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Arkansas Rice Research Studies 1994

B. R. Wells
University of Arkansas, Fayetteville

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B.R. Wells, editor

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FOREWORD

The research reports in this publication represent one year of results; therefore, these results should not be used as a basis for long-term recommendations.

Several research reports in this publication dealing with soil fertility also appear in Arkansas Soil Fertility Studies 1994, Arkansas Agricultural Experiment Station Research Series 443. This duplication is the result of the overlap in research coverage between the two series and our effort to inform Arkansas rice producers of all the research being conducted with funds from the rice check-off.

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All authors are either current or former faculty, staff or students of University of Arkansas Division of Agriculture. For further information about any author, contact Agricultural Publications (501)575-5647.

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BREEDING, GENETICS AND PHYSIOLOGY

AN UPDATE ON THE ARKANSAS SEMIDWARF RICE BREEDING PROGRAM

K.A. Gravois, J.N. Rutger, K.A.K. Moldenhauer, F.N. Lee, R.J. Norman, R.S. Helms J.L. Bernhardt and R.H. Dilday

ABSTRACT

In 1991 a semidwarf rice breeding program was established in Arkansas that is funded primarily by grower checkoff funds administered by the Arkansas Research and Promotion Board. This program was augmented by the initiation of a mutation breeding program in 1994, which is funded primarily by the USDA-ARS. This report will summarize progress to date in the Arkansas semidwarf rice breeding program.

INTRODUCTION

The advent of semidwarf rice in the mid 1960s established new record yields in Asia. Semidwarfing genes were first used in California in the mid 1970s, and their use was the impetus for establishing rice yields unmatched in the world. 'Lemont' was released in the early 1980s in the southern U.S. and, along with 'Newbonnet', set new yield records. Since the release of Lemont, several other semidwarf rice varieties have been released, most notably 'Lacassine', 'Cypress' and 'Bengal'. The popularity of laser leveling of fields continues, making the production of semidwarf varieties even more attractive. In 1994, semidwarf rice occupied approximately 43% of the rice acreage in Arkansas, indicating the acceptance of lodging-resistant, semidwarf rice varieties. However, all of these rice varieties were developed along the Gulf Coast. Breeding and developing semidwarf rice varieties specifically for rice growing conditions in Arkansas could further boost yields. Thus, in 1991 a semidwarf rice breeding program was established in Arkansas. This report will summarize progress to date in the Arkansas semidwarf rice breeding program.

PROCEDURES

Prior to the release of 'Kaybonnet' and 'LaGrue', the process of developing a new rice variety ranged from 10 to 12 years. By advancing early generations through the use of greenhouses and the winter nursery in Puerto Rico, this time period has been decreased to seven to eight years. The steps involved in developing a new variety include crossing, early generation selection, yield testing and seed increase. Crossing in the semidwarf rice breeding program began in 1991, and in 1995 experimental lines from these crosses will enter the preliminary yield trials. Dr. J.N. Rutger is also cooperating in the semidwarf breeding program by developing semidwarf germplasm via mutation breeding techniques. Briefly, rice seed of different tall varieties were irradiated at Davis, California, with a dosage of 20 kR of radiation to induce mutation. Plant height genes are easily mutated. The M_1 generation is grown, and panicles are selected from approximately 2000 different plants. Each panicle is grown as a row in the M_2 generation where semidwarf mutants can be easily identified. Afterwards, crossing studies are done to verify that the dwarfing gene is the sd_1 gene. Semidwarf mutants from some of these populations are ready for evaluation in the preliminary yield testing stage.

RESULTS AND DISCUSSION

The goals of the Arkansas semidwarf rice breeding program are to develop high-yielding, lodging-resistant rice lines along with good milling quality and disease resistance. One of the problems inherent with semidwarf rice is poor seedling vigor due to short mesocotyl and coleoptile lengths. To circumvent this problem, most crosses have utilized parents such as Cypress, some California germplasm and some CIAT germplasm lines, all of which possess good seedling vigor along with the semidwarfing gene. The Arkansas breeding program germplasm base consists of many high-yielding lines with good seedling vigor but a greater potential to lodge than most semidwarf rice varieties. Semidwarf lines have been crossed to the existing germplasm with the goal of developing semidwarf lines of similar high-yielding attributes but superior lodging resistance. Six hundred twenty-two semidwarf lines will be evaluated in the preliminary yield testing stage in 1995 (Table 1). Semidwarf mutants from the mutation breeding efforts will enter the preliminary yield testing stage in 1996 (Table 2).

