branch Station in 2000 and cropped to rice in even years and soybean [*Glycine max* (Merr.) L.] in odd years. Rice and soybean yield and soil-test results from 2000 to 2006 were described by Slaton et al. (2007). This report includes rice yield and stem rot data collected in 2006 and 2008. A composite soil sample (0- to 4-in. depth) was collected from each plot in January or February of 2006 and 2008. Soil samples were oven-dried, crushed, and passed through a 2-mm sieve. Soil water pH was determined in a 1:2 soil: water mixture, plant-available nutrients were extracted with the Mehlich-3 soil-test method, and nutrient concentrations were determined using inductively coupled plasma spectroscopy (ICPS). Selected soil chemical property means are listed in Table 1.

Each individual plot measured 16-ft long by 25-ft wide which allowed planting four, nine-row strips of rice per plot with a small-plot drill. In 2006 and 2008, rice was planted into an untilled seedbed. Each year, P (50 lb P_2O_5/acre) and Zn (10 lb Zn/acre) fertilizers were applied before seeding and 'Wells' rice was drill-seeded (7.5-in. drill spacing) at 100 to 110 lb seed/acre. Rice management with respect to irrigation and weed control was performed following University of Arkansas Cooperative Extension Service guidelines.

Muriate of potash (KCl, 60% K_2O) was broadcast to the soil surface before planting at annual rates of 0, 40, 80, 120, and 160 lb K_2O/acre. Potassium fertilizer rates were arranged as a randomized complete block with eight replications. At the 5-lf stage, urea was broadcast to a dry soil surface at 130 lb N/acre and within 48 to 72 hours of application a 4-in. deep flood was established. At panicle differentiation (PD) and early heading (~5% headed), whole, aboveground plants in a 3-ft section of an inside row was harvested at soil level, dried to a constant moisture, weighed, ground, digested, and analyzed for K concentration by ICPS. At maturity, another 3-ft section of an inside row was cut at ground level, wrapped in poly-tubing, and frozen until rated for stem rot index. Each stem was examined and assigned a rating of 1 to 5 with 1 being healthy and 5 being severely infested with stem rot as described by Krause and Webster (1973). The sum of ratings for all individual stems from the same plot was calculated and divided by the number of stems examined to calculate the average stem rot index. Rice yields were determined by harvesting the middle four rows of each drill pass from each K rate. Rice yield was adjusted to 12% moisture content before statistical analysis.

Potassium fertilizer rates were arranged as a randomized complete block design with eight replications. Analysis of variance was conducted with the PROC GLM procedure in SAS (SAS Institute, Inc., Cary, N.C.) using a split-plot treatment structure where the whole plot was annual K rate and the subplot was year. Mean separations were performed using Fisher's Protected Least Significant Difference (LSD) method at a significance level of 0.05

Potassium Application Rate and Time and Fungicide Rate Experiments

Six research sites were established in 2007 (2) and 2008 (4) in Lonoke, Prairie, and Poinsett county rice fields and the Lake Hogue Research Farm (LHRF, Poinsett County). Soybean was the previous crop grown at each site. Two composite soil samples (0- to 4-in. depth) were collected from each replicate in plots designated to receive 0 lb K_2O/acre to characterize plant-available, soil-K levels at each site. Samples were processed and analyzed for selected soil chemical properties as described previously for the long-term K trial at the PTBS (Table 1).

Potassium fertilizer was applied at 0, 60, and 120 lb K_2O/acre before flooding, at PD and the late boot growth stages. To ensure uniform disease among plots, stem rot inolculum was prepared as described by Krause and Webster (1972) and 500 mL of inoculum was applied to all plots just before PD. Azoxystrobin fungicide (Quadris) was applied at rates of 0 and 12.8 oz/acre in a 10 gal/acre spray volume with an automated spray system mounted on a MudMaster shortly after internode elongation. Stem rot index and grain yield were measured as described previously.

A single preflood application of urea-N was made for rice grown at LHRF07 (135 lb N/acre) and LHRF08 (156 lb N/acre). Nitrogen fertilization was performed by the cooperating producers for research conducted in commercial production fields (Lonoke, Poinsett, and Prairie counties). Producers applied N in two or three split applications with total N rates ranging from 152 to 166 lb N/acre. The preflood N rate ranged from 92 to 115 lb N/acre with the balance applied at midseason in one (Prairie08 and Poinsett08) or two (Lonoke07 & 08) applications.

Each experiment was a randomized complete block design with a 4 (K application time) by 3 (K rate) by 2 (fungicide rate) factorial structure of treatments which were replicated four times per site. Data were analyzed with the PROC GLM procedure using a split-plot, factorial treatment structure where location was the main plot and the factorial arrangement of K rates, K application times, and fungicide rates was the subplot. Each replicate contained three no K (0 lb K_2O/acre) controls for each fungicide rate which were considered as both a K rate and an application time (None). Only the significant interactions of the fixed effects (K rate, K application time, and fungicide rate) will be discussed. Mean separations were performed using Fisher's Protected LSD method at a significance level of 0.05.

RESULTS AND DISCUSSION

Long-Term Trial Results - Pine Tree Branch Station

Soil-test K of soil that has received no K fertilizer since 2000 averaged 65 ppm in 2006 and 87 ppm in 2008 which is classified as 'Low' (Table 1). Only the main effects of annual-K rate ($P<0.0001$) and year ($P<0.0001$) affected soil-test K. Soil-test K, averaged across all annual K rates, was 80 ppm in 2006 and 114 ppm in 2008. The reason why soil-test K was higher in 2008 is not known, but the annual differences within each rate were 22 to 42 ppm higher in 2008 compared to 2006 K values (data not shown). Averaged across years, soil-test K, in plots receiving 0, 40, 80, 120, and 160 lb K_2O/acre was 76 < 90 = 94 < 107 = 117 ppm (LSD 0.05 = 11 ppm), respectively, showing that soil-test K increased as annual-K rate increased.

The annual-K rate by year interaction was significant for rice grain yield ($P<0.0001$) and stem rot index ($P<0.0001$, Table 2). In 2006, annual application of 40 lb K_2O/acre produced near maximum grain yields. In 2008, annual application of 160 lb K_2O/acre produced the greatest grain yields. Comparison of K rates between years, showed that similar yields were produced with 40 and 80 lb K_2O/acre/yr. The no K control produced lower yields in 2008 than in 2006, which was expected as soil K removal by harvested grain was greater than K input. Within the 120 and 160 lb K_2O/acre/yr rates, rice yields were greater in 2008. The 87 bu/acre difference between the low and high yielding K rates in 2008 is the greatest yield response to K fertilization measured in K-fertilization trials in Arkansas and represents a 42% yield loss due to K deficiency.

Within each annual K rate, stem rot index was always greater in 2006 than 2008 (Table 2). The magnitude of difference between years for each annual-K rate ranged from 0.24 to 0.94 with the largest differences occurring for annual-K rates ≤80 lb K_2O/acre/yr. Within each year, stem rot was most severe in rice that received no K and diminished as K rate increased to 120 lb K_2O/acre/yr. Although the stem rot rating declined numerically for rice receiving 160 lb K_2O/acre/yr the difference was not significant. The number of rice culms in each 3-ft section of plants evaluated for stem rot was not different between years, but was significantly affected by annual-K rate (P<0.0001). Culm numbers, averaged across years, were statistically similar among rice receiving 40 to 160 lb K_2O/acre/yr (87 to 93 culms/3-ft row) and were all significantly greater than the culm number for rice receiving no K (74 culms/3-ft row, LSD0.05 = 7). These data clearly indicate that sufficient K nutrition plays an important role in reducing stem rot severity in rice and in either tiller formation or survival.

Short-Term Trial Results

Soil-test K levels were interpreted as 'Very Low' (<61 ppm) at Poinsett08; 'Low' (61-90 ppm) at LHRF07 and Prairie08; and 'Medium' (91-130 ppm) at Lonoke07, Lonoke08, and LHRF08 (Table 1). Previous research indicates that significant rice yield increases from K fertilization usually occur when soil-test K is <100 ppm.

Rice grain yields were affected by the significant K-application time by fungicide rate (P=0.0118) interaction and the main effects of K rate (P=0.0060) and site-year (P<0.0001). Rice grain yield, averaged across all K and fungicide treatments, was, in decreasing order, 207 bu/acre for Lonoke07, 180 bu/acre for Lonoke08, 177 bu/acre for Prairie08, 172 bu/acre for Poinsett08, and 126 bu/acre for LHRF07 and LHRF08 (LSD0.05 = 7). Grain yield increased as K rate increased, averaged across site-years, K application times and fungicide rates. Grain yields were lowest for 0 lb K_2O/acre (154 bu/acre, LSD0.05 = 3), intermediate for 60 lb K_2O/acre (166 bu/acre), and greatest for 120 lb K_2O/acre (177 bu/acre).

The significant K application time by fungicide rate interaction, averaged across site-years and K rates, showed application of K at preflood and panicle differentiation with fungicide produced the greatest grain yields (Table 3). When no fungicide was applied, application of K preflood produced the greatest rice yields. Yields of rice receiving mideason and late boot K applications were intermediate, but greater than yields of rice that received no K. Regardless of fungicide application rate, yield results showed rice grain yields can be increased significantly by mid- and late-season K applications. Within each K application time, application of fungicide significantly increased grain yield. The greatest yield benefit from fungicide application was for rice that received no K or K at midseason and the least yield benefit was for rice receiving K preflood or at late boot. Application of no K with fungicide produced yields that were similar to rice that received no fungicide and K applied preflood. These yield data suggest that yield loss from K deficiency is affected by the essential functions K performs in plant nutrition as well as from increased disease pressure. When K was supplied early in the growing season, disease was minimized and yield potential was maximized. However, rice yields were maximized only when K and fungicide were applied together.

Stem rot index was affected significantly by only the main effects of site-year (P<0.0001), K-fertilizer rate (P=0.0009), and fungicide rate (P<0.0001). Averaged across all K and fungicide treatments, stem rot index rating was, in decreasing numerical order, 2.08 at Poinsett08, 2.07 at LHRF08, 1.98 Prairie08, 1.86 Moery08, 1.82 at LHRF07, and 1.50 at Moery07 (LSD0.05 = 0.11). Although the two site-years having the greatest stem rot index also had the lowest soil-test K (Table 1), the overall severity of stem rot did not appear to follow any specific order relating to soil-test K. This is not surprising since other factors like N fertilization, stand density, and climatic conditions may interact with soil K availability to influence the incidence and severity of stem rot and other rice diseases.

The severity of stem rot decreased with each increase in K-fertilizer rate, averaged across K-application times, fungicide rates, and site-years. Stem rot was most severe in rice receiving no K (stem rot index rating =2.03, LSD0.05 = 0.06), intermediate for 60 lb K_2O/acre (1.87) and least severe for 120 lb K_2O/acre (1.76). Application of Quadris fungicide significantly reduced stem rot index from 2.09 for rice receiving no fungicide to 1.68 (LSD0.05 = 0.05) for rice receiving 12.8 oz/acre suggesting a timely application of Quadris is an effective tool in suppressing stem rot. Although K application time was not significant (P=0.22616) results do show a trend for stem rot index to increase as K fertilization was delayed (1.77 preflood, 1.82 midseason, 1.85 late boot, and 2.03 for no K).

SIGNIFICANCE OF FINDINGS

Results from all K-fertilization trials suggests that K plays an important role in suppression of stem rot. These trials were implemented to examine how K rate influences rice yield and stem rot and did not account for the possibility that chloride (Cl), a component of muriate of potash fertilizer, may also play a role in disease suppression. However, we assume that the yield and stem rot benefits measured in these trials are from K and not Cl, because irrigation water in eastern Arkansas supplies ample amounts of Cl that sometimes causes Cl toxicity problems in rice and soybean. Long-term mismanagement of K leads to more severe stem rot and lower rice yield potential. Short-term trials showed that suppressing or controlling stem rot, and perhaps other diseases, via fungicide application and/or sufficient K fertilization can increase yields of rice grown on soils having very low to medium soil-test K levels. To maximize the economic benefits of K fertilization, K fertilizer should be applied preplant or preflood. When K fertilizer is applied early in the season the potential need for fungicide may be reduced. Results also indicate that mid- and late-season K fertilizer application can increase rice yields, but yield potential declines as K application time is delayed.

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Table 1. Selected soil chemical characteristics (0- to 4-in. depth) of sites used to evaluate rice response K fertilization on silt loam soils in 2006 (06), 2007 (07), and 2008 (08).

	Soil	Mehlich-3-extractable soil nutrient concentrations[y]						
Site	pH[z]	P	K	Ca	Mg	Fe	Mn	Zn
		(ppm)						
Phosphorus trials								
PTBS06	7.7	24	65	1798	335	357	108	3.3
PTBS08	7.8	26	87	2131	383	322	114	5.6
Potassium Application Rate and Time and Fungicide Rate Trials								
Lonoke07	6.1	12	96	2276	343	528	239	1.7
Lonoke08	6.5	6	104	2172	341	325	81	1.0
LHRF07	7.1	8	81	874	211	179	188	2.4
LHRF08	6.8	9	103	1095	231	274	174	3.3
Prairie08	5.7	6	78	1179	164	249	183	0.6
Poinsett08	5.7	11	56	652	125	312	28	6.7

[z] Soil pH measured in a 1:2 soil:water mixture.

[y] All values are the mean of six or more composite samples taken from the 0- to 4-in. depth.

Table 2. Rice grain yield as affected by the annual K rate by year interaction for years 2006 and 2008 of a long-term K fertilization trial established at the Pine Tree Branch Station in 2000.

Annual	Rice grain yield		Stem rot index	
K rate	2006	2008	2006	2008
(lb K_2O/acre)	---------(bu/acre) --------		------ [rating (1-5)[z]]------	
0	157	120	3.73	2.80
40	177	171	3.44	2.49
80	180	183	2.96	2.13
120	181	193	2.24	2.00
160	187	207	2.22	1.79
LSD0.05[y]	11.9		0.21	
LSD0.05[x]	12.9		0.21	

[z] Stem rot index rating scale of 1-5 where 1 = a healthy culm and 5 = a dead culm.
[y] To compare the same K rate between years.
[x] To compare among K rates within a year.

Table 3. Rice grain yield as affected by the K application time by fungicide rate interaction, averaged across K rates and site-years, for six trials planted to Wells rice in 2007 and 2008.

	Fungicide (Quadris) rate	
K application time	0 oz	12.8 oz
	---------------- (bu/acre)------------------	
None	145	162
Preflood	166	176
Midseason	161	180
Late boot	159	169
LSD0.05	-------------------- 4.5---------------------	

Estimating Rice Optimal Harvest Moisture Content Using Individual Kernel Moisture Content Distributions at Harvest

R.C. Bautista and T.J. Siebenmorgen

ABSTRACT

This study quantified the effects of rice individual kernel moisture content distributions on milling quality as harvest moisture content (HMC) varied. Multiple samples of various rice cultivars were collected in 1999, 2000, 2004, 2005, and 2006 at various locations in Arkansas, Mississippi, and Missouri. Individual kernel moisture contents (MC) from five panicles were measured immediately after each harvest. The percentages of kernels at MC levels >21, >22, >23, >24, >25, and >26% (representing high MC, immature kernels) and at MCs <12, <13, <14, <15, <16, and <17% (representing low MC, often fissured kernels) were quantified at various bulk harvest MCs. Head rice yield reduction (HRYR) increased with increased percentages of both high and low MC kernels. Among low MC levels, the percentage of kernels at MCs less than 14% had the strongest correlation to HRYR (R^2=0.72) and fissured kernel percentage (R^2=0.76); whereas, among high MC levels, the percentage of kernels at MCs greater than 22% correlated most strongly with HRYR (R^2=0.61). Optimal HMCs were determined using quadratic equations derived from the percentages of kernels at MCs >22% and <14%. Based on this analysis, optimal HMCs for long-grain cultivars ranged from 18.2 to 21.6%, for medium-grain 'Bengal' from 19.0 to 20.4%, and for long-grain hybrid 'XL723' from 17.7 to 19.0%.

INTRODUCTION

Head rice yield (HRY), defined as the mass percentage of rough rice that remains as head rice (milled kernels that are at least three-fourths of the original kernel length after complete milling, USDA, 2005), is the most commonly used indicator of rice milling quality. Head rice yields are particularly affected by the individual kernel MC distributions at harvest. Because there is a premium for head rice relative to brokens, HRY, and thus rice kernel MC, is a direct determinant of economic return.

Significant losses in HRY can be incurred when long-grain rice in Arkansas is harvested at HMCs less than 15% or greater than 22% MC (Lu and Siebenmorgen, 1995). Above 22% MC, there is a large percentage of immature kernels. These high MC kernels are thinner, mechanically weaker, and thus prone to breakage during milling. Below 15% HMC, there is a proliferation of kernel fissuring that is normally caused by rapid moisture adsorption by low MC kernels in the field due to rainfall or exposure to high air relative humidity. The longer rice at low HMCs is left in the field, the greater the probability that the lower MC kernels will fissure before harvest (Chau and Kunze, 1982). With the large variation in kernel MCs within and among panicles at harvest, especially at HMCs below 16%, there are increasing numbers of kernels that have reached critically low MCs where fissures are apt to develop due to rapid moisture adsorption as bulk average harvest MC declines. However, there are also kernels within panicles that are immature (high MCs), which can cause HRYR; immature kernels are weak and tend to break during milling. It is important to determine the relationships between low MC kernels (kernels that are likely to have fissured) and high MC kernels (kernels that are likely immature) and milling quality across harvest MCs as a means of fundamentally estimating optimal HMCs.

A consideration in determining optimal HMC is that rice kernels mature asynchronously on the plant and within a single rice panicle. Therefore, the bulk MC is only an average of the individual kernel MCs constituting bulk rice from the field. Studies have shown individual kernel MCs can vary by as little as 10 percentage points (pp) (McDonald, 1967) to as much as 46 pp (Chau and Kunze, 1982) between kernels from the bottom of the least mature panicle to the top of the most mature panicle at harvest.

Siebenmorgen et al. (2007) reported that HRY is a quadratic function of harvest MC, which implies that there exists an optimal HMC to maximize HRY. The optimal harvest MC differs depending on cultivar and growing location. Siebenmorgen et al. (2007) reported that in Arkansas, Mississippi, and Missouri, optimal harvest MCs for long-grains ‘Cypress’ and ‘Drew’ were 18.7 to 23.5%[1] and for medium-grain Bengal, 21.5 to 24.0%.

The objective of this study was to quantify the effects of individual kernel MC distributions, as indicators of the percentage of fissured and immature kernels, on milling quality across HMCs from approximately 26% to 12% for cultivars produced in the US mid-South rice-production region. The study estimated the optimal HMC based on the percentages of high- and low-MC kernels above and below selected MC levels, respectively.

[1] All moisture contents have been expressed on a wet basis.

MATERIALS AND METHODS

Panicles of Bengal (medium-grain); ‘Cheniere’, ‘Cocodrie’, Cypress, Drew, ‘Francis’, ‘Wells’, and XL723 (long-grains) rice cultivars were hand-harvested from various locations in Arkansas, Mississippi, and Missouri at HMCs that ranged from 12 to 26% during the autumns of 1999, 2000, 2004, 2005, and 2006. Table 1 summarizes the HMCs of samples collected. Each sample lot comprised approximately 200 panicles, which yielded at least 2 kg of rough rice. Immediately after harvest, five panicles were randomly selected from each 200-panicle lot for individual kernel MC measurements. Kernels were stripped manually by hand and MCs of 300 kernels were measured using a single kernel moisture meter (CTR 800E, Shizuoka Seiki, Shizuoka, Japan). Fissured kernels were enumerated using 200 randomly selected and manually dehulled kernels from five panicles from each sample lot. Brown rice was inspected with a magnifying glass for fissures using a light box. The fissured kernel percentage was calculated as the number percentage of the 200 kernels that were fissured. The remaining 190 panicles were hand-threshed in 1999 and 2000, and mechanically-threshed (SBT, Almaco, Nevada, Iowa) in 2004, 2005, and 2006. Rough rice kernels were dried to approximately 12% MC in a chamber maintained at 21°C and 56% relative humidity for milling analysis.

Calculation of Head Rice Yield Reduction

The effects of high- and low-MC kernels on milling quality were determined using HRYR. Head rice yield reduction for each lot was calculated using the method of Siebenmorgen et al. (2007):

$$HRYR_n = HRY_{peak} - HRY_n \quad (1)$$

where: $HRYR_n$ is the HRY reduction for a rice lot, percentage points; HRY_{peak} is the greatest HRY for a rice lot set (Table 1), %; and HRY_n is the HRY of a given rice lot, %.