SIGNIFICANCE OF FINDINGS

Semidwarf varieties have greatly impacted rice yields in the southern U.S., California, Australia, Asia and many other areas. Developing semidwarf rice varieties adapted to Arkansas rice growing conditions is another means of further increasing Arkansas rice yields.

Table 1. Summary of progress for the 1991-1994 crossing series of the Arkansas semidwarf rice breeding program.

Crossing Series	Number of Crosses	Space Plants F_2 Populations	Winter Nursery F_3 Rows	Panicle Rows F_4	Panicle Rows F_5	Preliminary Yield Trials No. of Entries
1991	109	109	2800	2800	2562	622
1992	120	120	5000	5000	5544	
1993	118	118	5600	5600		
1994	129	129				

Table 2. Summary and projected progress for the Arkansas semidwarf rice breeding program via mutation breeding techniques.

Variety	M_1 Generation	M_2 Generation	Test for the sd_1 Gene	Preliminary Yield Testing
Orion	1993-94 Puerto Rico	1994 - Stuttgart	1995-96	1996
LaGrue	1994 - Stuttgart	1994-95 Puerto Rico	1995-96	1996
Adair	1994 - Stuttgart	1994-95 Puerto Rico	1995-96	1996
Katy	1994 - Stuttgart	1994-95 Puerto Rico	1995-96	1996
Kaybonnet	1994 - Stuttgart	1994-95 Puerto Rico	1995-96	1996
Alan	1994 - Stuttgart	1994-95 Puerto Rico	1995-96	1996
Millie	1994 - Stuttgart	1994-95 Puerto Rico	1995-96	1996

BREEDING AND EVALUATION FOR IMPROVED RICE VARIETIES - THE ARKANSAS RICE BREEDING AND DEVELOPMENT PROGRAM

K.A.K. Moldenhauer, K.A. Gravois, F.N. Lee, R.J. Norman, J.L. Bernhardt, B.R. Wells, M.M. Blocker and P.C. Rohman

ABSTRACT

The Arkansas rice breeding program is an ongoing program involving the development of new varieties, the testing of these varieties and the identification of important characteristics for further improvement. Disease resistance as well as high-yield potential, excellent milling yields, improved plant type (i.e., short stature, semi-dwarf, earliness, erect leaves) and superior quality (i.e., cooking, processing and eating) are all important components in this program. Currently there are several promising lines in this program. They are in all stages of the testing program and include lines with improved plant type, high grain and milling yields, disease resistance and acceptable cooking quality. New varieties will be released to rice producers in the future for the traditional Southern U.S. long- and medium-grain markets as well as for the emerging specialty markets. Funding for this work comes from grower check-off funds administered by the Rice Research and Promotion Board and the University of Arkansas.

INTRODUCTION

The rice breeding and genetics program at the University of Arkansas Rice Research and Extension Center is by nature a continuing project with the goal of producing new, improved rice cultivars for the clientele in Arkansas as well as the rest of the Southern U.S. rice growing region. Releasing cultivars with standard cooking quality, excellent milling and grain yields and improved plant type and disease resistance has been the objective of this program. Through the years, disease resistance and/or tolerance has been a major goal of this program. Blast resistance was addressed through graduate student research and by the release of 'Katy' and 'Kaybonnet'. Anther culture has also been utilized to speed up the breeding program for blast-resistant lines. Sheath blight tolerance has been an ongoing concern, and the cultivars produced by this program have the best sheath blight tolerance of any in the U.S. A recurrent selection program for increased sheath blight tolerance, which is a long-term approach to increasing resistance, also has been implemented, and information was given on this aspect of the breeding program in the 1993 report (Moldenhauer et al., 1994). As interest in specialty rices has increased, the program has taken on the added task of working to develop agronomically acceptable rice cultivars that are aromatic or have Japanese quality. Significant yield increases have been realized with the release of the three latest new long-grain cultivars 'Adair', 'LaGrue' and Kaybonnet developed in the program. New cultivars, lines currently in the program, are on the horizon that will offer even further increases in yield potential.

PROCEDURES

The rice breeding program continues to utilize the best available parental material from all sources, including other breeding programs in the U.S., the USDA/ARS World Collection and International programs such as CIAT and IRRI. Crosses are made each year to incorporate genes for broad-based disease and insect resistance, improved plant type (i.e., short-stature and semidwarf, earliness, erect leaves), superior quality (i.e., cooking, processing and eating) and N-fertilizer use efficiency into highly productive, well-adapted lines. Early generation selections are chosen from the various crosses each year and advanced a generation at the winter nursery in Puerto Rico. As outstanding lines are selected and advanced, they are evaluated extensively for yield, milling and cooking characteristics and by Dr. F.N. Lee for disease reactions. The advanced lines are extensively evaluated for proper timing and rates of N fertilization by Drs. R.J. Norman and B.R. Wells and for response to recommended weed control practices by Drs. R.H. Helms and C.B. Guy. The rice breeding program utilizes all feasible breeding techniques and methods, including hybridization, backcrossing, mutation breeding and biotechnology, to produce breeding material and new cultivars. Segregating populations and advanced lines are evaluated for grain and milling yields, quality traits, maturity, plant height and type and disease and insect resistance, as appropriate. The winter nursery in Puerto Rico is utilized to accelerate generation advance and breeders seed increases of potential varieties. The state-wide rice performance testing program, which includes rice varieties and promising new lines developed in the Arkansas program and from cooperating programs in the other rice producing states, is carried out each year to select the best materials for future release and to provide producers with current information on rice variety performance.

RESULTS AND DISCUSSION

Kaybonnet, the new blast-resistant, high-yielding, long-grain rice variety developed in this project, was released to qualified seed growers for the 1994 growing season. It originated from the cross Katy/ 'Newbonnet' made at Stuttgart, Arkansas, in 1986 and was selected from the 1988 panicle row STG88P2-81. It has yield potential and sheath blight tolerance similar to Newbonnet, blast resistance similar to Katy and excellent total and head rice milling yields. Data were presented on Kaybonnet in the 1993 annual report (Gravois et al., 1994). It continued to do well for producers and in the Arkansas Rice Performance Trials in 1994 (Helms et al., 1994)

Currently there are several promising lines in the breeding program. They have come from all phases of the breeding program (short-stature crosses, blast-resistance crosses, recurrent selection for sheath blight, anther culture and earliness crosses). Among these are two lines (RU9201176 and RU9201191) from a Newbonnet/Katy cross that are in the Arkansas Rice Performance Trials. These two lines have good grain yield and excellent milling yields as well as the blast resistance of Katy and the kernel size of Newbonnet. There are many lines in the Stuttgart Initial Test that are showing outstanding yield potential. Some of these have come from the crosses made in the recurrent selection program for sheath blight tolerance and could potentially result in new varieties.

Table 1 shows the number of lines that were in the different phases of this breeding project for the 1994 growing season. These numbers reflect approximately half of the crosses, F_2 space plants and panicle rows included in the entire program.

Anther culture has been used to quickly transfer blast resistance to shorter-statured and earlier-maturing material. Of the 104 anther culture lines that survived and were evaluated in the preliminary test in 1994, 73 had resistance to the blast races IB-49, IC-17 and IG-1 in initial evaluation, and only 31 were susceptible to these races. Many of these were semidwarf lines, and five of them had outstanding yields in the preliminary yield trials. Several of these lines will be advanced into the Stuttgart Initial Test for further evaluation in 1995. The anther culture program has been utilized only to produce blast-resistant cultivars. In the future, anther culture may be utilized to accelerate the development of lines with different quality characteristics such as high amylose, aromatic or Japanese quality.

Interest in development of a specialty rice for the Japanese market has increased since the Japanese purchased U.S. rice in 1994 and since passage of the GATT agreement. In 1990 we made our first crosses in the rice breeding program with the premium-quality, short-grain Japanese rice 'Koshihikari'. When compared to Southern medium-grain rice, this rice has a silky smooth texture, glossy appearance, mild aroma, sweet taste, poor agronomic characteristics and low yield potential. Fifty-three lines derived from five crosses involving Koshihikari were in the preliminary trials in 1994. Of these, 33 lines were selected for further evaluation based on improved plant type. These 33 lines and 90 other lines from Koshihikari crosses that were in the panicle rows in 1994 are currently being compared in both sensory and chemical tests to the Japanese rice cultivars Koshihikari and 'Akitakomachi'. The lines that score the best in these tests will be advanced into the 1995 Stuttgart Initial Test. Crosses were made this year between some of these lines and others lines with Koshihikari cooking-type to increase the chances of obtaining lines that are more desirable for the Japanese market. Through this program we hope to develop a high-yielding, agronomically adapted, short- or medium-grain rice that will have cooking quality acceptable to the Japanese market.