Determination of Critical Moisture Content Levels

The percentages of kernels with MCs <12, <13, <14, <15, <16, and <17% within a rice lot were used to serve as indicators of the percentage of fissured kernels that could potentially reduce HRY. The percentages of kernels with MCs >21, >22, >23, >24, >25, and >26% within a rice lot were used to indicate the percentage of immature kernels within that lot that could potentially reduce HRY. The percentages of kernels at these different low and high MC levels were calculated from the individual kernel MC distribution data obtained from each sample lot harvested at different MCs. The computed percentages of kernels less than the various low MC levels of all rice lots were correlated to the percentages of fissured kernels and to the HRYRs for those lots. The percentages of kernels at the various high MC levels were correlated to the HRYR for all rice lots. All correlation analyses were performed using JMP®, version 7.0.1.

Optimal HMC Calculations Based on Individual Kernel MC Distributions

To estimate the optimal HMC for each year/location/cultivar lot, individual kernel MC distributions were utilized as predictors of milling performance. Optimal HMC was calculated for each lot set using quadratic equations generated by plotting the percentages of kernels >22% MC and <14% MC across lot HMCs. The selection of these two MC levels was based on the results of the correlation analysis of the percentage of kernels at high and low MC levels and HRYR. The <14% MC level was most highly correlated to both HRYR and the percentage of fissured kernels (in the case of the low MC levels), and the >22% MC level was most highly correlated to HRYR (in the case of the high MC levels). Using the two equations for each rice lot set, the sums of percentages of kernels >22% and <14% MCs were calculated across HMC. The optimal HMC for each sample lot set was determined as the HMC at which the summed percentage was minimum.

RESULTS AND DISCUSSION

Figure 1 shows how HRYR varied across HMC for all lots indicated in Table 1. Head rice yield reduction generally increased as HMC decreased below 20% and also as HMC increased above approximately 22%. Such HRYR can be attributed to the individual kernel MCs in either the low- or high-MC range of the MC distributions.

Relationship of the Percentages of High MC Kernels to HRYR

Head rice yield reduction increased above 22% HMC, most likely due to the increased percentage of immature kernels present in the rice bulk. Unlike sound kernels, immature kernels, which are thin and mechanically weaker, tend to break when milled, causing reduction in HRY. Multiple regression analysis showed that the percentage of kernels in a rice bulk that were >22% MC was most highly correlated to HRYR (R^2=0.61) compared to the percentages of kernels >21 (R^2=0.56), >23(R^2=0.58), >24(R^2=0.57), >25 (R^2=0.58), and >26% (R^2=0.54) MC. This result suggests that the percentage of kernels with MCs >22% in the bulk rice corresponds to the percentage of immature kernels, which in turn would cause HRY reduction. This also suggests that the percentage of kernels >22% MC could be used as a potential gage for relating HRYR to HMC.

Relationship of the Percentages of Low MC Kernels to HRYR

Head rice yield reduction increased as the percentage of low MC kernels increase. Critically low MC kernels are susceptible to moisture adsorption when placed in rewetting conditions, which causes kernel fissuring. Fissured kernels usually break during milling, thus increasing HRYR. Multiple regression analysis showed that the percentage of kernels <14% MC was most highly correlated to the percentage of HRYR with an R^2=0.72 (SEE=0.0138 and P=<0.0001.

Relationship Between Head Rice Yield, Fissured Kernels, and Harvest Moisture Content

Figure 2 shows how the percentage of fissured kernels increased with decreased HMC for cultivars Cheniere, Francis, Wells, and XL723 in 2005 from different locations. This result indicates increasing kernel propensity to fissuring by critically low MC kernels caused by rapid moisture adsorption in the field due to rainfall or exposure to high air relative humidity. The increased percentage of fissured kernels caused significant reduction in HRY (P=<0.0001). Multivariate regression analysis showed that among low MC kernel percentages, the percentage of kernels <14% MC was most highly correlated to the percentage of fissured kernels with an R^2=0.76 (SEE=0.0343 and P=<0.0001). Since the percentage of kernels at <14% MC was shown to have the greatest correlation to both the fissured kernels percentage and HRYR, the <14% MC level was chosen as a basis for optimal HMC calculations as discussed below.

Optimal HMC Determination Based on the Percentages of Kernels at MCs > 22% and <14%

Figure 3 illustrates how the percentages of kernels at MCs >22% and <14% are correlated with HRY across HMC for lots harvested in 2005. Generally, HRY peaked at 18 to 22% HMC and decreased as the percentages of kernels >22 and <14% MC increased. Similar results were observed for the 1999, 2000, 2004, and 2006 lot samples (data not shown).

An approach to determine the optimal harvest MC was applied by using the percentages of high- (>22%) and low- (<14%) MC kernels in rice lots across HMC. The percentages of high- (>22%) and low- (<14%) MC kernels vs. HMC (Fig. 3) were described using quadratic functions:

$$\text{Kernels at >22\% MC} = a_i \cdot HMC^2 + b_i \cdot HMC + c_i \text{ (>22\% MC curve)} \quad (2)$$

$$\text{Kernels at <14\% MC} = a_i \cdot HMC^2 + b_i \cdot HMC + c_i \text{ (<14\% MC curve)} \quad (3)$$

where: HMC is expressed as % web basis (w.b.) and kernels >22% and <14% MC in %; a_i, b_i, and c_i are regression variables; subscript *i* refers to the year/location/cultivar lot sets of Table 1.

The coefficients of determination obtained from the Eq. 2 and 3 regression analyses generally described well the trends in the percentages of kernels at >22% and at <14% MC against HMC with R^2 values being greater than or equal to 0.90. From Eq. 2 and 3, the sum percentages of kernels at >22% and <14% MC were calculated across HMCs for each lot set shown in Table 1. Figure 3 shows the summed percentage of these kernels for 2005 sample lots from Stuttgart and Keiser. The goal was to determine the HMC at which this sum was minimum, with the hypothesis being that this would indicate the maximum HRY and corresponding optimal HMC. Optimal HMCs determined using this technique are shown in Table 1.

The results showed that the optimal HMCs obtained using the above procedure were generally lower than the optimal HMCs as determined by Siebenmorgen et al. (2007) shown in Table 1. One of the reasons for the lower optimal HMCs obtained using this technique is the manner by which the minimum sum percentage of kernels at low and high MC levels was based. In this study the optimum HMC was based on the minimum sum percentage of kernels at threshold levels of <14% and high >22% MC. The HMC corresponding to the minimum sum percentage of kernels could vary with different combinations of low- and high- MC threshold levels. These threshold levels could vary slightly with cultivar and location since those independent variables were found to significantly affect fissured kernels percentage at given HMCs.

Another possible reason for the slight discrepancies in optimal HMCs between Siebenmorgen et al. (2007) and the technique applied in this study is that the approach to determine optimal HMCs by Siebenmorgen et al. (2007) was to first model HRY versus HMC using a quadratic function, then determine optimal HMC as the MC at which this quadratic function peaked for each lot set. While the HRY versus HMC functions generally described HRY versus HMC trends well, the trends were not completely characterized by a quadratic function, particularly for high HMCs. This lack of complete fit at high HMCs would generally have caused HRYs to peak at HMCs slightly greater than the true optimal.

In summary, using the minimum summed percentage of kernels with MCs <14% and >22%, the optimal HMCs for long-grain cultivars generally ranged from 18.2 to 21.6%, 19.0 to 20.4% for the medium-grain cultivar Bengal, and 17.7 to 19.0% for the hybrid XL723.

SIGNIFICANCE OF FINDINGS

This study showed how rice individual kernel harvest MC distributions affect milling quality. Using the percentages of low- (representing fissured kernels) and high- (representing immature kernels) MC kernels and their correlation to HRYR and fissured kernels, optimal harvest MCs were determined for various medium- and long-grain cultivars. Using the minimum summed percentage of kernels with MCs <14% and >22%, the optimal HMCs for long-grain cultivars generally ranged from 18.2 to 21.6%, 19.0 to 20.4% for the medium-grain cultivar Bengal, and 17.7 to 19.0% for the hybrid XL723.

ACKNOWLEDGMENTS

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Table 1. Summary of information for rice lots harvested in 1999, 2000, 2004, 2005, and 2006. Peak head rice yields (HRYs) and the corresponding optimal HMCs (column six), were taken from Siebenmorgen et al. (2007). Optimal harvest MCs in column seven were obtained using the summed percentages of kernels >22% and <14% MC for each lot.

Year	Cultivar	Location	No. of HMCs; HMC Range	Peak HRY	Optimal HMC[z]	Optimal HMC
			(% w.b.)	(%)	------- (% w.b.)	-------
1999	Bengal	Stuttgart, Ark.	6; 12.4 - 22.4	66.3	23.7	20.2
		Keiser, Ark.	6; 14.0 – 24.0	68.5	23.8	20.3
	Cypress	Stuttgart, Ark.	6; 13.2 - 22.3	66.5	22.1	20.0
		Keiser, Ark.	6; 12.8 – 22.0	69.7	19.3	21.6
	Drew	Stuttgart, Ark.	7; 12.2 – 23.1	69.0	23.5	20.4
		Keiser, Ark.	7; 12.9 – 23.4	70.6	21.0	20.6
2000	Bengal	Stuttgart, Ark.	7; 12.2 – 23.6	69.9	23.0	19.0
		Keiser, Ark.	7; 13.1 – 24.0	68.7	21.5	19.3
	Cypress	Stuttgart, Ark.	5; 13.7 – 21.6	65.4	21.1	19.5
	Drew	Stuttgart, Ark.	5; 14.5 – 24.4	67.1	21.6	19.9
		Keiser, Ark.	5; 13.9 – 23.7	69.4	20.3	19.8
2004	Bengal	Brinkley, Ark.	5; 15.9 – 26.5	--[y]	--[y]	--[y]
	Bengal	Lodge Corner, Ark.	4; 11.6 – 23.0	67.5	22.4	20.4
	Cocodrie	Essex, Mo.	4; 13.5 – 23.9	67.5	19.3	20.2
	Cocodrie	Newport, Ark.	3; 14.9 – 24.4	--[y]	--[y]	--[y]
	Wells	Hunter, Ark.	3; 15.2 - 25.7	67.5	21.3	21.1
2005	Cheniere	Osceola, Ark.	5; 14.4 – 23.2	66.1	18.8	18.2
	Francis	Stuttgart, Ark.	5; 15.5 – 24.4	66.1	18.7	18.6
	Wells	Qulin, Mo.	5; 15.4 – 23.7	64.5	19.9	19.5
	XL723	Stuttgart, Ark.	6; 14.7 – 20.0	65.2	19.6	18.6
	XL723	Cleveland, Miss.	5; 12.0 – 23.5	63.8	19.5	17.7
2006	Wells	Stuttgart, Ark.	7: 12.0 - 26.9	65.6	21.2	20.4
	XL723	Shaw, Miss.	4; 14.2 – 24.7	66.4	20.4	17.4
	XL723	Stuttgart, Ark.	6; 12.1 – 26.5	66.2	20.1	19.0
	Cheniere	Des Arc, Ark.	5; 14.7 – 24.1	65.3	18.7	18.6

[z] Optimal HMC corresponds to the peak head rice yield calculated using a quadratic function relating HRY to HMC (Siebenmorgen et al., 2007).

[y] Head rice yields were not statistically related to harvest moisture content.

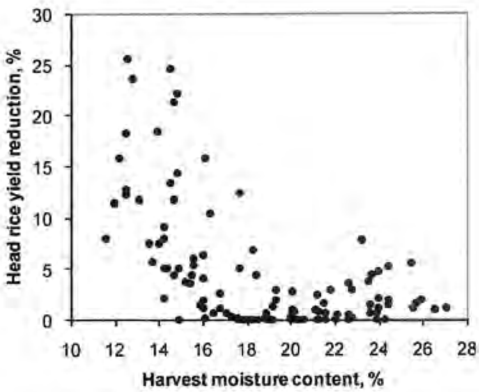

Fig. 1. Head rice yield reduction (HRYR) (Eq. 1) versus harvest moisture content for all rice lots indicated in Table 1. Each data point represents the average HRYR of two milling repetitions for each lot.

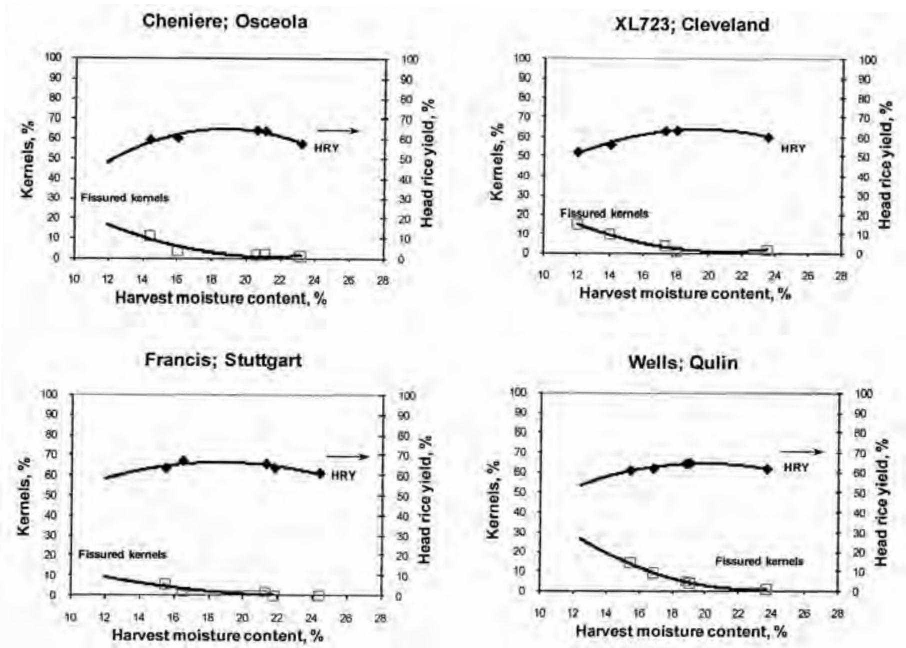

Fig. 2. Relationships of percentages of fissured kernels and head rice yield (HRY) to harvest moisture content for the indicated cultivars in 2005 (Table 1). Each point in the fissured kernel curves represents the percentage of fissured kernels in 200 brown rice kernels. Each HRY data point represents the average of two milling repetitions for each lot.

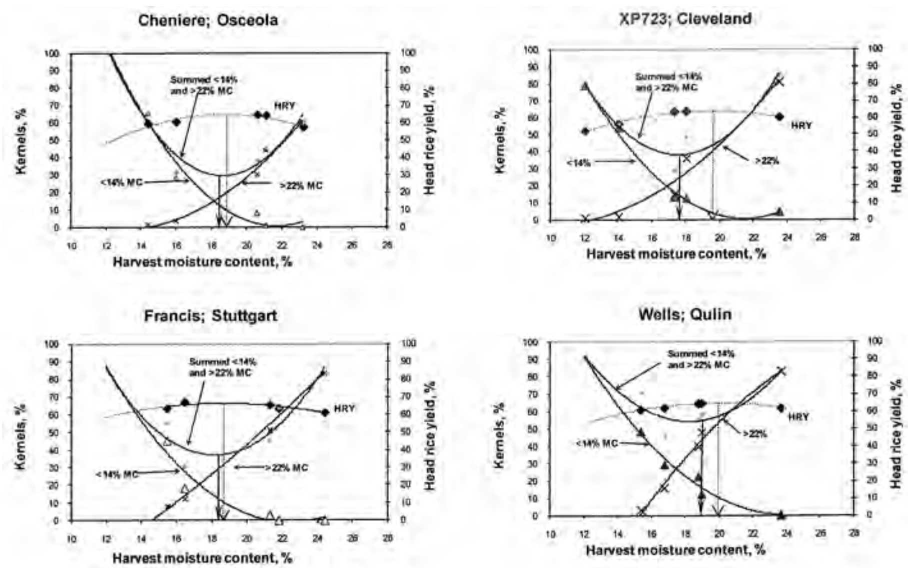

Fig. 3. Relationships of percentages of kernels at moisture contents (MCs) <14% and >22%, the summed percentages of kernels <14% and >22% MCs, and head rice yields (HRYs) to harvest MCs for lots harvested in 2005 (Table 1). Each data point in the MC curves represents the average of 300 kernel MCs from five panicles. Each HRY data point represents the average of two milling repetitions. The optimal harvest MCs obtained for each cultivar using the minimum summed percentage of kernels with <14% and >22% MCs are indicated by a solid arrow. Optimal harvest MCs obtained by Siebenmorgen et al. (2007) are indicated by a dashed arrow.

A Comparison of Laboratory-Milled to Commercially-Milled Rice

A.M. Graves, T.J. Siebenmorgen, and M.I. Saleh

ABSTRACT

The degree of similarity between rice milled in a McGill #2 laboratory mill and in commercial milling processes was evaluated using eight physicochemical and end-use properties. Twenty-nine rough rice, and accompanying milled rice, samples were collected from commercial rice mills in Arkansas, California, Louisiana, Mississippi, and Missouri. The rough rice samples were milled to the same degree of milling (DOM) as the corresponding commercially-milled (CM) sample. There was no statistical difference between rice milled in the two systems with respect to color parameters L^* and a^*, final viscosity, texture, and end-use cooking properties ($\alpha = 0.05$). Overall, the kernel dimensions of length, width, and thickness were less in the laboratory-milled (LM) rice than the same rice milled commercially. The incidence of bran streaks and peak viscosity values were each greater when rice was milled commercially in twenty-seven, and twenty-eight, respectively, of the 29 samples by means comparison. As the DOM increased and surface lipid content (SLC) decreased, L^* increased, and a^*, b^*, and the incidence of bran streaks decreased for both milling systems.

INTRODUCTION

Results from research using laboratory mills are often questioned due to the lack of evidence that laboratory mills adequately represent commercial milling processes. The objective of this study was to quantify the degree of similarity between commercially-milled (CM) and McGill #2 laboratory-milled rice across a range of physicochemical properties.

METHODS AND MATERIALS

Twenty-nine samples, comprising two medium-grain samples and 27 long-grain samples, with each sample comprising rough and milled rice sub-samples, were gathered from four rice processors, totaling seven commercial milling sites in Arkansas (3), California (1), Louisiana (1), Mississippi (1), and Missouri (1). Collection of the milled rice sub-samples was timed to match the milling completion of the respectively-collected rough rice sub-samples (Fig. 1). Samples were collected over a five-month period from 20 June 2006 to 4 October 2006, during which rice from the 2005 growing season was being milled. Once collected, the samples were stored at 4°C for 5 to 12 months prior to testing.

Because the SLC, as a quantifiable measurement of DOM, affects physicochemical and end-use properties, it was necessary to mill samples in the McGill #2 laboratory mill to the same SLC values as those of the CM samples. To match the SLC of the LM samples to the CM rice samples, milling curves were produced for each of the 29 rough rice sub-samples using a laboratory mill as described by Cooper and Siebenmorgen (2007).

Duplicate 150-g rough rice samples were dehulled in a laboratory huller (THU-35, Satake, Hiroshima, Japan). The resulting brown rice was milled with a laboratory mill (RAPSCO, Brookshire, Texas) for a duration that produced the same SLC as the respective CM sample. The samples were separated into head rice and broken rice using a shaker table. Approximately 100 g of each CM rice sample was separated into head rice and broken rice in the same manner. The head rice masses of the CM and LM samples were expressed, and subsequently compared, as a percentage of the milled rice mass, not the rough rice mass, because the exact mass of the corresponding rough rice from the CM sub-sample was unknown. Milled rice SLC values were determined using the method developed by Matsler and Siebenmorgen (2005). The SLC was the mass of extractable lipids expressed as a percentage of the original 5-g head rice sample.

Color was quantified using a color meter (ColorFlex, Hunter Associates Laboratory, Reston, Va.) which utilizes the International Commission on Illumination (CIE) L^* a^* b^* system. A color reading was taken and then the sample was rotated, approximately 120° in order to obtain two color readings for every 50 g. The length, width, and thickness of 200 head rice kernels from each duplicate of the CM and LM samples were taken using an image analyzer [Rice Image Analyzer (RIA 1A), Satake Corp., Hiroshima, Japan]. The number of bran streaks was quantified, using the method of Bhattacharya and Sowbhagya (1976), by staining 100 head rice kernels from each duplicate of CM and LM samples in a 3:1 mixture of ethyl alcohol to 2% potassium hydroxide. A kernel was counted as having a bran streak when 50% or more of the bran was present on the dorsal rim of the kernel.