SIGNIFICANCE OF FINDINGS

The goal of the rice breeding program is to develop maximum-yielding cultivars with good levels of disease resistance for release to Arkansas rice producers. The release of Kaybonnet to qualified seed growers for the 1994 growing season and the existence of the potential release of a Newbonnet/Katy line are examples of the continued improvement that is being realized through this program. Improved lines from this program will continue to be released in the future. They will have the characteristics of improved disease resistance, plant type and grain and milling yields. In the future new rice varieties will be released not only for the traditional Southern U.S. long- and medium-grain markets but also for specialty markets as they arise.

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Table 1. Number of lines in each phase for project ARK01387.

Evaluation Phase	Number of Lines
Crosses	105
F_2 Space Plants	55,600
F_3 Panicle Rows Puerto Rico	7000
F_4 P^z Panicle Rows	7000
L & M Panicle Rows	9660
Preliminary Trials	800
Stuttgart Initial Test	120
Arkansas Rice Performance Trials	60

^{z}P = panicles returned from Puerto Rico; L = long grain; M = medium grain.

GENETIC, PHYSIOLOGICAL AND BIOCHEMICAL ENHANCEMENT OF EXOTIC RICE GERMPLASM

R.H. Dilday, R.S. Helms, B.R. Wells, K.A. Gravois, W. Yan, J. Lin, M. Price, M. Jalaluddin, C. Guy and K.A. Moldenhauer

ABSTRACT

Accessions in the USDA/ARS rice germplasm collection were evaluated for allelopathy to ducksalad (5), redstem (5) and barnyardgrass (4000). Four rice germplasm accessions that demonstrated allelopathic activity reduced adjacent ducksalad dry weight and redstem plant number significantly when compared to the commercial check 'Rexmont', which has no allelopathic activity. Fifteen rice accessions showed apparent allelopathy to barnyardgrass. Nine of the 15 accessions originated either in India or at the International Rice Research Institute (IRRI) in the Philippines. Rice germplasm was identified that can tolerate up to a 1.0X rate of glyphosate without significant reduction in total grain yield. Most of the glyphosate-tolerant germplasm originated at the Central Institute of Tropical Agriculture (CIAT) in Columbia.

INTRODUCTION

The value of rice production in the U.S. is estimated at about $1.1 billion. The value of the rice crop in Arkansas is estimated at about $478 million (USDA, 1993). More than 50 weed species infest direct-seeded rice and cause major losses in U.S. rice production (Smith et al., 1977). In fact, annual losses due to weeds are estimated at about 17% of the total production. The greatest amount of genetic diversity in rice within a single collection in the U.S. is in the USDA/ARS rice germplasm collection. There are 16,476 rice varieties or accessions from 99 countries in the collection. The USDA/ARS collection is the primary genetic base for all variety development in rice in the U.S.

Two areas of germplasm evaluation and enhancement for weed control were emphasized in 1994. These areas were 1) allelopathy (ability of a rice plant to suppress adjacent weed growth and development) in rice to weed species including ducksalad (*Heteranthera limosa*), redstem (*Ammannia* spp.) and barnyardgrass (*Echinochloa crus-galli*) and 2) tolerance of rice germplasm to glyphosate (Roundup) for weed control, including red rice.

PROCEDURE

Investigations involving allelopathy in rice to ducksalad and barnyardgrass and germplasm tolerance to herbicides were conducted on a Crowley silt loam soil at the Rice Research and Extension Center (RREC) near Stuttgart, Arkansas.

Allelopathy

Ducksalad and Redstem. A field experiment was conducted to determine the effects of rice allelopathy and nitrogen (N) management on control of aquatic weeds, including ducksalad and redstem, in water-seeded rice. Four allelopathic rice lines (PI Nos. 312777, 338046, 366150 and 373026) and 'Rexmont' (PI 502968), a standard cultivar without allelopathic activity, were tested. The experiment was arranged in a split-plot design with four replications. N rates (0, 60, 90, 120 and 180 lb/acre) were main plots, and rice lines were sub-plots (3 ft x 6 ft). The 60-, 90- and 120-lb/acre N rates were incorporated 2 in. deep in the soil before flooding. For the 180-lb/acre N treatment, 120 lb/acre N was incorporated in the soil before flooding, and 60 lb/acre N was applied topdress at midseason. Rice seed that had been pregerminated for 36 hours was broadcast in a 2-in. flood. Because a natural infestation of ducksalad and redstem occurs in the field, seeding the test with aquatic weeds was not necessary. Aquatic weeds germinated 5 to 7 days after flooding. Grasses, such as barnyardgrass and sprangletop (*Leptochloa* spp.) were controlled by flooding. Other unwanted weeds were controlled by handweeding. Visual ratings were taken 7 weeks after flooding. At rice maturity, ducksalad, redstem, rice straw and grain were harvested from the entire plot after counting the number of redstem plants within each plot. Above-ground rice root biomass and roots 0.5 in. below the soil surface in a 16-in.-diameter circle were harvested. The 16-in. samples were collected randomly from the plots, and roots were separated from the soil by washing through a sieve (No. 20). All materials harvested were dried and weighed. Weed dry weights expressed as a percentage of weed reduction when compared with Rexmont plots were analyzed by SAS.

Barnyardgrass. Approximately 4 lb of barnyardgrass seed/acre was seeded with a cyclone-seeder and incorporated with a harrow prior to seeding the rice. Approximately 4,000 accessions, including checks, were seeded in paired rows 8 in. apart and 4 ft long. Paired row plots were 21 in. apart and seeded in two replications. The percentage reduction in barnyardgrass plant population between the 8-in. paired rows was recorded at pre-flood and at rice maturity.

Germplasm Tolerance to Glyphosate (Roundup)

Twelve rice germplasm accessions (PI Nos. 319703, 319704, 350468, 350469, 353719, 388582, 399662, 414714, 414715, 430438, 431481 and 433838), two commercial checks ('Alan' and 'Katy') and two red rice biotypes (Blackhull and Strawhull) were seeded in six row plots that were 4 ft in length and replicated four times. Each accession was treated at three rates, 0.5X, 1.0X and 2.0X (0.375, 0.75 and 1.5 lb active ingredient (ai)/acre), respectively, of glyphosate at three dates: pre-flood, two weeks and three weeks after first flood. Each plot was harvested at maturity for total grain yield.

RESULTS

Allelopathy

Ducksalad. At the 0 level of N, the four germplasm lines with allelopathy were not significantly different for aquatic weed control when compared visually to Rexmont at 7 weeks after seeding. At the 60-, 90-, 120- and 180-lb/acre N levels, the allelopathic rice lines controlled aquatic weeds 61, 69, 70 and 74% (averaged over the four allelopathic lines), respectively, when compared to Rexmont. However, at maturity, ducksalad plants were harvested and dried, and the four rice germplasm accessions with allelopathy significantly reduced ducksalad dry weight at all fertilizer rates (Table 1). The mean reduction in ducksalad dry weight by the four rice accessions with allelopathy at the 0-, 60-, 90-, 120- and 180-lb/acre N level were 52, 66, 93, 100 and 100%, respectively, when compared to Rexmont.

Redstem. At rice maturity, Rexmont plots contained about six times as many redstem plants/ft^2 as plots seeded to the allelopathic rice lines over all N treatments (Table 2). Redstem biomass in Rexmont plots was 10 times greater than in allelopathic rice line plots. With the allelopathic lines, redstem control was significantly greater in plots seeded to allelopathic lines and treated with 60 lb/acre N than in plots treated with no N. At 90 to 180 lb/acre, N levels of the allelopathic lines controlled 99 to 100% of the redstem (Table 3). Increasing N levels from 60 to 180 lb/acre did not change above-ground rice root biomass but increased straw biomass averaged over all rice lines. There was a negative correlation between total rice biomass (root, straw and grain) and weed biomass (-0.85 for ducksalad and -0.78 for redstem).

Barnyardgrass. Fifteen rice accessions reduced the percentage of barnyardgrass plants from 40 to 78% in a field test when compared to the commercial check, 'Lemont' (Table 4). The 15 accessions originated in China, India, Italy, Japan, Mexico, Peru, Philippines, Taiwan and Turkey. However, 9 of the 15 accessions originated from either India or the Philippines.