Peak and final viscosities were taken with a viscometer (RVA-4 Rapid Visco Analyzer, Foss North America, Eden Prairie, Minn.) as described in Perdon et al. (2001). The methods for measuring the textural analysis traits of firmness and stickiness were those used by Saleh and Meullenet (2007). Water uptake and volumetric change, both calculated on a wet-weight basis, were determined by cooking 5 g of head rice in excess water for 20 min.

RESULTS AND DISCUSSION

Surface lipid contents ranged from 0.23 to 0.93 (average 0.43) percent for the CM rice and 0.15 to 0.85 (average 0.42) percent for the LM samples. The difference in mean SLC between paired CM and LM samples ranged from -0.140 to 0.086 (average 0.015) percentage points.

The mean head rice percentage, averaged across the 29 lots, was statistically different between the CM and LM samples. The CM rice samples and the LM samples had mean head rice percentages of 86.8%, and 80.2%, respectively (Fig. 2). The magnitude of the difference in head rice percentages between the CM and LM samples was associated with the rice processor. Two of the four rice processors contributed CM rice sub-samples that were 8.8 to 19.0 percentage points greater than the rough rice sub-sample milled in the McGill #2 laboratory mill. The CM rice sub-samples contributed by the other two processors ranged from 6.3 percentage points more to 4.6 percentage points less head rice percentage than the McGill #2 laboratory-milled counterpart.

Color parameters were not statistically different between the CM and LM samples within the *L** and *a** values, but were different for *b** values (Fig. 3). The CM samples had mean *L* a* b** values of 72.8, 0.25, and 16.0, respectively. The LM samples had mean *L* a* b** values of 73.3, 0.24, and 15.8, respectively. The *L** values linearly increased as the milling duration increased and the SLC correspondingly decreased for both milling systems (Fig. 3). Concurrently, the *a** and *b** values linearly decreased as milling duration increased in both systems (Fig. 3). The rates of linear decrease of *L**, and increase of *a** and *b**, with SLC were not statistically different between the CM and LM rice samples. For both milling systems, SLC explained 77, 78, and 66 percent of the variation in *L*, a*,* and *b**, respectively.

Overall, the CM rice samples were of statistically equal or greater size, by length, width, and thickness, than those milled in the McGill #2 laboratory mill (Fig. 4), based on a means comparison of each of the 29 samples. The mean length of the 27 long-grain samples was 6.5 mm for the CM rice, and 6.4 mm for the LM samples. The mean width and thickness of the 27 long-grain samples was 2.1 mm, and 1.6 mm, respectively, for rice milled in both systems. The mean length, width, and thickness of the two medium-grain samples was 5.9 mm, 2.7 mm, and 1.8 mm, respectively, for rice milled in both systems.

The CM rice samples had a statistically greater number of bran streaks than the LM counterparts in 27 of the 29 samples using a means comparison. The number of bran streaks for the CM samples averaged 12 per 100 kernels, whereas the LM samples averaged 5 per 100 kernels. The incidence of bran streaks increased as the SLC increased for both the CM and LM samples (Fig. 5).

Of the 29 samples, 17 of the CM samples had statistically equal, and 11 had statistically greater peak viscosity values than the corresponding LM sample by means comparison. The difference in peak viscosity is attributed to the different bran removal methods in the two milling systems. Laboratory mills can leave disproportionate amounts of bran and germ at the kernel ends which would decrease the peak viscosity of ground rice. There was no statistical difference in the final viscosities between the CM and LM samples. The CM rice samples had a peak viscosity mean of 220 RVUs and a final viscosity mean of 257 RVUs. The LM samples had a peak viscosity mean of 211 RVUs and a final viscosity mean of 258 RVUs.

There was no statistical difference in the firmness or stickiness between the CM and LM samples. The CM rice samples had a mean firmness value of 95.8 N, whereas the LM samples had a mean of 94.9 N. The mean stickiness was 2.8 N·s for the CM rice samples and 2.9 N·s for the LM rice samples.

The end-use cooking parameters of volumetric expansion and water uptake were not statistically different between the CM and LM samples. The mean volumetric expansion was 316% and 314% for the CM and LM rice, respectively. Water uptake averaged 229% and 231% for CM and LM rice, respectively.

SIGNIFICANCE OF FINDINGS

The results of this study indicate a degree of similarity between rice milled in a McGill #2 laboratory mill and commercial milling processes with respect to color parameters L^* and a^*, kernel thickness, final viscosity, texture, and end-use cooking properties. However, there were differences in head rice percentage, the color parameter b^*, kernel length and thickness, bran streaks, and peak viscosity between rice milled in the two systems. Furthermore, the similarity of the regression analysis of the L^* a^* b^* color parameters between the CM and McGill #2 LM samples extends previous research conducted in a McGill #2 laboratory mill. The aggressive nature of the McGill #2 milling process is evident in the decrease in kernel dimensions and the incidence of bran streaks compared to the CM rice samples.

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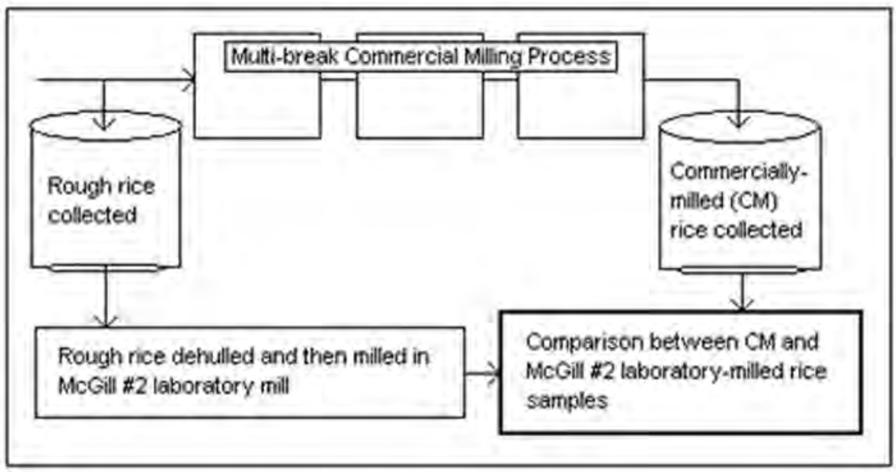


Fig. 1. Sample procurement schematic showing collection and comparison of commercially-milled (CM) and McGill #2 laboratory-milled rice subsamples.

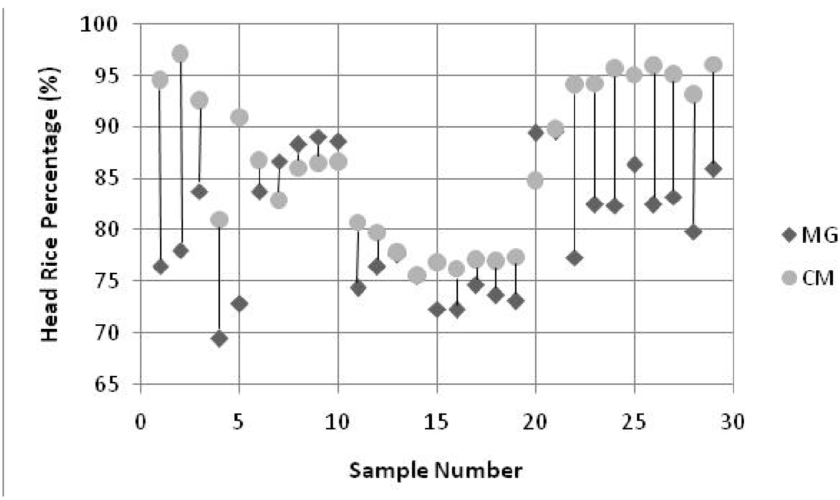
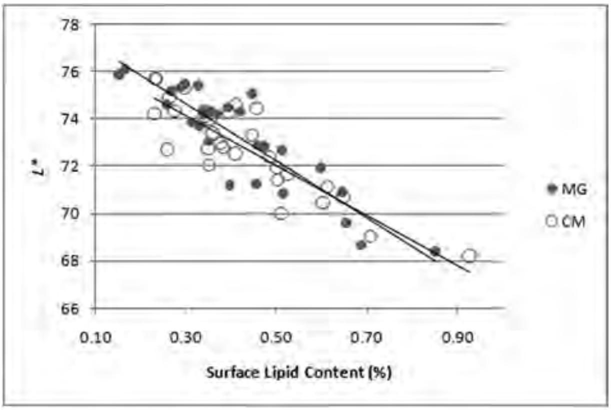
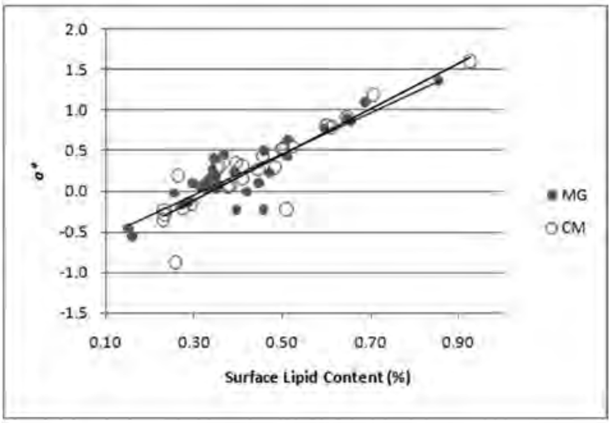


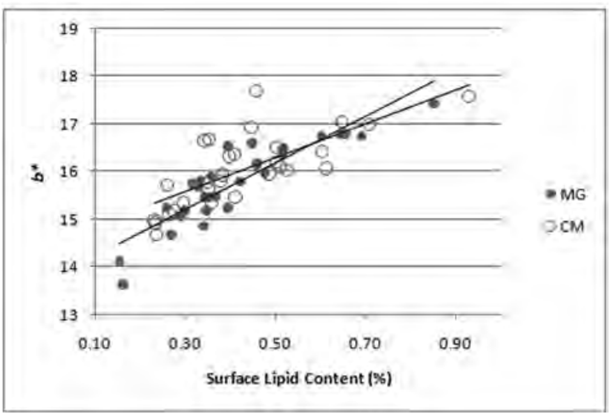
Fig. 2. Graph depicting the mean values of head rice percentage for the commercially-milled (CM) and McGill #2 laboratory-milled (MG) rice samples. Each data point represents the average of two measurements.



(a)

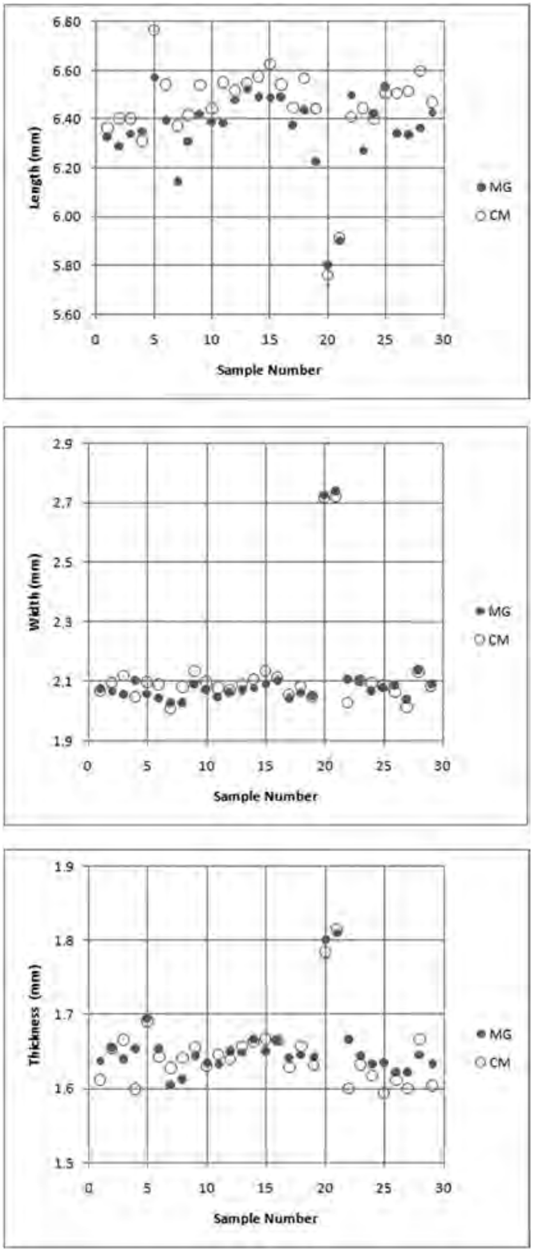


(b)



(c)

Fig. 3. Graphs depicting *L (a), *a** (b), and *b** (c) by surface lipid content for commercially-milled (CM) and McGill #2 laboratory-milled (MG) samples. Each data point represents the average of two measurements.**



(a)

(b)

(c)

Fig. 4. Graphs depicting particle size distributions of length (a), width (b), and thickness (c) by sample number for commercially-milled (CM) and McGill #2 laboratory-milled (MG) samples. Each data point represents the average of two, 200-kernel measurements.

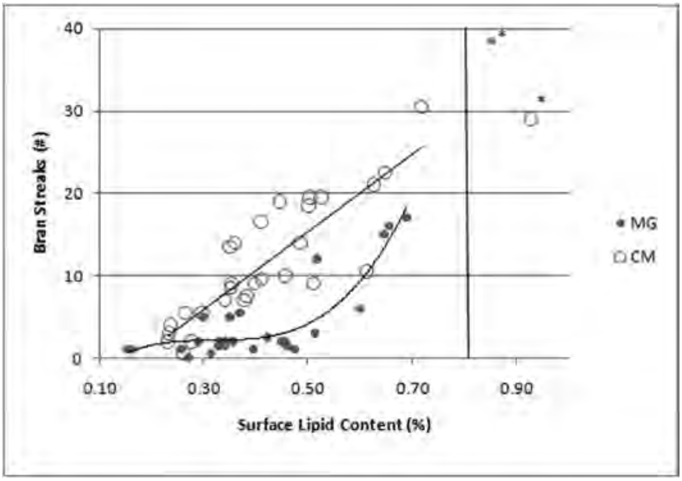


Fig. 5. Graphs depicting the number of bran streaks by sample number (a), and surface lipid content (b) for commercially-milled (CM) and McGill #2 laboratory-milled (MG) samples. Each data point represents the average of two, 100-kernel measurements. *Samples with SLC greater than 0.8 were not used in this analysis.

RICE QUALITY AND PROCESSING

Surface Lipid Content and Color of Individual Milled Rice Kernels Using Near Infrared Reflectance Spectroscopy

M.I. Saleh, J. Rash, and J.-F. Meullenet

ABSTRACT

Twenty-five rice samples including medium- and long-grain cultivars, harvested from locations in Arkansas in 2007 were used in this study. One hundred individual milled rice kernels were scanned using a diode-array-analyzer fitted with single kernel adapter. Partial least squares regression was performed using Unscrambler software to develop prediction models of individual rice surface lipid content (SLC) and color. Measured and predicted kernels SLC and *L**, *a**, and *b** color had coefficient of determinations of 0.86, 0.86, 0.61, and 0.83, respectively. The correspondent root mean square errors of prediction (RMSEP) were 0.06, 0.79, 0.22, and 0.50, respectively. Distributions of SLC and color of individual kernels were further evaluated as indications of milled rice bulk SLC and color. SLC and color of individual kernels were normally distributed around means that are highly correlated with SLC and color of milled rice bulk.

INTRODUCTION

The use of Near Infrared Spectroscopy (NIRS) has been shown to generate accurate and consistent results in determining various characteristics of agricultural crops including apparent amylose content (Wu et al., 2004; Delwiche et al., 1996), amino acids (Wu et al., 2002; Barton et al., 2000), lipids (Wang et al., 2006; Chen et al., 1997), moisture content (Natsuga and Kawamura, 2006) and starch quality parameters (Bao et al., 2001).

The majority of published work for the prediction of rice physicochemical properties using NIRS has aimed at measuring the characteristics of a rice bulk. However, the properties of the individual kernels making up a rice bulk seem to be equally important as being able to estimate the distribution of these properties in indicating a cultivar's uniformity.

Characterization of kernel distributions is relevant to the industry as more uniform rice tends to have superior performance in various processes. For example, Sun and Siebenmorgen (1993) indicated that uniform rice bulk kernels milled more evenly than a rice bulk containing kernels varying greatly in kernel size. Recently, the prediction of bulk milled rice surface lipid content and color parameters using diode array NIRS was reported (Saleh et al., 2008). The authors reported accurate and robust models for predicting rice surface lipids and color parameters as a basis for predicting rice degree of milling. However, measurements were performed on bulk milled rice. This study was undertaken to evaluate models for predicting individual kernels SLC and color parameters using near infrared spectroscopy.

PROCEDURES

Sample Preparation and Milling

Twenty-five milled rice samples including medium- and long-grain rice cultivars namely 'Jupiter' and 'Wells,' respectively, were used in this study. Cultivars were harvested at a moisture content range of 12.2 to 26.8% from locations in Arkansas during the 2007 harvest season. Rice samples were cleaned (Carter-Day Dockage Tester, Carter-Day Co., Minneapolis, Minn.), and dried in a chamber maintained at 21°C and 62% relative humidity, corresponding to a rough rice equilibrium MC of approximately 12.5% (ASAE, 1994).

Duplicate rough rice aliquots (150 g) from each sample were dehulled in a laboratory sheller (Type THU, Satake, Tokyo, Japan) and subsequently milled for 30 sec in a laboratory mill (McGill No. 2, RAPSCO, Brookshire, Texas). Excess bran and endosperm were removed from milled rice using an aspirator (Grain Blower, Seedburo Equipment Co, Chicago, Ill.). Head rice was then separated from brokens with a sizing device (Seedburo Equipment Co., Chicago, Ill.).

Milled Rice SLC, Color, and Spectroscopic Measurements

Bulk head rice SLC and color were predicted according to Saleh et al. (2008) using a diode array analyzer (DA 7200, Perten instruments, SE-141 05 Huddinge, Sweden).

Single rice kernel scans were performed using DA 7200 diode array analyzer fitted with a single kernel adapter. One-hundred individual rice kernels from each sample were randomly selected and scanned by placing each kernel within 2 mm of the center of the adaptor. Absorbance readings at 5 nm wavelength increments were collected over a near-infrared wavelength range of 950 to 1650 nm. A total of 2500 scans were collected for predicting milled rice SLC and color parameters.

Calibration Model Development

Absorbance reading of individual kernels collected in the wavelength range of 950 to 1650 nm were averaged across cultivars and used to develop models for predicting milled rice SLC and color parameters. Absorbance values were standardized so that all variables were given equal influence on the predicted variables. Using a multivariate regression software (Unscrambler, version 9.2, CAMO, Oslo, Norway), Partial Least Squares Regressions was performed to develop prediction models for milled rice SLC and L^*, a^*, and b^*.

Full cross validation was employed to validate the predictive ability of the calibration models. In this approach, each sample was used to test the model derived from all other samples. The deviation from the expected value, as a result of excluding each sample from the models was measured. This process was repeated so that each sample was excluded once, to test if its removal had seriously affected the model. A root-mean square error of cross validation was then calculated (RMSEP). The uncertainty test was also performed during the full cross validation computation to assess the stability of the predictions and the usefulness of the model.

These procedures allowed for the removal of predictive variables that either did not influence the prediction or created interference in the model. This technique has also been reported to reduce the uncertainty in the prediction models and, in most cases, improves the validation statistics. Calibrated and validated coefficient of determinations (R^2) and RMSE values were obtained to evaluate each calibration model. Absorbance values were treated using the first derivatives to eliminate noise generated at the extremes of the wavelength scans. Individual rice kernels SLC and color were then predicted using calibrated models.

RESULTS AND DISCUSSIONS

SLC and L^*, a^*, and b^* Calibration Models

Figure 1 shows scatter plots of measured and predicted SLC and color parameter of milled rice samples used to develop the calibration models. Model statistics of the PLS regression developed using NIR scans of milled rice samples are shown in Table 1. SLC, L^*, a^*, and b^* of milled rice samples ranged from 0.36 to 0.65%, 73.3 to 77.1, -1.13 to -0.33, and 14.0 to 16.0, respectively.

Models for predicting SLC had a calibrated correlation (R_c) of 0.93 and corresponding RMSEC and RMSEP of 0.03 and 0.06, respectively. Results indicate the suitability of the model developed for predicting milled rice SLC. Models for predicting milled rice color also provided accurate predictions having predicted and measured L^*, a^*, and b^* coefficients of determinations of 0.86, 0.61, and 0.83 and corresponding RMSEC of 0.40, 0.13, and 0.29, respectively.

Distributions of SLC and color of individual kernels predicted using the calibration models were further evaluated as indications of milled rice bulk SLC and color. Figure 2 shows the distribution of SLC of 100-individual kernels scanned using the DA

7200 diode array analyzer fitted with single kernel adapter. Measured bulk SLC and the average SLC of 100-individual milled rice kernels are also presented in Figure 2. SLC and color of individual kernels were normally distributed around the means that were highly correlated with SLC and color measured on milled rice bulk.

Results are similar to Siebenmorgen et al. (2006) approach in that weighted averages of rice thin, medium, and thick fraction physicochemical property provide good predictions of most un-fractionated bulk rice properties. In addition, a similar approach was followed by Delwiche (1998) where models for predicting protein content of wheat single kernels were developed using near-infrared reflectance spectroscopy. The authors reported accurate partial least squares and multiple linear regression models (R^2= 0.90 to 0.97) for predicting protein content of five commercial U.S. wheat classes. Greater performance of the models was reported when including several wheat classes. As such long- and medium-grain rice cultivars harvested from four locations in Arkansas were used in this study. Wu and Shi (2004) also investigated the use of near infrared spectroscopy to predict individual brown rice weight and milled rice amylose content. A total of 474 brown and/ or milled rice grains from 34 varieties that included 20 *Indica* and 5 *Japonica* rice were used where single grains were scanned using a near infrared range of 1100 nm to 2500 nm. The authors reported coefficients of determination of 0.85, 0.71, and 0.67 for predicting milled rice amylose content, brown rice weight, and rice grain weight, respectively. The corresponding prediction standard errors were 2.82, 1.09, and 1.30. However, the authors reported high rates of error measuring single rice grains when compared to the bulk milled samples. This was attributed to using black rubber sheets as a background when predicting single grains' properties. In contrast, the single kernel adaptor used in this study; having a highly reflective background, allowed maximum light absorbance by the rice grain.

SIGNIFICANCE AND CONCLUSIONS

Individual milled rice kernels SLC and color were successfully predicted using near infrared reflectance spectroscopy. Measured individual kernels surface lipid content and color were normally distributed around means representing bulk rice properties. The use of near-infrared spectroscopy showed great potential to measure individual milled rice kernels quality parameters.

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Table 1. Model statistics for prediction of rice SLC and Hunter colorimeter (*L, *a**, and *b**) using averaged scans of 2500 single milled rice kernels using DA7200 Diode array analyzer (n=25 samples).**

	SLC[z]	*L**	*a**	*b**
Calculated				
Min value	0.36	73.30	-1.13	14.00
Max value	0.65	77.10	-0.33	16.90
Slope	0.86	0.86	0.61	0.83
Offset	0.06	10.25	-0.27	2.60
R_c	0.93	0.93	0.78	0.91
RMSEC	0.03	0.40	0.13	0.29
SEC	0.03	0.41	0.13	0.30
BIAS	-1.48E-06	2.66e-05	3.00e-06	2.80E-04
Validated				
Min value	0.35	73.10	-0.30	14.29
Max value	0.66	77.00	-0.90	16.95
Slope	0.58	0.68	0.42	0.70
Offset	0.21	23.49	-0.38	4.53
R_v	0.62	0.73	0.43	0.73
RMSEP	0.06	0.79	0.22	0.50
SEP	0.07	0.80	0.22	0.51
BIAS	0.01	-0.13	0.02	0.03

[z] SLC, *L**, *a**, and *b** represent surface lipid content and Hunter color parameters respectively. Rc, Rv, RMSEP, SEC, and SEP represent calculated and validated correlation, root mean square error, and calculated and predicted standard error.

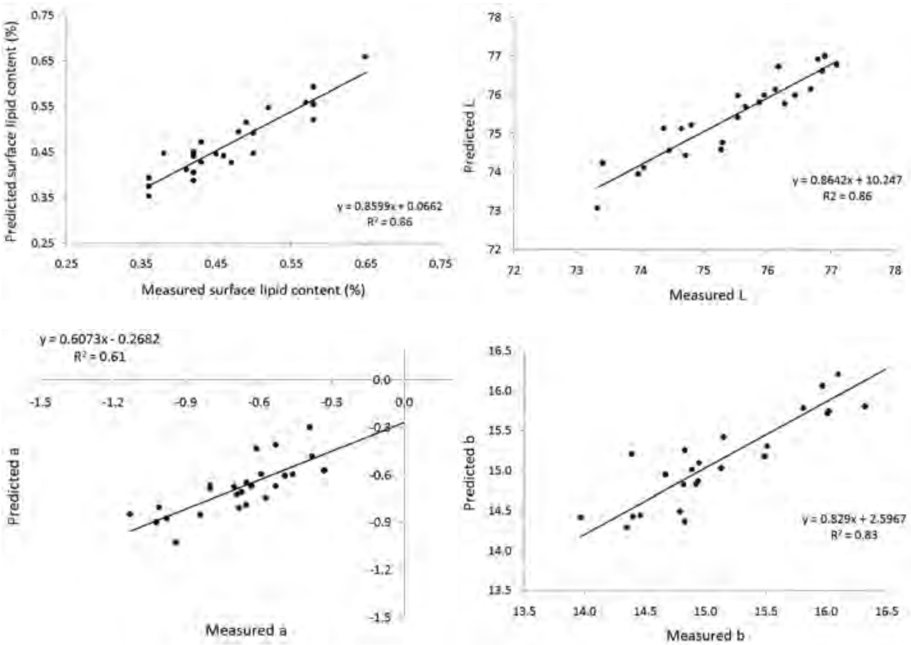

Fig. 1. Predicted and measured surface lipid content and *L*, a*, and b color measurements of milled rice samples (n=25).**

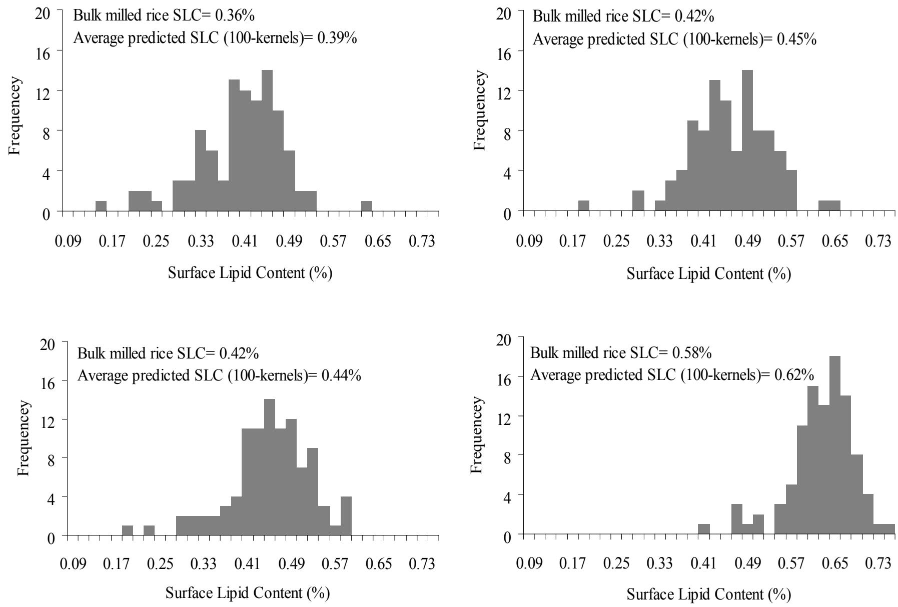

Fig. 2. Distributions of predicted surface lipid content (%) of 100 individual milled rice kernels predicted using near infrared spectroscopy.

A Preliminary Investigation Relating Nighttime Air Temperature Levels to Plot-Scale Milling Quality

M.I. Saleh, T.J. Siebenmorgen, P.A. Counce, J. Gibbons, and K.A.K. Moldenhauer

ABSTRACT

Nighttime temperature can affect rice kernel development and subsequently influence head rice yield (HRY). The effects of nighttime temperature on HRYs of 'Bengal', 'Cypress', 'Jupiter', 'LaGrue', 'Wells', and 'XL723' samples taken from plots of the Arkansas Rice Performance Trial (ARPT) program was investigated. Each of the rice cultivars were grown at ARPT locations that represented expected variations in ambient temperature exposure during kernel development. Samples from each plot were harvested at various moisture contents (MCs) in order to determine peak HRYs. Results demonstrated that low nighttime temperatures during R6 and R7 developmental stages positively influenced HRY. The results reported represent the first year of a 3-year study investigating the effects of nighttime temperatures on rice quality at the field level.

INTRODUCTION

Sensitivity of certain rice cultivars to various environmental conditions, especially nighttime temperature, may hide the effects of some genetic improvements, thus hindering progress in rice production research. Therefore, understanding the effects of nighttime temperature during kernel development on rice quality could improve precision of rice breeding efforts.

Previous studies on the effects of nighttime air temperature on rice quality have been conducted in controlled chambers (Cooper et al., 2008; Counce et al., 2005; Ziska and Manalo, 1996) to simulate field environmental conditions. Results of these studies showed positive correlations between high nighttime air temperatures and HRY decreases. However, controlled atmospheric chambers may not entirely represent field conditions in which systematic temperature fluctuations do not exist. Furthermore, historical analyses of weather and milling quality data usually include personnel and study-to-study variability during sampling and processing; thus may not accurately separation of the effect of weather data on rice quality. Therefore, this study was undertaken to assess nighttime temperature effects on rice quality using field samples and ambient temperature data.

PROCEDURES

Rice Staging

Four long- (Cypress, LaGrue, Wells, and XL723) and two medium- (Bengal and Jupiter) grain rice cultivars were grown as part of the ARPT system at Corning, Newport, Rohwer, and Stuttgart, Ark., in 2007. Physiological stages of rice development were visually identified for all cultivars according to a staging system developed by Counce (2000) at the Stuttgart site. This staging system begins with vegetative stages (V), which describe leaf growth, and reproductive stages (R) that classify rice kernel development of the main stem panicles. During this study, the reproductive stages from R3 to R9 of rice plant growth were identified and day of year of the occurrence of each R stage were determined.

Weather Data and Thermal Unit Calculation

Weather data from 2007, comprising 30-min intervals of temperature and relative humidity, were collected at all four test locations. DD50 thermal units (°F-day) over the course of each day were calculated using the following equation:

$$DD50 = \sum_{i=1}^{48} \left[\left\{ \frac{(\text{Max Temp. (°F)} + \text{Min Temp. (°F)})}{2} \right\} - 50°\text{F} \right]_{30\text{ min } duration} \times 0.5h \ x \ \frac{1\ day}{24h}$$

- Max Temp. and Min Temp. represent the maximum and minimum temperature during a 30-min. interval, respectively
- Maximum temperatures was considered 94°F if maximum temperature during a duration was greater than 94°F and the minimum temperature was considered 70°F if minimum temperature was greater than 70°F.

The R3 stage of rice development was considered the “datum line” at which thermal unit accumulation was assigned a value of zero. From that datum, DD50 values accumulated for R stages were computed using the 30-min temperature data. These accumulated DD50 values, in conjunction with the staging data collected at Stuttgart, were used to determine the duration required for a particular rice cultivar to develop from one R stage to another. The rate of R-stage development was assumed constant for each cultivar across all four locations. Consequently, the amounts of accumulated thermal units necessary for a rice cultivar to develop from one R stage to another were measured in Stuttgart and applied to that cultivar grown in Corning, Newport, and Rohwer. Fifty percent heading of cultivars grown in Corning, Newport, and Rohwer was visually determined as the R3 stage for thermal unit accumulation for each cultivar at each location. Days of year of the R development stages were then identified.

Rice Harvesting and Milling

Rice cultivars were harvested over a MC range of 11.4 to 28.6% from the four locations in 2007, with at least five different harvest MCs at each location. This approach was adapted to determine the peak HRY for a given field (Siebenmorgen et al., 2007). The peak HRY was desired to minimize the effects of immature kernels or fissuring of low MC kernels, both of which can cause HRY reduction; this approach thus allowed for better comparison of possible nighttime air temperature effects. Samples were cleaned (Carter-Day Dockage Tester, Carter-Day Co., Minneapolis, Minn.) and dried in a chamber maintained at 21°C and 62% relative humidity, corresponding to a rough rice equilibrium MC of approximately 12.5% (ASAE, 1993).

Prior to milling, samples of rice were removed from storage and placed at room temperature for at least 24 h. For each milling test, a 150-g rough rice sample was first de-hulled in a laboratory sheller (Type THU, Satake, Tokyo, Japan) with a clearance of 0.048 cm (0.019 in.) between the rollers, as specified by USDA (1982). The resultant brown rice samples were milled for 30 s using a laboratory mill (McGill No. 2, RAPSCO, Brookshire, Texas). The mill had a 1.5-kg weight on the lever arm situated 15 cm from the milling chamber. Head rice was then separated from brokens using a sizing device (Seedburo Equipment Co., Chicago, Ill.) and HRY was expressed as the mass percentage of the 150 g of rough rice that remained as head rice.

To account for the effect of degree of mlling, HRY values were adjusted for differences in surface lipid content (SLC) of milled rice samples according to Cooper and Siebenmorgen (2007). Peak HRYs were adjusted using the following equation.

$$\text{Adjusted HRY} = HRY_{Sample} - 0.4\,(SLC_{Sample} - SLC_{Standard})$$

Surface lipid content of each rice sample was measured using a Soxtec system (Avanti 2055, Foss North America, Eden Prairie, Minn.) and a standard SLC of 0.50% was used.

Nighttime Temperature During R Stages

Based on staging system data for each cultivar, days of year of each R stage occurrence were determined for cultivars grown in the four locations. Ambient nighttime temperatures, for each 30-min increment, during the spans that extended from 8:00 pm to 6:00 am (Fig. 1) of each period required for rice cultivars to develop from one R stage to another, were collected. The frequency of each ambient nighttime air temperature during the R6 through R9 stages was then plotted for each rice cultivar grown at the four locations.

RESULTS AND DISCUSSION

Rice Milling Quality

Peak HRYs of cultivars harvested from the four locations were computed from the HRY vs. HMC relationships (Fig. 2). For all cultivars and locations, harvesting rice at either high or low HMC resulted in lower HRYs, with a peak HRY achieved usually in the MC range of 17 to 20%.

Nighttime Temperature Effects on Head Rice Yield

Frequencies of nighttime temperatures during R6, R7, R8, and R9 stages for Cypress and LaGrue cultivars harvested from Corning, Newport, Rohwer, and Stuttgart are shown in Figure 3. Results indicate that low nighttime temperatures during the R6 developmental stage generally corresponded to greater HRYs. For example, for Cypress and LaGrue rice grown in Newport, which had peak HRY values of 72.5% and 69.8%, respectively, the nighttime air temperatures during R6 were generally low, being primarily between 58 and 72°F (top graphs of Fig. 3). For Rohwer, where the R6 stage mostly occurred during a nighttime temperature range of 70 to 80°F, peak HRYs for Cypress and LaGrue decreased to 65.0% and 56.3%, respectively. Similar trends are indicated for Cypress and LaGrue during the R7 developmental stage with the exception of rice harvested from Corning.

Figure 4 shows frequencies of nighttime temperatures during the R6 to R9 stages for Jupiter and XL723 cultivars harvested from the four test locations. Although only small differences in peak HRYs were observed for both cultivars, results generally supported that the exposure of rice to lower nighttime temperatures during the R6 and R7 stages corresponded to greater peak HRYs than when exposed to higher nighttime temperatures.

Results presented in Figures 3 and 4 demonstrate that nighttime temperature exposure during the R8 and R9 stages had limited effect on HRY. These results indicate that nighttime temperatures during the early (R6 and R7) reproductive stages played a critical role in affecting milling quality. By definition, the R6 reproductive stage represents that stage in which the first kernel on the main stem panicle has completed elongation to the end of the hull and grain filling begins. Because subsequent kernels pass through grain filling after this first kernel, it is reasonable to believe that nighttime temperatures during the plant's R7 stage could be critical in affecting the grain filling of those subsequent kernels. However, nighttime temperatures during the later reproductive stages, in which most kernels would have experienced kernel filling, would not be expected to affect milling quality. The results are in accordance with Cooper et al. (2006), who indicated that the effect of nighttime temperature on rice quality is a collective result of the response of all kernels to nighttime temperature during kernel filling.

Peng et al. (2004) also reported significant reduction in grain filling percentage with the increase in nighttime temperature from 25 to 33°C in a constant day temperature of 33°C. Peng et al. (2004) further showed a 10% decrease in biomass production for every 1°C increase in nighttime temperature. Yoshida and Hara (1977) and Cooper et al. (2008) reported an increase in chalky incidence with the increase in nighttime temperature.

SIGNIFICANCE OF FINDINGS

The results presented are the first of a multi-year study of the effect of nighttime temperature on rice quality. The results of the first year (2007) demonstrated that low nighttime temperature exposure during early stages of kernel reproductive development (R6 and R7) corresponded to better milling quality than to higher nighttime temperatures. The results thus far also have indicated that the effects of nighttime temperatures are most prominent during the R6 and R7 stages and have little effect during later stages (R8 and R9).

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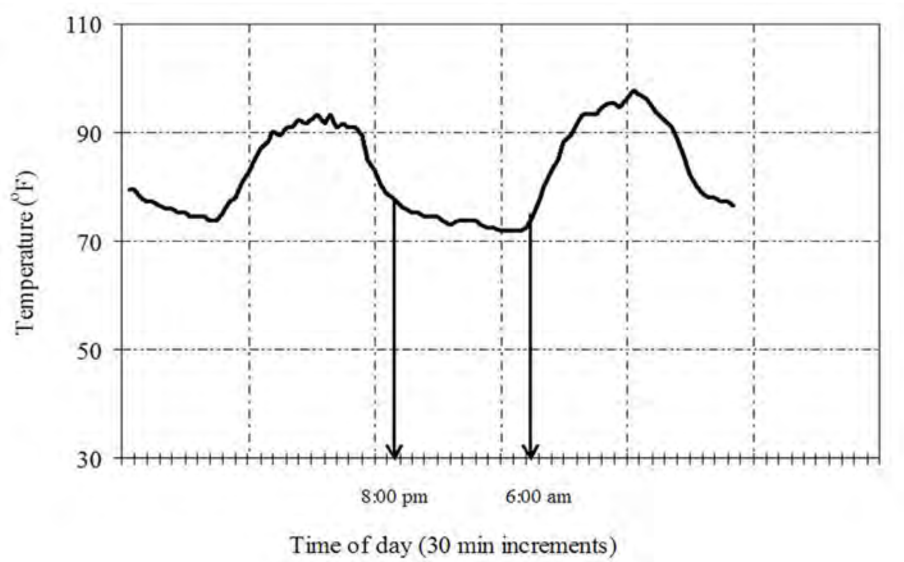

Fig. 1. Profile of measured ambient temperature obtained in 30-min. increments using temperature and RH sensors. The 8:00 pm to 6:00 am span represents the nighttime duration during which temperature frequencies were determined during each reproductive developmental stage for assessing nighttime air temperature effects.