Glyphosate

There was no significant difference in total grain weight between the untreated checks and the 0.5X and 1.0X rate for spray dates 1 and 2 or the 0.5X rate at spray date 3 for five accessions (PI Nos. 319703, 388582, 414714, 414715 and 433838) tolerant to glyphosate. Furthermore, no treatment except the 2.0X rate at spray date 3 significantly reduced total grain weight of PI 430438 when compared to the untreated check. However, the total grain weight of the untreated check of PI 430438 was significantly lower than the total grain weight of each of the other accessions. Glyphosate at the 2.0X rate at spray dates 1 and 2 caused significant reduction in yield for all the accessions and the two cultivars and resulted in almost no yield for Alan and Katy, especially at spray date 1. The two red rice biotypes (blackhull and strawhull) are very sensitive to glyphosate and did not survive any glyphosate treatment level at any spray date (Table 5).

SIGNIFICANCE OF FINDINGS

Annual losses due to weeds in rice and the cost of herbicides to control weeds in rice result in large losses to the rice producer annually. Developing cultivars that possess allelopathic activity to weed species can significantly reduce these losses. Identifying rice germplasm possessing tolerance to glyphosate and developing improved cultivars that are tolerant to the herbicide could result in a single application of a herbicide for weed control in rice that is non-toxic and environmentally safe when it contacts the soil.

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Table 1. Effect of rice accessions with allelopathy on the percentage reduction of ducksalad dry weight compared to 'Rexmont' (PI 502968).

N Levels (lb/acre)	PI No.	% Reduction
0	312777	54
	338046	53
	366150	54
	373026	48
	502968	0
60	312777	69
	338046	83
	366150	53
	373026	59
	502968	0
90	312777	88
	338046	95
	366150	97
	373026	92
	502968	0
120	312777	100
	338046	100
	366150	100
	373026	100
	502968	0
180	312777	100
	338046	100
	366150	100
	373026	100
	502968	0
$LSD_{(0.05)}$		20

Table 2. Effect of four rice accessions with allelopathy on redstem plants/ft² over all nitrogen (N) levels compared to 'Rexmont' (PI 502968), a cultivar without allelopathy.

PI No.	Plants/ft²
312777	0.89
338046	1.00
366150	1.19
373026	1.04
502968	5.68
$LSD_{(0.05)}$	0.92

Table 3. Effect of rice accessions with allelopathy on the percentage reduction of redstem dry weight compared with 'Rexmont' (PI 502968).

N Levels (lb/acre)	PI No.	% Reduction
0	312777	73
	338046	66
	366150	79
	373026	68
	502968	0
60	312777	94
	338046	96
	366150	91
	373026	89
	502968	0
90	312777	99
	338046	99
	366150	99
	373026	99
	502968	0
120	312777	100
	338046	100
	366150	100
	373026	100
	502968	0
180	312777	100
	338046	100
	366150	100
	373026	100
	502968	0
$LSD_{(0.05)}$		10

Table 4. Origin, percent weed reduction, plant height, grain type, days to maturity and seed coat color of rice germplasm accessions that showed apparent allelopathic activity to barnyardgrass in 1994.

PI or CI Number	Germplasm Identification	Country of Origin	Percent Weed Reduction	Plant Height (cm)	Grain Type[z]	Days to Maturity[y]	Seed Coat Color[x]
CI 12108	Paraga Selection	Philippines	50	110	S	110	Lt.Br.
CI 12198	Kinai Early no.70	Japan	45	132	M	154	Lt.Br.
CI 12220	Palman Sel.	India	40	150	L	97	Lt. Br.
CI 12225	Vansi Sel.	India	45	148	L	90	Lt.Br.
160530	Pan Ju	China	50	139	M	85	White
180177	Lambaygue no. 1	Peru	78	160	L	90	Brown
182256	No. 10623	Turkey	45	112	M	78	Lt.Br.
230105	Reata	Mexico	60	128	M	92	Lt.Br.
233894	S 67	India	45	117	L	92	Lt.Br.
245067	Nanton no. 84	Taiwan	45	136	L	148	Purple
248164	Chin Nung Yu	Italy	40	131	S	122	Lt.Br.
312524	IR 36-27-1-1	IRRI	55	100	L	104	Lt.Br.
312709	IR 4-90-3-2	IRRI	50	105	S	124	Lt.Br.
338060	IR 753-175	IRRI	65	82	L	115	Lt.Br.
376253	Arc 11611	India	65	168	N/A	159	Lt. Br.
475833	Lemont (Ck)	U.S.A.	0	74	L	85	Lt.Br.