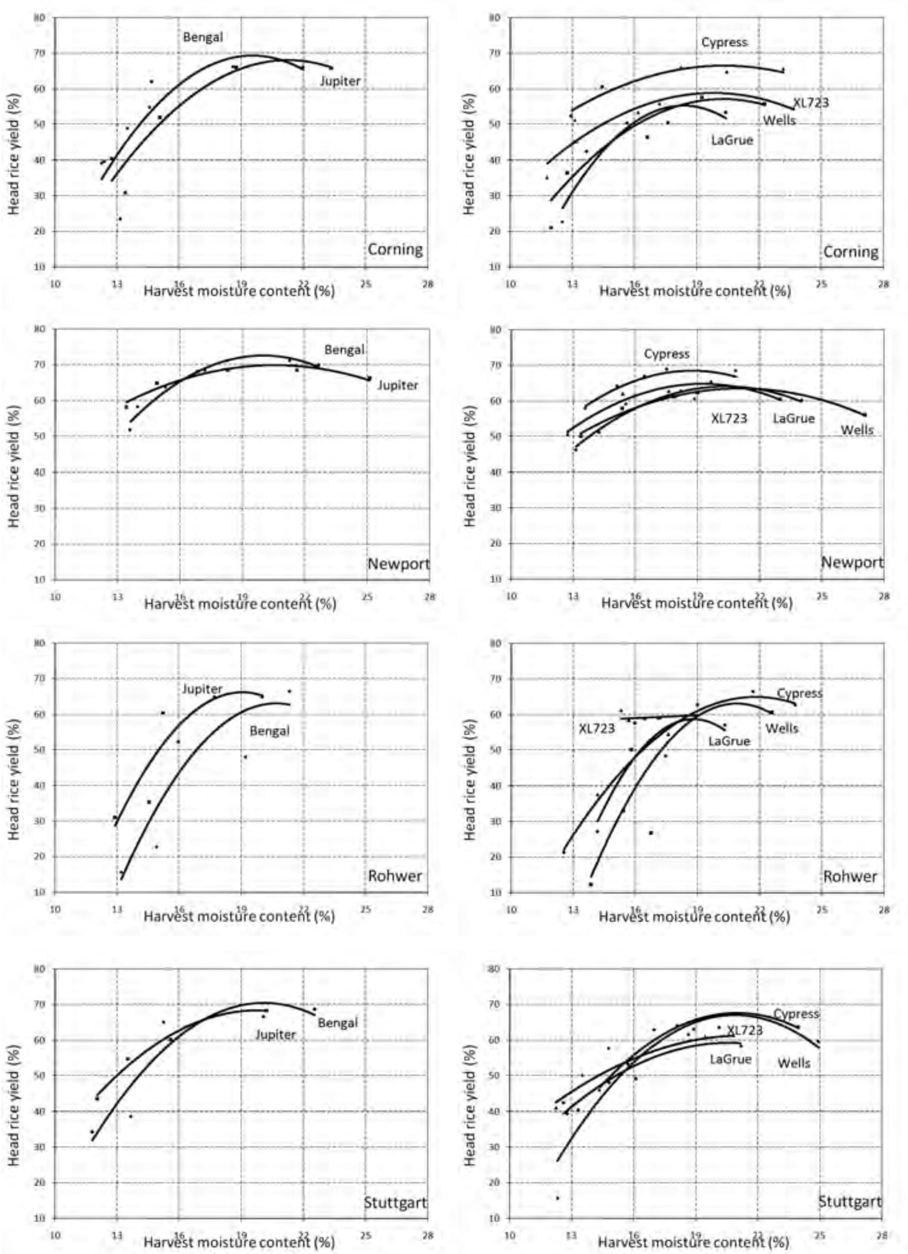

Fig. 2. Plots of head rice yields vs. harvest moisture contents of medium- (Bengal and Jupiter) and long- (Cypress, LaGrue, Wells and XL723) grain cultivars harvested from Corning, Newport, Rohwer, and Stuttgart in Arkansas in 2007.

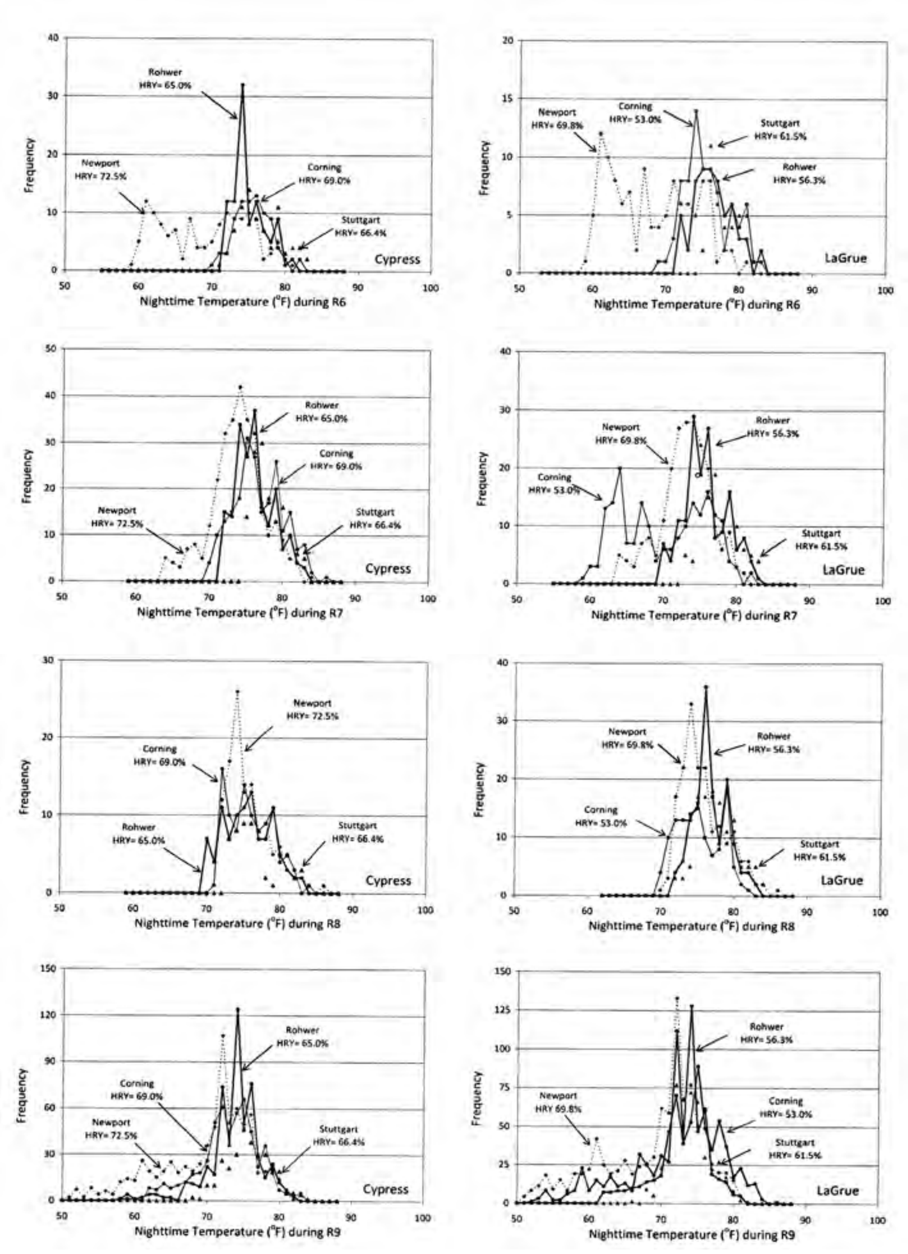

Fig. 3. Plots of nighttime temperature frequencies during R development stages of long-grain rice (Cypress and LaGrue) cultivars harvested from Corning, Newport, Rohwer, and Stuttgart in Arkansas in 2007. Peak head rice yields (HRYs) are also presented.

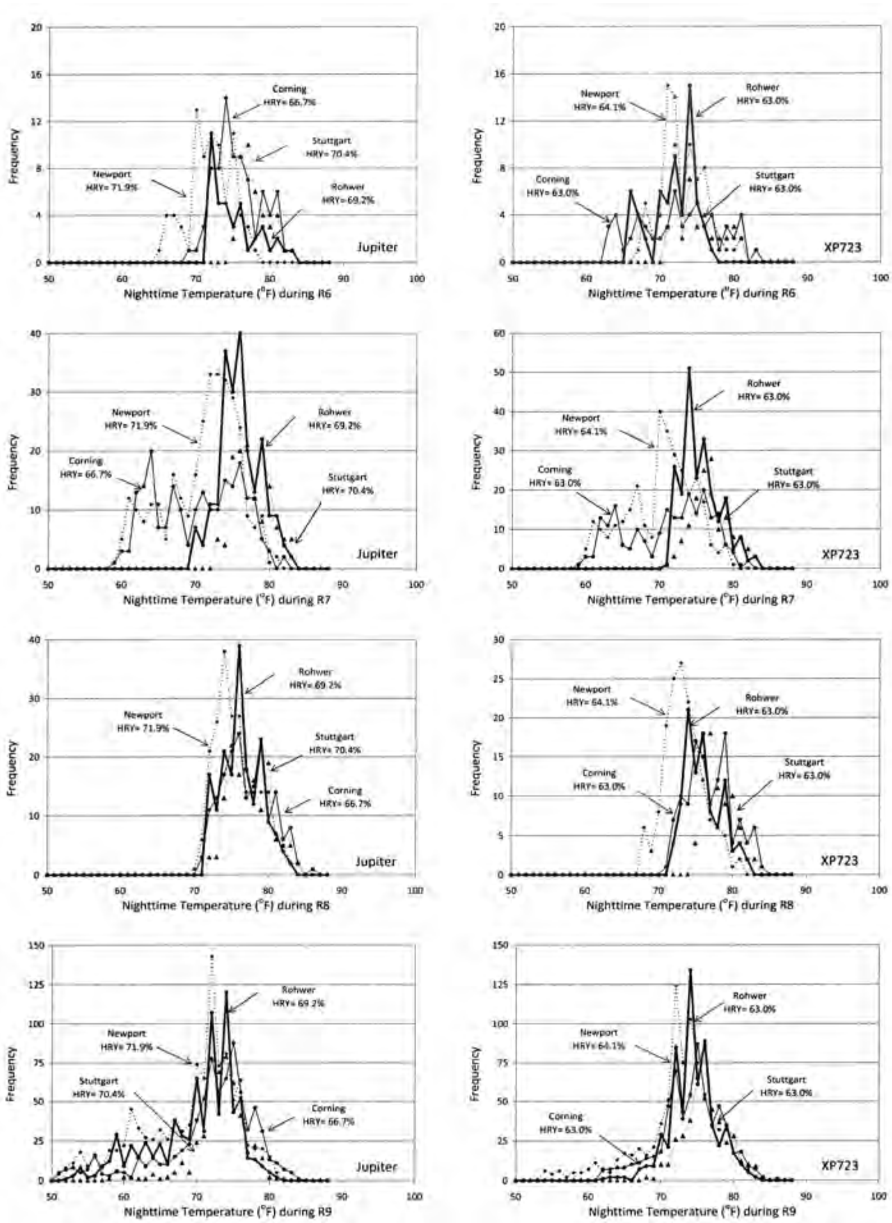

Fig. 4. Plots of nighttime temperature Frequencies during R development stages of medium- (Jupiter) and long- (XL723) grain rice cultivars harvested from Corning, Newport, Rohwer, and Stuttgart in Arkansas in 2007. Peak head rice yields (HRYs) are also presented.

Impact of Average Crop Revenue Elections on Arkansas Crop Producers' Financial Position

J.A. Hignight, E.J. Wailes, and K.B. Watkins

ABSTRACT

The last two years of increased commodity prices and now the prospect of lower market prices have increased the probability that Average Crop Revenue Elections (ACRE) will provide a higher pay out in Arkansas than the traditional programs for all commodities except cotton. Cotton's ACRE price is around loan rate while the other commodities are well above their loan rate. Uncertainty exists with what market prices and state yields will do in the future and if any payments in ACRE will be more than the loss of direct payments, Counter-cyclical Payments (CCPs) and Loan Deficiency Payments (LDPs) over the next four year.

Farm yields and their correlations with state yields must be considered due to the fact ACRE only pays if both state and farm guarantee levels are triggered. A state payment could be triggered while a farm payment may not be triggered and vise versa. Another consideration is how closely base acres match actual production acres. For example, if a farm has cotton base acres and now plants corn or soybeans it is probably better to stay in the traditional program since it is highly likely CCPs will occur for cotton. From the current data and analysis, ACRE does look favorable for all commodities except cotton. It is important for each farmer to look at their own operation and base acreage to determine which program will work best on their farm.

INTRODUCTION

The USDA announced on 22 December 2008 that producers could begin signing up for either the 2009 Traditional (direct and counter-cyclical payments, DCP) commodity programs or ACRE program and have until 14 August to decide. The decision of which program to sign up for should be based on an understanding of the programs and which program will benefit the producers the most. This analysis looks at the most current data available (February, 2009) and simulates outcomes for both the Traditional and ACRE programs at the state level for cotton, rice, grain sorghum, soybeans, corn, and wheat for Arkansas representative farms. It is a comparison of a base acre of the specific commodity to that commodity being planted and enrolled in the ACRE program.

ACRE is designed to provide a revenue guarantee that changes year to year based upon the moving two-year average U.S. crop price and the 5-year Olympic state yield. The revenue guarantee cannot change more than 10% plus or minus compared to the previous year's guarantee. If a payment is triggered on the state level it cannot be more than 25% of the revenue guarantee for the year. Participants in ACRE must take a 20% reduction of direct payments and 30% reduction of loan rates. After a state payment is triggered a farm level guarantee must be triggered as well. It is possible that the state could trigger a payment but the farm does not. Determining how well the farm level yields are correlated with the state average yield must be analyzed by the individual farmer in the decision making process. The ACRE program is a one-time sign up and the producer is locked in for the life of the 2008 Farm Bill. The program can be signed up for the years 2009 to 2012.

Future payments in both the Traditional and ACRE programs are not known with any certainty. ACRE payments will depend upon the National Agricultural Statistics Service national seasonal average market price and state yield for each commodity. Loan Deficiency Payments (LDPs) and CCPs are also determined each year based upon the U.S. seasonal average market price.

PROCEDURES

Yield distributions for the crops were created using variation from trend over the past 20 years. Trend was also used to create the predicted yield in 2009 to 2012 which the historical variation will be simulated around. Price distributions came from the previous 10 crop-years average market price adjusted for inflation. These price distributions were used to simulate variability around the predicted crop prices from 2009 to 2012. Policy parameters come from the two commodity programs available to producers during the 2008 Farm Bill. The simulated years had 500 iterations using yield and price distributions along with the policy parameters to generate revenue per acre for both the Traditional DCP and ACRE programs.

Previous ACRE analysis in Hignight et al. (2008) simulated the representative panel farms constructed based on data collected by economists from the Arkansas Cooperative Extension and Agricultural Food and Policy Center of Texas A&M. In the analysis, the representative farms showed low probabilities ranging from 6% to 27% that the specific farm would be better off in ACRE than the Traditional DCP program. This analysis looks at the state level impact of participation in the ACRE program relative to staying in the DCP program for the period 2009 to 2012 using stochastic methods to capture the variability in state yields and prices.

RESULTS AND DISCUSSION

Relative to preliminary analysis conducted and reported in August 2008, current data and market conditions indicate that the prospect of an ACRE payment has increased for the upcoming year unless market prices start to climb again. Producers of all program commodities produced in Arkansas except cotton could increase their financial position by signing up for the ACRE program.

Table 1 presents the current data to compare the commodities in Arkansas for the Traditional and ACRE program. The cotton ACRE price guarantee is 5 cents above loan rate and has a revenue guarantee of $539/acre. The rice program in the 2008 farm bill is now separated between long- and medium-grain. The ACRE price for long-grain rice is $13.33/cwt and $17.40/cwt for medium-grain rice. Long-grain's revenue guarantee is $821/acre and medium-grain is $1,081/acre. Grain sorghum has an estimated ACRE price of $3.63/bu and a revenue guarantee of $280/acre. Soybeans have an ACRE price of $9.68/bu and a revenue guarantee of $316/acre. Corn has an ACRE price of $4.05/bu and a revenue guarantee of $538/acre while wheat has an ACRE price of $6.59/bu and a revenue guarantee of $320/acre. The ACRE price is determined by the following 2-year market price and 2008 market price will not be finalized until after the current marketing year. The State Yield Average is determined by the 5 previous years and NASS finalized the 2008 state crop yields in January. The guarantee levels are subject to change based upon the finalized calculations as determined by the Secretary of Agriculture.

Table 2 presents each commodity's mean revenue on the State level for 2009 to 2012 based on estimated prices for the time period. The estimated price was simulated using historical variation. Cotton was the only crop that clearly does not favor participation in the ACRE program. Over the four years, there is a possibility of an ACRE payment each year but the amount never surpasses payments in the Traditional program. Long-grain rice averaged a 28% probability of earning more payments in the ACRE program compared to the Traditional program. The highest probabilities of an ACRE payment greater than the Traditional program are in 2009 and 2010. Medium grain rice averaged a 41% probability that ACRE will pay more than the Traditional program from 2009 to 2012. Grain sorghum averaged a 38% probability that ACRE will pay more than the Traditional program during the four years. As with the other commodities, the probability of a payment is greatest in the first two years and decreases over time.

Soybeans averaged a 40% probability of receiving more payments under the ACRE program than the Traditional program over the four years. In 2009, the probability is 58% for the year that ACRE payments will be larger than Traditional payments and the probability decreases to 27% in 2012. Corn has a 37% probability that ACRE payments will be greater than the Traditional program over the four years. The probability of a ACRE payment greater than Traditional in 2009 is 50% and decreases to 27% in 2012. Wheat ACRE payments had a 40% probability of paying more than the Traditional program during the four years. The highest probability of ACRE being greater than Traditional programs is in 2009 at 65% and the probability decreases to 18% in 2012.

The last two years of increased commodity prices and now the prospect of lower market prices have increased the probability that ACRE will provide a higher pay out in Arkansas than the Traditional programs for all commodities except cotton. Cotton's ACRE price is around loan rate while the other commodities are well above their loan rate. Uncertainty exists with what market prices and state yields will do in the future and if any payments in ACRE will be more than the loss of direct payments, CCPs and LDPs over the next four year.

Farm yields and their correlations with state yields must be considered due to the fact ACRE only pays if both state and farm guarantee levels are triggered. A state payment could be triggered while a farm payment may not be triggered and vice versa. Another consideration is how closely base acres match actual production acres. For example, if a farm has cotton base acres and now plants corn or soybeans it is probably better to stay in the traditional program since it is highly likely CCPs will occur for cotton. From the current data and analysis, ACRE does look favorable for all commodities except cotton. It is important for each farmer to look at their own operation and base acreage to determine which program will work best on their farm.

SIGNIFICANCE OF FINDINGS

Arkansas rice producers must make important farm program decisions regarding participation in the traditional DCP program or the new ACRE program developed in the 2008 Food, Conservation, and Energy Act. This research suggests that as a result of volatile price movements over the past year that producers need to carefully examine their program participation decision. Changes in national and local prices for crops since August 2008 that have been used in this study indicate that the appropriate decision for each farm must be made after a careful review of the state and farm-level trigger mechanisms that affect federal price and income support for that farm.

ACKNOWLEDGMENTS

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Table 1. Farm program direct, counter-cyclical, loan, and ACRE guarantees in 2009.

	Cotton	Long-grain rice	Medeium-grain rice	Grain sorghum	Soy-beans	Corn	Wheat
	(¢/lb)	-----($/cwt) ----		--------------------($/bu) --------------------			
Traditional Programs							
Direct payment rate	6.67	2.35	2.35	0.35	0.44	0.28	0.52
CCP target price[z]	71.25	10.50	10.50	2.57	5.80	2.63	3.92
Loan rate[y]	52.00	6.50	6.50	1.95	5.00	1.95	2.75
ACRE							
Direct payment rate	5.34	1.88	1.88	0.28	0.35	0.22	0.42
Loan rate	36.40	4.55	4.55	1.37	3.50	1.37	1.93
ACRE price[x]	57.25	13.33	17.40	3.63	9.68	4.05	6.59
	(lb/acre)	---(cwt/acre) --		------------------(bu/acre) ------------------			
State average yield[w]	1,046.0	68.5	69.0	85.7	36.3	147.7	54.0
	----------------------------------($/acre)--						
Revenue guarantee[v]	539	821	1,081	280	316	538	320
	(lb/acre)	---(cwt/acre) --		------------------(bu/acre) ------------------			
Base history estimates[u]							
Direct payment yield	599.0	48.2	48.2	56.6	30.8	102.4	34.5
CCP yield	634.0	51.3	51.3	58.2	34.1	114.4	36.1

[z] Target prices change for some commodities in 2010 to 2012.
[y] Loan rates change for some commodities in 2010 to 2012.
[x] Estimated price based upon current NASS data.
[w] Estimated yield based upon current NASS data.
[v] Based upon estimated State Average Yield and 90% of ACRE Price.
[u] Estimated average base yield.

Table 2. Simulated results from the Traditional and ACRE programs, 2009-2012.

	2009	2010	2011	2012	AVG[z]
Cotton	------------------ ($/acre)-------------------------------				
Traditional	707	713	727	739	722
ACRE	588	614	636	655	623
	-------------- (Probabilities)---------------------------				
ACRE payment is received	58%	22%	17%	16%	28%
ACRE > Traditional	0%	0%	0%	0%	0%[y]
Long-grain rice	------------------ ($/acre)-------------------------------				
Traditional	902	886	918	958	916
ACRE	911	889	879	914	898
	-------------- (Probabilities)---------------------------				
ACRE payment is received	77%	80%	41%	22%	55%
ACRE > Traditional	57%	47%	7%	3%	28%
Medium-grain rice	------------------ ($/acre)-------------------------------				
Traditional	1,382	1,205	1,186	1,204	1,244
ACRE	1,371	1,265	1,233	1,237	1,277
	-------------- (Probabilities)---------------------------				
ACRE payment is received	31%	64%	60%	41%	49%
ACRE > Traditional	15%	63%	52%	34%	41%
Grain sorghum	------------------ ($/acre)-------------------------------				
Traditional	327	330	347	354	339
ACRE	340	340	356	364	350
	-------------- (Probabilities)---------------------------				
ACRE payment is received	47%	41%	33%	35%	39%
ACRE > Traditional	46%	39%	32%	34%	38%
Soybeans	------------------ ($/acre)-------------------------------				
Traditional	339	345	361	375	355
ACRE	360	358	370	382	368
	-------------- (Probabilities)---------------------------				
ACRE payment is received	59%	45%	32%	28%	41%
ACRE > Traditional	58%	44%	31%	27%	40%
Corn	------------------ ($/acre)-------------------------------				
Traditional	620	628	664	683	649
ACRE	647	648	677	696	667
	-------------- (Probabilities)---------------------------				
ACRE payment is received	52%	44%	29%	29%	39%
ACRE > Traditional	50%	42%	28%	27%	37%
Wheat	------------------ ($/acre)-------------------------------				
Traditional	306	309	321	329	316
ACRE	331	324	326	332	328
	-------------- (Probabilities)---------------------------				
ACRE payment is received	67%	54%	30%	21%	43%
ACRE > Traditional	65%	50%	28%	18%	40%

[z] The average of revenue and government payments per acre from 2009-2012.

[y] The probability the sum of ACRE payments are larger than the Traditional payments.

An Economic Comparison of Tillage and Fertility on a Rice-Soybean Rotation, 2000-2008

J.A. Hignight, K.B. Watkins, and M.M. Anders

ABSTRACT

From 2000 to 2008 an on-going rice-soybean rotation study comparing no-till to conventional tillage with two different fertility treatments has been conducted at the University of Arkansas Rice Research and Extension Center near Stuttgart, Ark. Four management strategies were analyzed in this study and included no-till-high fertility, no-till-low fertility, conventional-till-high fertility, and conventional-till-low fertility. Rice grain yield averaged the highest for conventional-till-high fertility at 184 bu/acre and the lowest was no-till-low fertility at 179 bu/acre. No-till-high fertility soybean yields averaged the best at 50 bu/acre and conventional-till-low fertility averaged the least at 48 bu/acre. Rice grain yields indicate that conventional tillage may have a slight agronomic advantage over no-till while no-till soybeans showed a yield advantage. Higher fertility rates did not improve rice or soybean yields sufficiently to pay for the additional fertilizer costs. Variability in grain yield was least for no-till-low fertility and highest for conventional-till-high fertility. Return above variable costs were best in five of the nine years for no-till-low fertility management strategy while all four management strategies were the least profitable in one or more years. When machinery and equipment costs were included, no-till-low fertility was the most profitable six of nine years. Results from the on-going study indicate that no-till-low fertility would have been the most profitable management strategy for a rice and soybean rotation while the use of conventional-till-high fertility would have been the least profitable.

INTRODUCTION

Arkansas is the largest producer of rice and the leading soybean producer in the southern states. Production of these two crops typically relies on intensive tillage. Rice grain yield loss is commonly cited as a reason for not adopting no-till although there are studies that found no significant difference in rice grain yield between conventional tillage and no-till (Anders, 2005; Anders, 2006). In 2007 approximately 55% and 9% of Arkansas rice produced was planted using conventional tillage and no-till, respectively (Wilson and Runsick, 2007). No-till soybean research has presented yields better than conventional tillage at lower production costs while increasing profitability and reducing risk (Klerk et al., 1998; Ribera et al., 2004).

Fertility recommendations usually are designed to maximize the agronomic yield. The UA recommendations on nitrogen for rice production on silt loam soils are 150 lb/acre N for conventional varieties and 120 lb/acre N for hybrid varieties (Wilson, 2007). Phosphorus and potassium recommendations are generally made based upon the Mehlich-3 soil test method for a particular field (Wilson et al., 2001). Generally, nitrogen is considered the most important nutrient in rice production for increasing yield assuming phosphorus, potassium, and micro-nutrients are not a limiting factor on productivity.

The purpose of this study is to determine what would have been the best tillage and fertility strategy from 2000 to 2008 for an owner-operator producer to maximize economic returns. The study looks at four management options: 1) no-till with high fertility (NT-HF); 2) no-till with low fertility (NT-LF); 3) conventional till with high fertility (CT-HF); and 4) conventional till with low fertility (CT-LF). Economic returns will be analyzed yearly and by using net present value (NPV).

PROCEDURES

The field trials were conducted at the University of Arkansas Rice Research and Extension Center near Stuttgart, Ark. The plot location was cut to a slope of 0.15% in February of 1999. Soil at the site is referred to as a Stuttgart silt loam and classified as a fine, smectitic, thermic Albaqultic Hapludof. Initial soil samples show a pH range of 5.6 to 6.2 with carbon content averaging 0.84% and nitrogen 0.08%. Plots measuring 250-ft by 40-ft were laid out in a north-south direction. These plots were then divided in half east-west with each side randomized as conventional or no-till treatments. Each tillage treatment was then split into a low- and high-fertility treatment. For rice, "low" fertility consisted of a single pre-flood N application of 100 lb/acre, 40 lb/acre P_2O_5, and 60 lb/acre K_2O while rates for the "high" fertility increased to 150 lb/acre N, 60 lb/acre P_2O_5, and 90 lb/acre K_2O. For soybeans, "low" fertility consisted of 40 lb/acre P_2O_5 and 60 lb/acre K_2O while "high" fertility consisted on 60 lb/acre P_2O_5 and 120 lb/acre K_2O. For the no-till treatment all plant residues were left on the plots while conventional-till plots were burnt following harvest. Phosphorus and Potassium fertilizers were applied prior to planting with both fertilizers incorporated with tillage in the conventional tillage plots and left on the soil surface in the no-till plots.

Two rice and two soybean varieties were used each year. Table 1 presents a time-line of the rice and soybean varieties planted in this rotation. Herbicide use for weed control in rice was generally the same from year to year but no-till had an early glyphosate application for weed control instead of tillage. The same herbicides were not used every year for weed control in rice but included Command, Facet, Permit, and Clincher while weed control in soybeans relied on glyphosate.

Input costs for each year came from the United States Department of Agriculture National Agricultural Statistical Service (NASS), Economic Research Service (ERS), and input costs data gathered by University of Arkansas Extension Economists. Input costs were matched with the quantities used in each crop and year. Machinery repair, maintenance, and ownership costs were calculated with the use of the Mississippi State Budget Generator. Machinery was matched as closely to replicate machinery on a farm with a rice and soybean 1:1 rotation. The value of rice and soybeans used each year came from NASS and also included the estimated loan deficiency payment if applicable.

The rice and soybean yields from the trials were simulated 500 times by creating an multivariate empirical distribution with the Excel add-in Simetar. Simulating the yields within the parameters of the real data gives a range of possibilities that could have occurred during the year for the specific variety allowing for risk analysis of alternative management strategies. The two simulated rice variety yields were averaged together and the two simulated soybean variety yields were averaged together as well. Gross revenue was calculated multiplying the crop price and average yield of the two varieties and then averaging the rice and soybean gross revenue per acre. Gross revenue minus variable costs generated a return above variable costs (RAVC) and return above total costs (RATC). RAVC is calculated by deducting the variable costs from the gross returns per acre. RATC equals RAVC minus the fixed or ownership costs per acre of machinery and equipment. Although this is an analysis for RATC, the analysis does not include land rent, management, overhead, and risk premium costs. The results for gross revenue, variable costs, RAVC, fixed costs, and RATC in the analysis are averaged across both rice and soybean. It is assumed to be the average results across an entire farm.

Net present value (NPV) is also used to determine which system would have been the most profitable and less risky to begin in 2000. NPV can be defined for this analysis as the sum of all RATC discounted back to the year 2000 using a 6% discount rate. Discounting back allows a risk assessment to be made over the nine years. The purpose of this is to determine if a specific management strategy totally dominates the others in profitability or if more than one management strategy had some probability of being the most profitable over the nine years. In other words, what is the risk of the dominant management strategy actually being less profitable than another strategy?

RESULTS AND DISCUSSION

Rice and Soybean Yields

Figures 1 and 2 present the simulated average yields for rice and soybeans during the nine years. NT-HF had the highest rice yield in two years and the highest soybean yield in four of the nine years. The nine year average yield in this system for rice and soybeans was 180 bu/acre and 50 bu/acre, respectively. NT-LF had the highest average rice yield in 2008 but never the highest soybean yield. Average rice yield for this strategy was 179 bu/acre and a soybean yield of 49 bu/acre. CT-HF averaged the highest rice and soybean yield three of the nine years. This strategy averaged 181 bu/acre rice and 49 bu/acre soybean. The last strategy was CT-LF and it averaged the highest rice yield in three years and the highest soybean yield in two years. This strategy averaged over the nine years 184 bu/acre rice and 48 bu/acre soybean.

Economic Analysis

Table 2 presents the simulated average gross revenue, variable costs, return above variable costs, fixed costs, and return above total costs for each year and management strategy. These results are an average combining rice and soybean revenue, costs, and returns. Gross revenue was generally highest with CT-LF and the lowest for NT-LF although this was not the case every year. On the other hand, variable costs were generally highest for CT-HF and lowest for NT-LF. Variable costs cover inputs, repair, maintenance, and hired labor but do not include management costs, risk premiums, or land costs. Fertility and tillage influenced variable costs making the high fertility treatments more expensive than the low fertility treatments and tilled plots more expensive than no-till.

RAVC per acre for the rice-soybean rotation is calculated by deducting the variable costs per acre from gross revenue for each of the years. NT-HF never averaged the highest RAVC but was lowest in three years. This management strategy's RAVC ranged from $135 to $444/acre during the nine years. NT-LF had the highest average RAVC in five years and ranged from $156 to $490/acre. CT-HF had the highest average RAVC in one year but was lowest in two years. This management strategy ranged from $91 to $355/acre over the nine years. CT-LF was the best strategy in three years but was also the least profitable in three. This management strategy ranged from $69 to $436/acre in the nine years.

Fixed costs were higher for the conventional tilled than for no-till due to more equipment needed for production. RATC were calculated by deducting the fixed cost from RAVC. NT-HF never averaged the highest RATC in any year. This strategy was the least desirable, on average, in two of nine years and had a range from $89 to $382/acre. NT-LF averaged the highest RATC in six years and was lowest in one year. This management strategy ranged from $109 to $427/acre during the nine years. CT-HF averaged the highest return in 2007 at $276/acre but was the lowest in three years. The range for this management strategy was from $20 to $276/acre. CT-LF averaged the highest RATC in two of the nine years and the lowest in three years. The range for this management strategy was from $7 to $355/acre.

Risk Analysis

Risk analysis is a measure of the variability of outcomes that may occur. It is useful for analyzing multiply strategies in determining which one might have the potential for highest and lowest returns. It is also useful to look at variability and the probability that one strategy may have higher returns than another strategy. To look at risk, the 500 outcomes were discounted back to 2000 using a discount rate of 6%. Table 3 presents the net present value (NPV) of the RATC per acre from 2000 to 2008. NT-LF had the highest average NPV at $1,414/acre while CT-HF had the lowest at $1,057/acre.

Coefficient of variation (CV) is a measure of relative risk. It is useful in comparing risk among alternative strategies. The CV for each management strategy ranged from 4.7 (NT-LF) to 5.9 (CT-HF). The minimum and maximum column presents the lowest and highest NPV/acre for each of the four management strategies from the 500 possible outcomes. NT-LF has the highest minimum and the highest maximum NPV while CT-HF had the lowest minimum and maximum value out of the four strategies. NT-LF was ranked first due to the highest mean NPV, less variability (CV) and the highest minimum and maximum value in the simulated outcomes while CT-HF is ranked fourth due to the lowest mean NPV, highest variability, and lowest minimum and maximum NPV.

SIGNIFICANCE OF FINDINGS

Results from this analysis indicate that a producer on silt-loam soils starting in 2000 would have been the most profitable by adopting the NT-LF management strategy. On average, rice yields in no-till averaged slightly below conventional tilled but no-till soybeans were competitive with conventional tilled soybeans (NT-HF having the highest average four of the nine years). Fertility also played a significant part in the average yield. Rice and soybean yields typically were higher with the high fertility treatment as compared to the low fertility treatment. NT-LF had the highest yield in rice one year and never the highest soybean yield on average but would have been the most profitable management strategy while CT-HF would have been the least profitable strategy. Most Arkansas producers on silt loam soils would fit into the CT-HF strategy. These results illustrate the potential to increase profitability with no-till and that current use of fertilizers may be lowering potential profits and unnecessarily increasing risk.

ACKNOWLEDGMENTS

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Table 1. Rice and soybean varieties used in study, 2000 to 2008.

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Rice	Lagrue Wells	Lagrue Wells	Lagrue Wells	Lagrue Wells	Cybonnet Wells	Cybonnet Wells	Cybonnet Wells	XL723 Wells	XL723 Wells
Soybean	AG4702 H4994RR	AG4702 H4994RR	AG4702 H4994RR	AG4902 P94M80	AG4902 P94M80	AG4902 P94M80	AG4902 P94M80	AG4902 P94M80	AG4903 P94M80

Table 2. Financial results from the rice:soybean rotation, 2000 to 2008[z].

	2000	2001	2002	2003	2004	2005	2006	2007	2008
	(%/acre)								
No-till & high fertility									
Gross revenue	439	362	430	504	448	556	584	697	994
Variable costs	236	227	258	236	262	315	325	386	551
RAVC[y]	202	135	171	268	186	240	259	311	444
Fixed costs	45	46	48	48	51	53	56	59	62
RATC[x]	157	89	123	221	135	187	202	252	382
No-till & low fertility									
Gross revenue	449	360	415	514	469	548	572	656	979
Variable costs	217	204	238	214	242	286	292	345	489
RAVC	232	156	177	300	226	262	280	311	490
Fixed costs	45	46	48	48	51	53	56	59	62
RATC	186	109	129	251	174	207	223	250	427
Conventional-till & high fertility									
Gross revenue	519	373	412	584	485	408	553	753	877
Variable costs	260	251	250	247	280	317	340	398	566
RAVC	260	122	162	337	205	91	212	355	311
Fixed costs	60	62	64	64	68	71	75	79	81
RATC	200	60	98	273	136	20	137	276	230
Conventional-till & low fertility									
Gross revenue	549	337	388	643	489	373	579	703	946
Variable costs	244	268	229	231	256	285	309	358	510
RAVC	306	69	160	411	232	88	270	345	436
Fixed costs	60	62	64	64	68	71	75	79	81
RATC	246	7	96	348	164	17	194	266	355

[z] Average per acre from the 500 iterations.
[y] RAVC is Return Above Variable Costs.
[x] RATC is Return Above Fixed Costs.

Table 3. NPV per acre from the rice:soybean rotation, 2000 to 2008[z].

	Average	SD[y]	CV[x]	Min.	Max.	Ranking
No-till & high fertility	$1,257	$65.50	5.2	$1,081	$1,454	2
No-till & low fertility	$1,414	$65.91	4.7	$1,207	$1,614	1
Conventional-till & high fertility	$1,057	$62.83	5.9	$875	$1,229	4
Conventional-till & low fertility	$1,235	$63.05	5.1	$1,000	$1,421	3

[z] NPV is the Net Present Value of the 500 iterations.
[y] SD is the standard deviation from the average NPV.
[x] CV is the coefficient of variation and is a measure of relative risk.

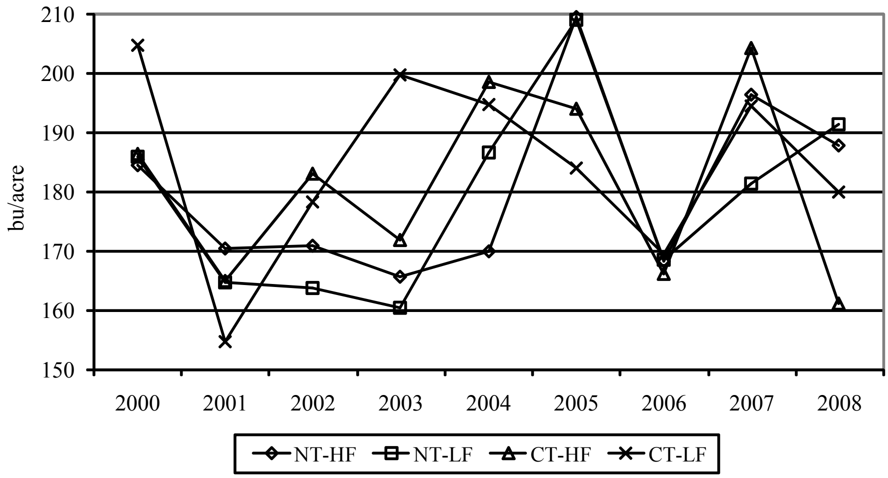

Fig. 1. Average rice yield by tillage and fertility, 2000 to 2008.

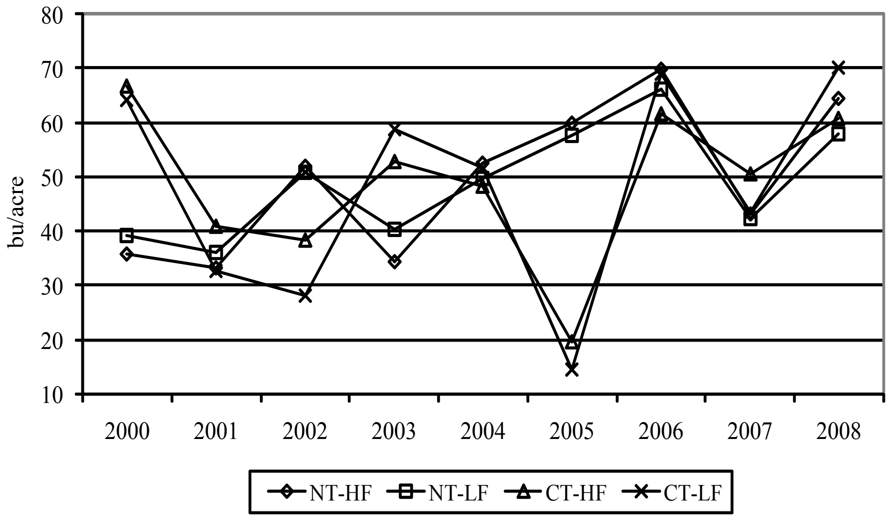

Fig. 2. Average soybean yield by tillage and fertility, 2000 to 2008.

Impact of Field Topography and Seed Variety in the Rice Research Verification Program, 2006 to 2008

J.A. Hignight, K.B Watkins, S.K. Runsick, R. Mazzanti, and C.E. Wilson, Jr.

ABSTRACT

Since 2006, 54 farms have participated in the Rice Research Verification Program (RRVP) across the state. The program has given a snapshot of the influence of field topography and seed varieties on profitability. Over the past three years fields with improvements have averaged higher grain yields and have been more profitable by $66/acre over unimproved fields assuming an 80/20 land rental arrangement. Seed selection has influenced profitability as well. Hybrid varieties averaged $52 more per acre than conventional varieties and $31/acre more than Clearfield hybrid varieties.

INTRODUCTION

The rice research verification program (RRVP) was created in 1983 to provide a system to verify University recommendations on fields that have previously had less than optimal yields. From 2006 to 2008, the RRVP has provided a snapshot of the profitability of field improvements and rice varieties. Since 2006, 54 farms for a total of 3,151 acres have participated in the RRVP. Table 1 breaks down the participating acreage by year, field topography, and the type of seed. This will be the format for looking at the profitability of the selected categories. The results for the tables will be based upon a weighted acre average. Straight levee fields had the highest participation in the RRVP while conventional varieties have been the dominant variety used although hybrid and Clearfield (CL) hybrid use has been increasing.

PROCEDURES

The RRVP fields and cooperators are selected prior to the beginning of the growing season. Cooperators agree to pay production expenses, provide expense data, and implement university recommendations in a timely manner from planting to harvest. A designated county agent from each county assists the RRVP coordinator in collecting data, scouting the field, and maintaining regular contact with the producer. Weekly visits by the coordinator and county agents were made to monitor the growth and development of the crop, determine what cultural practices needed to be implemented, and to monitor type and level of weed, disease, and insect infestation for possible pesticide applications.