[z]Grain type: S = short, M = medium and L = long.
[y]Day to maturity: From seedling emergence to 50% of the panicles emerged.
[x]Seed coat color: Lt. Br.=light brown.

Table 5. Total grain yield (lb/acre) of rice germplasm tolerant to glyphosate at three spray rates and three maturity dates (pre-flood, 2 and 3 weeks after first flood).

		Date 1			Date 2			Date 3		
PI or name	CK	0.5X	1.0X	2.0X	0.5X	1.0X	2.0X	0.5X	1.0X	2.0X
319703	6192	6132	5988	3702	5808	6246	4104	5544	3672	0.0
388582	6636	6516	7032	4650	6402	6210	4248	6132	4344	0.0
414714	6114	6994	6486	4914	6288	6150	3828	5364	3462	0.0
414715	6408	6198	6870	3960	5434	5922	4446	5364	3816	0.0
430438	4146	4662	3588	3006	3948	3228	2670	5028	4116	0.0
433838	5976	6252	5802	4800	6414	6132	3156	5496	3462	0.0
Alan	5310	5700	4980	216	4806	3186	636	2340	360	0.0
Katy	5754	5412	4764	102	5724	5538	2622	5418	2226	0.0
Strawhull[z]	0	0	0	0	0	0	0	0	0	
Blackhull	0	0	0	0	0	0	0	0	0	

LSD-1 = 984 : compare lines for CK yield only;
LSD-2 = 1080 : compare lines for TRT yield only;
LSD-3 = 1026 : compare lines between CK & TRT yield.
[z]Red rice plants in the untreated checks were removed from the field prior to maturity.

HIGH-YIELDING CHINESE RICES: POTENTIAL VALUE FOR IMPROVING ARKANSAS RICE VARIETIES

Paul A. Counce, Kenneth A. Gravois and Thomas A. Costello

ABSTRACT

Physiological reasons for greater grain yields for the Chinese rice variety 'Gui-chao' compared to U.S. rice varieties were investigated. A field experiment was conducted at the Northeast Research and Extension Center at Keiser, Arkansas, to compare grain-filling and endosperm enzyme activities of Gui-chao, 'Bengal' and 'Lemont'. Sucrose metabolism enzymes in the endosperm of Bengal, Lemont and Gui-chao grain were assayed during the course of grain-filling. Higher sucrose synthase activity was observed from mid-grain filling onward for Gui-chao. Gui-chao had a higher grain yield than either Lemont or Bengal. The increased grain yield appeared to be related to more culms and panicles per ft^2 and more filled grains per panicle for Gui-chao than for either Bengal or Lemont. During grain filling, the number of filled grain appears to increase for Gui-chao for a longer time than for U.S. varieties. It is expected that the greater sucrose synthase activity of Gui-chao confers its ability to fill grain over a longer period of time than U.S. varieties. Consequently, the higher sucrose synthase activity appears to be related to Gui-chao's high grain yield.

Future yield advances for Arkansas rice varieties may be accomplished by learning how to incorporate the yield traits of Gui-chao into Arkansas rice varieties. This research effort can be a part of that accomplishment.

INTRODUCTION

Several Chinese rice varieties have extremely high rice grain yields. The grain yields of elite Chinese lines are substantially greater than those of elite U.S. rice lines. The Chinese variety 'Gui-chao', for instance, yielded 40 to 60 bu/acre more rice than 'Lemont' in field trials at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas (1991-1993). Incorporation of the yield characteristics of these Chinese varieties into high-yielding U.S. rice lines adapted to Arkansas growing conditions would be advantageous.

Grain quality and taste of U.S. rice lines are superior to those of Chinese varieties by both American and Chinese standards. Through many years of breeding, primarily for grain yield, the Chinese breeders have made great accomplishments in grain yield at the sacrifice of grain quality. These high-yielding Chinese rice varieties are not unrefined breeding lines. They share many agronomic traits with the best U.S. rice varieties. They produce stable yields over years, and they have erect leaves and short plant stature. Consequently, incorporating the best traits of the Chinese varieties into U.S. lines may be less difficult than for traits from more exotic germplasm.