An advisory committee consisting of extension specialists and university researchers with rice responsibility assists in decision-making, development of recommendations, and program direction. Field inspections by committee members were utilized to assist in fine-tuning recommendations.

The collected data from inputs, machinery, field topography, and irrigation method are used to calculate the production costs. Inputs and quantity on a specific field are used to calculate costs while labor and machinery costs are calculated as closely with what occurred on the field. Land costs are assumed to be 20% of the crop for all fields. By keeping constant input prices and land rent the fields can be compared each year based upon profitability. This data was then separated based upon field topography (i.e., zero-grade, straight levee, or contour levee) and seed variety (i.e., hybrid, conventional, Clearfield hybrid, and Clearfield conventional). The results will be given by the weighted acre average for each year.

RESULTS AND DISCUSSION

Yield

Table 2 presents the rice grain yield per acre by year, field topography, and by type of seed selected. Year influence is evident in the three years. Yields for all categories were typically the lowest in 2006. The following year, yields increased to a RRVP record as well as a state average record according to the National Agricultural Statistics Service (158.4 bu/acre). Field improvements also influenced yield. Typically field improvements such as zero-grade and grading to a 0.15% slope (straight levees) improves water management, uniformity of input applications, and increases area in production within the field. Fields with zero-grade had the highest yield on average two of the three years. In 2006 there were two zero-grade fields that averaged the lowest yield. There were problems with both fields. One did not follow management recommendations on water seeding correctly and fertilizer timing. The other field had issues with emergence and glyphosate drift. Straight levee fields averaged the highest yield in 2006 at 170 bu/acre, one bushel less than zero-grade in 2007, and 11 bushels less than zero-grade in 2008.

Rice varieties have been broken down between hybrid, conventional, CL hybrid, and CL conventional. Hybrid varieties in the RRVP have been 'XP710' and 'XL723' but only XL723 was used in 2007 and 2008. Conventional varieties would include those such as 'Wells', 'Francis', and 'Cocodrie', etc. Wells has been the most common variety used in the RRVP from 2006 to 2008. CL hybrids include 'CLXL729' and 'CLXL730' for 2008 and 2007 while only CLXL730 was used in 2006. CL conventional includes only 'CL171' used in 2008. The other two years did not have any RRVP acres planted with CL conventional varieties. During the three years either the hybrid or CL hybrid averaged the highest yield. These two have averaged 22 and 28 bu/acre, respectively higher than the conventional varieties within the RRVP. The CL conventional variety averaged the lowest yield at 141 bu/acre on two fields. This was 29 bu/acre lower than the conventional varieties and 38 bu/acre lower than the CL hybrid average.

Variable Costs

Table 3 presents the variable costs for the selected categories and years. Zero-grade fields for all three years had the lowest costs. Straight levee fields had lower costs than contour levee fields in 2008 and 2007 but averaged $38/acre more in 2006. The three year average of zero-grade was $35/acre less than straight levees and $45/acre less than contour levee fields in the RRVP. Seed choice also influences costs of production. Conventional varieties had the lowest variable costs for all three years. This is partially due to seed costs and the different chemical usage for CL varieties. The next lowest was hybrid followed by CL hybrid, and then CL conventional. Both of the fields planted in CL conventional in 2008 needed fungicide applications which partially influenced the higher costs compared to CL hybrid varieties.

Return Above Variable Costs

Table 4 presents the return above variable costs (RAVC) which includes an 80/20 rental arrangement for the selected categories. The 80/20 arrangement is used in the analysis as a standard measure of field costs but should not be considered as the typical rental arrangement for rice production. Zero-grade RAVC was the highest in two of the three years. RAVC does not include the costs of management, risk premium, or overhead. As stated in the yield section, there were production and management issues with the two zero-grade fields in 2006. Straight levee fields had the highest three-year average RAVC. Over the three years contour levee fields averaged $66/acre less than straight levee fields and $63/acre less than the zero-grade fields.

Hybrid varieties had the highest RAVC for two of the three years and the highest three-year average at $31/acre, $52/acre, and $200/acre more than CL hybrid, conventional, and CL conventional varieties, respectively. CL hybrid had the highest RAVC in 2006 and averaged higher returns than conventional varieties two of the three years. The average RAVC for the two fields of CL conventional in 2008 was $135/acre.

SIGNIFICANCE OF FINDINGS

The 54 farm fields that have participated in the RRVP since 2006 have provided useful yield and economic information. The three years provide real world examples of how land improvements, i.e., leveling to zero or a 0.15% slope, can increase yield, decrease costs, and increase profitability. The three years have also provided comparison of seed varieties across fields and years. These seed categories do not show the differences for each particular variety but by specific traits, i.e., hybrid, conventional, CL hybrid, and CL conventional. The results indicate that hybrids typically have the highest returns followed by CL hybrids, conventional, and CL conventional. One year and one variety on two fields of CL conventional does not provide a clear picture on how varieties in this category would compare to the other three. More data is needed for an accurate comparison. Overall, the three-years of data indicate that returns to a producer with an 80/20 crop share increased with field improvements by $66/acre when compared to unimproved fields and $52/acre with hybrid seed use when compared conventional varieties. These results do not imply that contour or specific varieties never outperform zero-grade fields and hybrids. It only illustrates on average from 2006 to 2008 land improved fields and hybrids have been more profitable in the RRVP.

ACKNOWLEDGMENTS

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Table 1. RRVP participation acres by category.

	2006	2007	2008	3-Year Average
	------------------------------ (RRVP acres) ------------------------------			
Field topography				
Zero grade	84 (2)[z]	126 (4)	184 (6)	131
Straight levee	696 (14)	325 (5)	806 (9)	609
Contour levee	230 (2)	194 (3)	506 (7)	310
Seed variety				
Hybrid	68 (3)	226 (4)	186 (2)	160
conventional	809 (13)	361 (6)	707 (11)	626
CL hybrid	133 (2)	58 (2)	405 (7)	199
CL conventional	----	----	198 (2)	198

[z] Parentheses represent number of farm fields that coincide with the acreage.

Table 2. Rice grain yields from the RRVP fields.

	2006	2007	2008	3-Year Average
	-------------------------------- (bu/acre)----------------------------------			
Field topography				
Zero grade	132	197	184	171
Straight levee	170	196	173	180
Contour levee	163	173	163	166
Seed variety				
Hybrid	185	198	191	191
Conventional	155	183	170	169
CL hybrid	214	197	179	197
CL conventional	----	----	141	141

Note: Results are a weighted acre average.

Table 3. Variable costs from the RRVP fields.

	2006	2007	2008	3-Year Average
	($/acre)			
Field topography				
Zero grade	312	403	650	455
Straight levee	399	408	663	490
Contour levee	361	441	698	500
Seed variety				
Hybrid	445	448	676	523
Conventional	361	393	649	468
CL hybrid	482	449	692	541
CL conventional	----	----	721	721

Note: Results are a weighted acre average.

Table 4. Return above variable costs from the RRVP fields.

	2006	2007	2008	3-Year Average
	($/acre)			
Field topography				
Zero grade	108	347	443	300
Straight levee	169	348	391	303
Contour levee	194	203	313	237
Seed variety				
Hybrid	181	310	513	335
Conventional	159	304	385	283
CL hybrid	227	288	397	304
CL conventional	----	----	135	135

Note: Results are a weighted acre average.

ECONOMICS

Price and Policy Analytical Baseline

E.J. Wailes and E.C. Chavez

ABSTRACT

International rice prices remained high in 2008/09 as major rice exporting countries continued to implement export restrictions and stocks controls to slow increases in domestic prices. This prompted some major rice importing nations to tender larger than normal import bids and relax import restrictions. Rice export prices have weakened in the short run as more exportable supplies become available. Resource constraints – higher input prices and limits on land and water for irrigation – are expected to cause price to increase steadily over the baseline, driven by strong consumption and trade, reaching $526/mt by 2018/19. Population-driven consumption growth keeps the global rice stocks-to-use ratio between 15 to 21% over the baseline. Over the next decade, total global rice trade is projected to grow by 2.1% annually, reaching 36.3 million mt in 2018/19. Thailand, Vietnam, and India account for 91.4% of the volume growth in world rice exports. With strong growth in population and per capita rice consumption, rice imports in Africa and the Middle East continue to increase substantially, accounting for 42.1% of the total volume growth in world rice imports over the next decade.

INTRODUCTION

Prices for U.S. rice are heavily influenced by the global rice economy. Supply, demand, trade, and stocks as well as policies in the U.S. and other major exporters and importers determine rice price paths. This study provides an assessment of the primary driving forces that are expected to determine rice prices and trade over the next ten-year period. This research is conducted in collaboration with the Food and Agricultural Policy Research Institute at Iowa State University and the University of Missouri-Columbia to provide U.S. policy decision-makers and the rice industry with a framework by which to evaluate alternative policies and market and technology changes.

PROCEDURES

We use the Arkansas Global Rice Model, a 30-country econometric model developed and maintained by the Department of Agricultural Economics and Agribusiness at the University of Arkansas, to generate projections of international rice production, consumption, trade, and prices for the period 2008 to 2018. Macroeconomic assumptions for national income, population, exchange ranges, price deflators, and energy prices are provided by Global Insight and are used exogenously to develop 10-year baseline projections for all major grains, oilseeds, cotton, sugar, and livestock. The framework for rice is developed and maintained by the authors in collaboration with other researchers at the Iowa State University and the University of Missouri who maintain the other agricultural commodity models of the Food and Agricultural Policy Research Institute. In November of each year, the researchers iterate the models to develop a preliminary baseline which is evaluated in Washington, D.C., by commodity and policy experts from various U.S. and international government agencies. Based on this evaluation a final baseline is developed in January and then made public for use by congressional committees and their staffs, USDA, and other domestic and international government agencies, and other researchers (FAPRI, 2009). The Arkansas Global Rice model is a system of over 200 econometric equations that specify functional relationships among area, yields, per capita consumption, trade (exports and imports), stocks, rice policies, and prices; and exogenous variables including per capita incomes, exchange rates, price deflators, and population growth rates.

RESULTS AND DISCUSSION

High international rice prices persisted in marketing year 2008/09 as major rice-exporting countries like India, Egypt, Pakistan, China, and Thailand continued to implement export restrictions and stock controls to dampen domestic price increases. The reference Thai 100% Grade B fob rice price averaged $550/mt (Table 1). This prompted some major rice-importing nations to tender larger-than-normal import bids; and to relax import restrictions. The global rice stocks-to-use ratio is 19.7% as supplies remain relatively tight (Table 2). The export price premium of U.S. long-grain rice over the Thai price remained high at $116/mt. Vietnam, however, sold rice at a discount by as much as $150/mt below the Thai price – making it very competitive in the global rice market. Rice export prices are projected to weaken in 2009/10 and 2010/11 as more exportable supplies become available. They then increase steadily over the baseline, driven by strong consumption and trade, reaching $526/mt by 2018/19. Population-driven consumption growth keeps the rice stocks-to-use ratio between 15% and 21% over the baseline.

World rice area in 2008/09 increases nearly 1.0%, to 155.8 million hectares (Table 2), as area gains in China, India, Bangladesh, Nigeria, Pakistan, and Thailand more than offset declines in Myanmar, Vietnam, and the Middle East. World rice production increases by 1.8%, to 439.1 million metric tons, as the world average yield improves by 0.8%. While yield gains occur in Argentina, China, Indonesia, Ivory Coast, Japan, South Korea, Nigeria, Taiwan, Turkey, and Uruguay during the same period, a number of countries experience declines, including the E.U., Myanmar, Pakistan, Vietnam, the U.S., and the Middle East. Global rice yields are expected to improve by 1.2% in 2009/10, offsetting a slight decline in area. Over the baseline, while world rice area is projected to decline marginally, average milled yield grows by 0.8% per year, reaching 3.06 metric ton per hectare by 2018/19.

Total world rice consumption in 2008/09 increased by 1.7%, to 432.4 million metric tons, as world population grew by 1.2% and average per capita use increased by 0.5%. China and India accounted for 77.4% of the net gain in global rice consumption in 2008/09. Total world rice trade in 2008/09 was 29.3 million metric tons, down 3.5% from the previous year, as declines in total export shipments from Thailand, India, Myanmar, and U.S. offset increases in Vietnam, Pakistan, China, and Egypt. Net world rice trade in 2008/09 is 26.9 million metric tons, up 0.6% from the previous year (Table 1).

World rice production has outpaced consumption since 2005/06, a situation that is projected to persist until 2011/12. Despite a slight decline in area in 2009/10, global rice production is projected to expand by 0.9%, to 443.2 million metric tons, as a result of 1.2% yield improvement. With world population growth of 1.2% and an increase of 0.1% in per capita use, total global rice consumption in 2009/10 increases by nearly 1.3%, to 438.1 million metric tons as world rice prices decline. Total world rice trade expands to 31.1 million metric tons during the same period, up 6.1% from the previous year, as more export supplies come from Thailand and India. With increased available supply relative to demand, international rice prices are expected to weaken in 2009/10.

Over the next decade, while global rice area declines marginally to 155 million hectares, yields continue to increase by 0.8% annually – causing total production to grow at the same rate. Likewise, total consumption continues to increase steadily by 1.0% annually, with expansion driven solely by population growth – as average per capita use declines marginally (Table 3). The decline in per capita use of rice in Asia is a result of the combined effects of the westernization of diets, urbanization, and diet diversification toward more protein-based foods, especially in rice economies with rising incomes, such as China, India, Indonesia, Vietnam, Thailand, Japan, South Korea, and Taiwan.

Area expansions in India, Bangladesh, Indonesia, Myanmar, Philippines, and Vietnam are not enough to offset the projected substantial contraction of 2.4 million hectares in China's rice sector. India accounts for 38% of the net growth in total production; with 45% coming from Vietnam, Thailand, the Philippines, Myanmar, Indonesia, and Bangladesh. India and Bangladesh account for 41% of the net gain in world rice consumption; with Brazil, Indonesia, Myanmar, Nigeria, the Philippines, and Vietnam accounting for 24%.

Over the baseline, global total rice trade is projected to grow by 2.1% annually, reaching 36.3 million metric tons in 2018/19, nearly 16% higher than the record set in 2006/07 (Table 2). Despite this growth, rice remains thinly traded in the international market relative to other grains, with the share of total trade to total consumption at 7.6% in 2018/19. All the growth in trade is accounted for by long-grain rice, as both exportable supplies of medium-grain rice are limited and demand is constrained by trade policies. Throughout the baseline, medium-grain prices relative to long-grain prices reflected in the US No. 2 Medium California fob price in Table 1 maintain a strong premium over long-grain prices.

Thailand, India, and Vietnam combined account for 91% of the volume growth in world net rice exports over the next decade. Per capita consumption in these three countries is projected to decline – allowing yield-based growth in production to outpace that of consumption. Pakistan's growth in production exceeds domestic consumption, enabling its rice exports to grow by 0.8% annually. In the U.S., however, growth in domestic rice consumption outpaces that of production, causing U.S. rice exports to decline by 0.8% per year over the same period. Despite the projected substantial contraction in rice area, China is expected to remain a rice net exporter although net exports decline at 4.8% annually, as yields improve slightly and per capita consumption declines. Uruguay and Argentina are also expected to increase exports, as area expands and yields improve, causing domestic output to substantially exceed domestic use. While Egypt's rice area remains flat and its domestic use expands faster than production, yield improvements enable the country to remain an exporter of 700,000 to 900,000 metric tons of rice over the baseline.

Over the same period, 64% of the projected net growth in import volume is accounted for by Bangladesh, Indonesia, Brazil, Ivory Coast, and the Philippines. With strong growth in population and per capita rice consumption, rice imports in Africa and the Middle East continue to increase substantially, accounting for 42.1% of the total volume growth in world rice imports over the next decade. Nigeria alone is expected to import 2.2 million metric tons by 2018/19, as consumption continues to outstrip production. Rice imports in Iran, Iraq, and Saudi Arabia are expected to continue to expand, since water availability remains a constraint in rice production in the region.

Despite declining per capita consumption in Indonesia and Bangladesh, strong population growth in these two countries causes total rice consumption to expand. The Philippines is projected to be the top rice importer over the baseline, as its rice self-sufficiency program has yet to attain significant traction and progress. Malaysia's rice imports remain around 800,000 to 900,000 metric tons over the baseline. Japan's rice imports, on the other hand, remain flat at the minimum access level of 482,000 metric tons in the absence of any expansion under the WTO.

Despite increasing rice yields, Brazilian imports are expected to expand over the baseline, as growth in consumption exceeds production. CAP reforms in the EU result in slow growth in production and an increase in rice imports. With area competition from cash crops and continued strong growth in per capita rice use in Mexico, imports expand 3.7% per year. Driven by growth in population and income, rice imports in Turkey continue to grow at 5.1% annually. Irrigation constraints have made Australia a net importer of rice since 2007/08, but its imports are projected to decline 3.0% annually over the baseline, as area recovers slightly.

SIGNIFICANCE OF FINDINGS

With nearly one-half of the Arkansas rice crop exported to foreign markets each year, an understanding of the market and policy forces that are driving the global rice economy are important for Arkansas rice producers and millers. Market prices received by Arkansas rice producers are primarily determined by the factors that affect international rice trade. This includes changes in rice production and consumption patterns, the economics of alternative crops, domestic and international rice trade policies as well as the general macroeconomic environment in which global commodity trade is transacted. The baseline presented in this report reflects research which brings together in a system of equations the major factors that will affect the Arkansas and U.S. rice economy over the next decade.

ACKNOWLEDGMENTS

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Table 1. World net rice

Marketing year	08/09	09/10	10/11	11/12	12/13
	------------------	------------------	------------------	------------------	------------ (thousand
Net exporters					
Argentina	546	586	607	642	655
Australia	-223	-246	-260	-225	-207
China	956	758	673	661	651
Egypt	791	692	770	816	837
India	2,444	4,134	4,716	4,377	4,388
Myanmar	213	299	290	292	255
Pakistan	4,155	3,661	3,919	4,100	4,248
Thailand	9,555	10,393	10,394	10,829	10,904
United States	2,658	2,646	2,434	1,943	1,986
Uruguay	850	965	1,018	1,045	1,039
Vietnam	4,936	4,659	5,004	5,479	5,741
Total net exports[z]	26,882	28,547	29,565	29,960	30,496
Net importers					
Bangladesh	1,306	1,293	1,904	2,411	2,493
Brazil	190	559	665	752	805
Canada	345	362	375	388	404
EU-27	963	970	980	1,025	1,067
China - HK	315	321	330	332	332
Indonesia	708	779	1,233	1,125	1,064
Iran	1,567	1,477	1,395	1,427	1,595
Iraq	1,125	1,195	1,229	1,261	1,294
Ivory Coast	762	1,081	1,094	1,135	1,193
Japan	500	482	482	482	482
Malaysia	876	821	784	798	808
Mexico	586	612	625	653	681
Nigeria	1,601	1,454	1,519	1,607	1,728
Philippines	2,416	2,722	2,563	2,571	2,617
Saudi Arabia	995	1,345	1,360	1,391	1,419
South Africa	856	937	948	963	971
South Korea	281	307	327	348	368
Taiwan	77	147	147	147	147
Turkey	195	208	202	208	219
Rest of world	11,217	11,474	11,402	10,934	10,810
Total net imports	26,882	28,547	29,565	29,960	30,496
	------------------	------------------	------------------	------------------	------ (U.S. dollars per
Prices					
Thai 100% Grade B	550	403	385	390	422
Thai 5% Broken	521	383	366	371	402
U.S. FOB Gulf Ports	666	610	611	605	602
U.S. No. 2 Medium	1070	882	806	785	795

[z] Total net exports are the sum of all positive net exports and negative net imports.

trade and prices.

13/14	14/15	15/16	16/17	17/18	18/19
metric tons)------					
705	721	740	781	843	865
-193	-177	-161	-158	-149	-165
664	656	662	641	612	583
899	897	896	901	871	928
3,859	3,746	3,683	3,837	4,217	4,410
224	178	147	140	149	174
4,405	4,392	4,445	4,481	4,484	4,502
11,089	11,259	11,474	11,601	11,659	11,849
2,164	2,302	2,522	2,592	2,512	2,444
1,055	1,077	1,087	1,125	1,148	1,179
6,003	6,257	6,152	6,263	6,298	6,642
30,875	31,307	31,646	32,203	32,643	33,411
2,513	2,659	2,760	2,654	2,482	2,619
863	858	882	930	971	956
418	431	445	458	474	488
1,046	1,032	1,050	1,095	1,101	1,102
331	332	333	335	339	342
1,035	1,178	1,183	1,425	1,611	1,510
1,708	1,743	1,698	1,726	1,854	1,840
1,325	1,348	1,374	1,402	1,432	1,474
1,215	1,239	1,291	1,322	1,365	1,439
482	482	482	482	482	482
796	825	862	881	893	890
706	729	753	780	810	842
1,871	1,876	1,974	2,016	2,145	2,191
2,656	2,763	2,721	2,887	3,021	3,041
1,443	1,471	1,497	1,525	1,555	1,586
977	997	1,015	1,044	1,076	1,122
388	409	409	409	409	409
147	147	147	147	147	147
237	260	267	287	304	321
10,718	10,528	10,504	10,397	10,171	10,609
30,875	31,307	31,646	32,203	32,643	33,411
metric ton) ------					
465	485	516	528	527	526
448	467	498	509	508	507
622	629	654	655	658	660
785	785	787	763	754	748

Table 2. World rice supply

Marketing year	08/09	09/10	10/11	11/12	12/13
	--				
Area harvested	155,841	155,427	155,362	155,107	154,641
	-- (metric				
Yield	2.82	2.85	2.88	2.90	2.91
	-- (thousand				
Production	439,081	443,189	447,517	449,269	449,448
Beginning stocks	78,687	85,353	90,440	94,998	96,672
Domestic supply	517,768	528,542	537,957	544,267	546,120
Consumption	432,415	438,102	442,959	447,595	451,388
Ending stocks	85,353	90,439	94,997	96,672	94,732
Domestic use	517,768	528,541	537,956	544,266	546,120
Trade	29,355	31,158	32,225	32,651	33,208
	--				
Stocks-to-use ratio	19.74	20.64	21.45	21.60	20.99

and utilization.

13/14	14/15	15/16	16/17	17/18	18/19
(thousand hectares)-------					
154,506	154,662	154,851	154,989	154,966	154,952
tons per hectare)-------					
2.93	2.95	2.97	2.99	3.03	3.06
metric tons)-------					
452,270	456,647	460,213	463,691	470,002	474,581
94,732	90,913	87,728	83,878	79,466	76,549
547,002	547,560	547,941	547,569	549,468	551,130
456,089	459,832	464,063	468,103	472,920	477,823
90,912	87,728	83,878	79,466	76,548	73,306
547,002	547,560	547,941	547,569	549,468	551,129
33,608	34,058	34,416	35,005	35,476	36,304
(percent)-------					
19.93	19.08	18.07	16.98	16.19	15.34

Table 3. Per capita rice consump-

Marketing year	08/09	09/10	10/11	11/12	12/13
	-------------	-------------	-------------	-------------	-------------
Argentina	7.7	7.6	7.6	7.6	7.7
Australia	14.3	15.2	17.3	17.1	17.0
Bangladesh	201.3	201.8	201.6	201.6	200.5
Brazil	44.2	45.4	45.7	45.8	45.9
Canada	10.4	10.8	11.1	11.4	11.8
China	89.7	89.7	89.5	89.6	89.5
Egypt	44.3	43.8	43.5	43.3	43.3
EU-27	5.6	5.6	5.6	5.6	5.6
China - HK	44.9	45.5	46.5	46.6	46.4
India	81.5	81.2	80.6	81.0	80.8
Indonesia	154.8	154.6	154.4	152.8	152.3
Iran	47.0	48.7	49.8	51.1	52.4
Iraq	40.2	43.6	43.9	44.3	44.5
Ivory Coast	70.9	80.2	81.6	81.5	82.4
Japan	63.8	64.4	65.1	65.0	64.7
Malaysia	95.0	91.4	90.3	89.4	88.9
Mexico	7.5	7.4	7.5	7.7	7.8
Myanmar	208.9	220.1	220.6	221.1	222.6
Nigeria	32.8	31.8	32.0	32.3	32.8
Pakistan	15.3	14.4	14.2	14.0	13.8
Philippines	136.5	137.5	139.1	139.0	138.7
Saudi Arabia	45.5	46.1	46.4	46.7	46.9
South Africa	17.5	18.5	19.2	19.6	19.9
South Korea	95.4	95.5	95.4	95.2	95.1
Taiwan	50.6	51.3	51.3	50.9	50.5
Thailand	144.9	146.9	146.6	145.8	144.8
Turkey	8.3	8.6	8.7	8.7	8.8
United States	13.4	13.9	14.0	14.0	14.0
Uruguay	28.8	28.6	29.5	30.3	31.2
Vietnam	220.9	220.8	219.8	218.7	218.9
Rest of world	44.6	44.3	45.3	45.0	44.6
World	64.5	64.6	64.5	64.4	64.2

tion of selected countries.

13/14	14/15	15/16	16/17	17/18	18/19
(kilograms)------					
7.7	7.7	7.8	7.8	7.8	7.9
17.4	17.6	17.8	17.8	17.9	17.9
199.7	200.0	199.9	199.7	198.6	198.4
46.2	46.3	46.3	46.5	46.6	46.6
12.1	12.4	12.7	13.0	13.3	13.6
89.1	88.3	87.2	86.7	85.2	84.5
43.5	43.4	43.4	43.5	43.5	43.4
5.6	5.6	5.6	5.6	5.7	5.7
46.0	46.1	46.0	46.2	46.6	46.9
80.9	80.9	80.9	80.8	80.7	80.3
150.8	150.2	149.1	148.8	148.8	147.5
53.2	53.5	52.8	53.0	54.3	54.1
44.7	44.7	44.8	44.9	45.0	45.3
82.6	83.4	84.9	85.8	86.4	87.7
64.5	64.3	64.1	64.1	63.9	63.7
87.5	88.2	88.6	88.8	88.9	88.4
8.0	8.1	8.3	8.4	8.6	8.8
223.1	223.6	224.7	225.3	226.0	226.5
33.4	33.3	33.6	33.5	33.6	33.4
13.6	13.6	13.4	13.1	13.2	13.2
138.8	138.7	138.1	138.8	139.1	138.9
47.0	47.2	47.3	47.6	47.9	48.3
20.1	20.5	21.0	21.5	22.1	23.0
95.0	94.7	94.6	94.7	94.7	94.5
50.1	49.8	49.4	49.3	48.9	48.6
143.6	142.8	141.9	140.5	139.9	139.4
9.0	9.2	9.3	9.5	9.7	9.8
14.0	14.0	14.0	14.1	14.1	14.2
31.9	32.7	33.3	34.0	34.6	35.2
219.2	219.0	218.7	218.7	218.9	218.5
45.5	45.8	47.5	48.0	50.7	53.4
64.2	64.0	63.8	63.7	63.7	63.7

ECONOMICS

Maximizing Returns to Nitrogen Application in Arkansas Rice Production

K.B. Watkins, J.A. Hignight, R.J. Norman, C.E. Wilson, Jr., N.A. Slaton, and D.L. Frizzell

ABSTRACT

High price volatility and historically high nitrogen (N) prices in recent years have increased farmer interest in determination of economically optimal N rates for rice production. This study uses eight years of variety by N data from the University of Arkansas to estimate rice yield response to N functions and applies the Maximum Return To N (MRTN) method to determine economically optimal levels of applied N for four different rice research locations in eastern Arkansas. The results indicate that N application levels that maximize returns at high urea prices may also produce returns not appreciably different from maximum returns achieved at lower urea prices. Therefore potentially less N may be required to achieve similar profitability. Nitrogen rates that either maximize or approximate maximum returns across different urea prices were 162 lb/acre at the Northeast Research and Extension Center (Keiser, Ark.); 148 lb/acre at the Southeast Research and Extension Center (Rohwer, Ark.); 127 lb/acre at the Rice Research and Extension Center (Stuttgart, Ark.); and 100 lb/acre at the Lake Hogue Research Farm (Wiener, Ark.).

INTRODUCTION

Nitrogen is a major input of rice production and accounts for approximately 19 to 25% of total variable production expenses for rice depending on the soil type (Watkins et al., 2008 a,b). Nitrogen prices were at record highs in 2008, with U.S. Gulf urea prices averaging \$463/ton and ranging from \$191 to \$753/ton for that year (Anonymous, 2008). The high volatility of fertilizer prices in recent years has led to increased desire among rice farmers to apply N optimally in the most profitable amounts. Nitrogen application also has environmental implications. Over-application of N can lead to nitrate contamination of water resources (Yadav et al., 1997). The objective of this study is to estimate economically optimal rates of applied N for different rice-producing locations in eastern Arkansas. The study uses eight years of variety by N data from the University of Arkansas to estimate rice yield response to N functions and applies the Maximum Return To N (MRTN) method to determine economically optimal levels of applied N for four different rice research locations in eastern Arkansas.

PROCEDURES

This study utilizes data from the Variety by Nitrogen Fertilizer Rate Study conducted annually by the University of Arkansas (Norman et al., 2008). Yield by N data were collected for non-hybrid, non-Clearfield varieties from four research locations for the period 2001 through 2008. The four research locations were: 1) the Southeast Research and Extension Center (SEREC) at Rohwer, Ark.; 2) the Northeast Research and Extension Center (NEREC) at Keiser, Ark.; 3) the Rice Research and Extension Center (RREC) at Stuttgart, Ark.; and 4) the Lake Hogue Research Farm (LH) in Wiener, Ark. Variety by N information was available for all eight years from both the RREC and the NEREC. Variety by N information was available for 2001 to 2006 from the SEREC and for the years 2004 to 2008 from LH.

Grain yield data were averaged across varieties by N application treatment and replication for each year and location. Nitrogen treatments were 0, 90, 120, 150, 180, and 210 lb/acre for the SEREC and NEREC locations, while N treatments were 0, 60, 90, 120, 150, and 180 lb/acre for the RREC and LH locations. Yield by N treatment data were replicated 6 times during the years 2002 to 2003; yield by N treatment data were replicated 4 times during all other study years. Four different yield response functions (quadratic, quadratic-plus-plateau, linear-plus-plateau, and Mitscherlich) were estimated for each location/year based on potential N response functions reported in the literature (Cerrato and Blackmer, 1990; Rajsic and Weersint, 2007; Yadav et al., 1997). The response functions were estimated using the REG and NLIN procedures in SAS. A quadratic function fit the data best for most location/years with the exception of 2003 for the RREC and SEREC locations and the years 2002, 2003, and 2005 for the NEREC location. A linear-plus-plateau function fit the data best during years in which the quadratic function performed poorly.

The MRTN method was used to determine economically optimal applied N levels for each location (Nafzinger et al., 2004; Sawyer et al., 2006). The MRTN method calls for estimation of yield response curves by site/year. Yields are estimated by site/year using the yield response curves in 1-lb N rate increments from 0 to the maximum rate (180 lb/acre for the RREC and LH locations; 210 lb/acre for the NEREC and SEREC locations). Net returns to N are calculated for each N rate and averaged across all site/years. The N rate with the highest average return to N for each site is defined as the MRTN rate. Net returns to N were calculated using the following formula:

$$RTN = P_Y Y - P_N N - A_n N$$

where RTN = Return to N (\$/acre); P_Y = rice price (\$/bu); Y = estimated yield response curve yield (bu/acre); P_N = N price (\$/lb); A_N = N application expense (\$/lb); and N = N rate (lb/acre). The rice price used for this study was \$5.50/bu and the N application cost was \$0.075/lb for aerial urea application (\$0.16/lb N applied). Urea prices were parameterized from \$150 to \$950/ton (\$0.16 to \$1.03/lb N).

RESULTS AND DISCUSSION

The average rice yield response to N by location is presented in Figure 1. The values separated by a comma in Figure 1 represent the yield maximizing level of applied N (left of comma) and the corresponding maximum yield (right of comma) for each yield response curve. Soils in the RREC and LH locations are predominately silt loam, and both regions have approximately equal yields when N applied is zero. Alternatively, soils in the SEREC and NEREC locations are predominately clay soils, and yields are similar for both locations when the amount of N applied is zero.

Yield potential is greatest for the RREC and SEREC locations (maximum yields of 178 and 177 bu/acre, respectively) followed by the NEREC location (maximum yield of 171 bu/acre). The LH location has the lowest yield potential of the four locations examined (maximum yield of 161 bu/acre). Yield maximizing N levels vary by location, with the SEREC location having the largest N level (179 lb/acre) and the LH location having the smallest N level (122 lb/acre). Although yield potential is approximately equal for both the RREC and the SEREC, the RREC location requires approximately 27 pounds less N to maximize yields than the SEREC location, and reflects the need for more N per acre on clay soils per University of Arkansas Cooperative Extension Service recommendations.

The MRTN and the profitable N range within 1% of MRTN is plotted using a urea price of \$350/ton and a rice price of \$5.50/bu in Figure 2. The numbers separated by a comma in the middle of each plot represents the MRTN level of applied N (left of comma) and the corresponding MRTN (right of comma), while the numbers separated by a comma on the right and left sides of each plot represent the low (left side) and the high (right side) levels of N necessary to achieve a return within 1% of the MRTN. The low and high N rates represent ranges of N application rates with similar profitability. These ranges reflect small yield changes near the MRTN level and indicate the choice of a specific N rate within each range is not critical for the rice producer.

The MRTN levels are smaller for the RREC and LH locations (the “silt loam” locations) relative to the SEREC and NEREC locations (the “clay” locations), reflecting that more N is required to maximize returns on clay soils relative to silt loam soils. Lake Hogue has the smallest MRTN level at 110 lb/acre but also has the lowest MRTN (\$823/acre), while the RREC has the second smallest MRTN level (138 lb/acre) and the largest MRTN (\$898/acre). These differences are largely due to the differences in yield potential between the two locations. Both “clay soil” locations have equal MRTN nitrogen levels (162 lb/acre) at the \$350/ton urea price, but the SEREC location has a larger MRTN ($883/acre for SEREC versus $849/acre for NEREC). The MRTN plot is not flat for the NEREC location as are the corresponding MRTN plots for the other three locations. The corresponding profitable N range for the NEREC location is also much narrower than that of the other three locations. These results are largely due to the number of years in which the yield response to N was linear rather than quadratic for the NEREC location relative to the other three locations.

The MRTN and the profitable N range for each location are presented for varying urea prices in Table 1. The price of rice is held constant at $5.50/bu in Table 1. Increasing the price of urea while holding the rice price constant reduces both the net return to N and the N rate at the point of maximum return. However, rice yields vary little across MRTN nitrogen rates as the urea price increases. For example, the MRTN rice yield at the RREC location is 175 bu/acre when the urea price is $750/ton. This yield is little different from the MRTN yields specified for lower urea prices (177 bu/acre at $150 and $350/ton urea; 176 bu/acre at $550/ton urea). Therefore, a rice producer at the RREC location could apply N at the lower MRTN rate specified for a $750/ton urea price (127 lb/acre) and achieve approximately the same return as that achieved for higher MRTN rates specified for lower urea prices. This result is verified by the fact that the 127 lb/acre application rate falls within the profitable N range specified for each urea price at the RREC location. Similar results occur at the SEREC and LH locations. The MRTN rate at the $750/ton urea price for each location (100 lb/acre for LH; 148 lb/acre for SEREC) falls within each profitable N range specified for lower urea prices. The NEREC location is the exception to the rule. The MRTN application rate at the NEREC location is constant at 162 lb/acre for all but the $950/ton urea price due to a large number of years having a linear yield response to N at this location. For the $950/ton urea price, the MRTN application rate is only 1 lb less than for the other ura prices at the NEREC location.

SIGNIFICANCE OF FINDINGS

The results of this study indicate that N application levels that maximize returns can vary by location, but more importantly that rice producers can, in some instances, apply less N than optimal and receive returns that are not appreciably different from the maximum returns achievable. Nitrogen rates at the point of maximum return decline as the price of urea increases. However, N application levels that maximize returns at high urea prices may also produce returns not appreciably different from maximum returns achieved at lower urea prices. Therefore potentially less N may be required to achieve similar profitability. These results apply to non-hybrid, non-Clearfield varieties. More research is required to determine profit maximizing N rates for Clearfield and hybrid varieties.

ACKNOWLEDGMENTS

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Table 1. Maximum Return to N (MRTN) and profitable N range within 1% of maximum return by urea price and location.

Urea	MRTN[z]			Low[y]		High	
Price	N Rate	Yield	Net return	N Rate	Yield	N Rate	Yield
($/ton)	(lb/acre)	(bu/acre)	($/acre)	(lb/acre)	(bu/acre)	(lb/acre)	(bu/acre)
Rice Research and Extension Center							
150	144	177	928	122	174	164	178
350	138	177	898	117	173	159	178
550	132	176	868	111	172	153	178
750	127	175	840	106	170	147	177
950	121	174	813	101	168	141	177
Lake Hogue							
150	115	161	847	96	158	134	161
350	110	160	823	91	157	129	161
550	105	160	799	87	156	124	161
750	100	159	777	82	155	118	161
950	95	158	756	77	153	113	161
Southeast Research and Extension Center							
150	168	177	919	145	174	192	177
350	162	176	883	141	173	185	177
550	155	176	848	139	172	177	177
750	148	175	815	136	171	170	177
950	144	174	784	135	171	163	177
Northeast Research and Extension Center							
150	162	170	885	154	168	181	171
350	162	170	849	153	168	176	171
550	162	170	814	151	168	172	171
750	162	170	779	148	167	170	171
950	161	170	744	144	165	168	171

[z] Rice price held constant at $5.50/bu.

[y] Low and High approximate the range within 1% of the MRTN for each urea price.

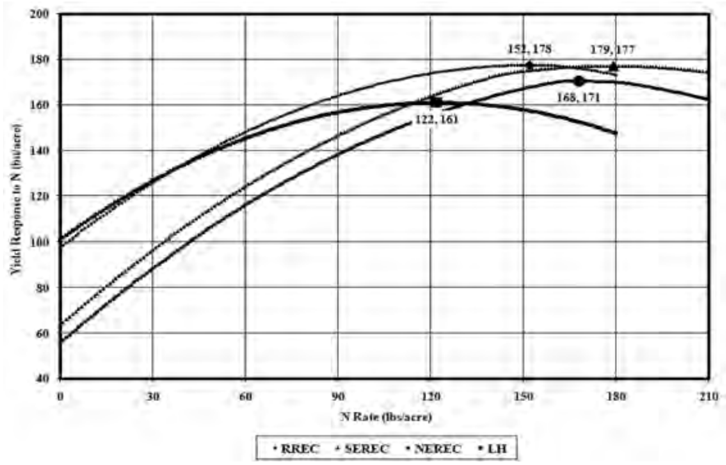

Fig. 1. Average rice yield response to fertilizer N at the Northeast Research and Extension Center (NEREC), Southeast Research and Extension Center (SEREC), Rice Research and Extension Center (RREC), and Lake Hogue Research Farm (LH). Values separated by a comma represent the yield maximizing level of applied N (left of comma) and the corresponding maximum yield (right of comma) for each yield response curve.

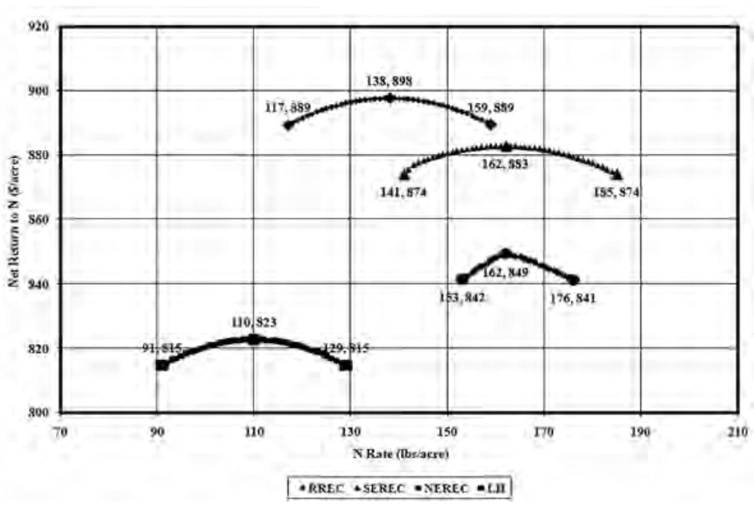

Fig. 2. Average rice net return to N and maximum return to N (MRTN) by research location at $350/ton urea price and $5.50/bu rice price. Locations are: the Northeast Research and Extension Center (NEREC), Southeast Research and Extension Center (SEREC), Rice Research and Extension Center (RREC), and Lake Hogue Research Farm (LH). The numbers separated by a comma in the middle of each plot represent the MRTN level of applied N (left of comma) and the corresponding MRTN (right of comma), while the numbers separated by a comma on the right and left sides of each plot represent the low (left side) and high (right side) levels of N necessary to achieve a return within 1% of the MRTN.

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