The newer U.S. varieties, such as 'Kaybonnet' and 'Adair', are valuable breeding resources. Our presently available rice varieties are well adapted to a wide range of Arkansas growing conditions and have excellent grain quality and taste. From 'Starbonnet' to 'Newbonnet' to Kaybonnet, Arkansas rice varieties have produced high-quality, long-grain-type rice with progressively higher grain yields. Infusing Arkansas varieties with the best characteristics of Chinese varieties could potentially produce rice varieties with much higher yield potential while maintaining grain and cooking quality.

MATERIALS AND METHODS

'Bengal', Gui-chao and Lemont rice were seeded in 6 ft X 70 ft plots with five replications. Rice was seeded with 45 seeds/ft^2 in the field at the Northeast Research and Extension Center at Keiser, Arkansas, in 7-in. drill rows. Rice was fertilized with 120 lb N/acre and flooded within a day at the five- to seven-leaf growth stage. At 0.5-in. internode elongation, an additional 30 lb N/acre was applied, and 7 days later another 30 lb N/acre was applied to the crop. A flood was maintained until 7 days after 50% heading for the latest heading variety in the experiment.

Panicles judged to be uniform were tagged on the date of beginning anthesis (when the green flowers that become rice grains open). Enough panicles to provide four to five samples were harvested at 7-day intervals for determination of enzyme activity and weight increases. This was done until at least 49 days after anthesis. Kernel development was determined by weight from panicles collected concurrently with the enzyme assay samples. Individual panicle samples were dried at 70 C until weights stabilized. Subsequently, the dried rough rice grains were weighed.

The enzyme extraction consisted of removing the endosperm from the developing kernels within 3 hours of collection. The endosperm was ground in liquid N_2 and extracted with a 200-mM Hepes extraction buffer followed by desalting and assay, as described by Xu et al. (1989). For the assay, the number of developing kernels and number of panicles were recorded for the assay so that enzyme activity could be expressed on fresh weight, protein, per kernel, per panicle or per mg protein basis. Enzymes assayed were sucrose synthase, UDP glucose pyrophosphorylase, pyrophosphate phosphofructokinase, NTP-phosphofructokinase and acid and neutral invertases. Enzyme assays were done within 7 hours of collection except for the invertases. In some cases, acid and neutral invertase assays were done as much as 30 hours after collection due to our findings that invertase activities of desalted extract did not decline below initial activities for 3 days or more after collection.

Lengths of 6.5 ft x 7 in. of interior rows (third row from outside) of the standing crop were cut at ground level at maturity to determine yield components and harvest indices. Grain yields were determined from the combine harvest. The combine-harveted area was 28 in. by 20 ft. Harvest index (decimal fraction of grain to total above-ground dry matter (grain and stubble)) is a useful measure of how a crop partitions its above-ground dry matter yield into grain.

RESULTS AND DISCUSSION

Yields were greater for Gui-chao than for either Lemont or Bengal (Table 1). The yield components in Table 1 show that the increased yield was the result of more tillers/ft^2, more panicles/ft^2 and more grains/panicle. Gui-chao had lower individual kernel weights than Bengal. The harvest index was about the same for Bengal and Gui-chao and slightly higher than that for Lemont.

The kernels developed at similar rates for all three varieties, although Bengal kernels grew to be much heavier than Gui-chao or Lemont kernels (Table 2). As in previous experiments, Gui-chao either had or tended toward having higher sucrose synthase activity per kernel or per mg of protein.

Gui-chao probably achieves its high yield by several selected traits, including increased tillering, filled grains as a percentage of total florets and panicles per culm. The higher sucrose synthase activity may be involved in some of these yield component traits but not in others. Gui-chao, however, does appear to have a high number of filled grain per panicle, and the high sucrose synthase activity likewise appears to be related to the number of filled grain.

Incorporating Gui-chao genes into Arkansas rice varieties could improve the yields of Arkansas rice. A Chinese line derived from Gui-chao ('Qi-gui-zao') yielded 207 bu/acre at Keiser in 1994. (In that test Lemont yielded 136 bu/acre.) Qi-gui-zao has grain dimensions nearly acceptable for a long-grain variety. It also has long-grain cooking characteristics. Future yield advances in Arkansas rice varieties may be accomplished by learning how to incorporate the yield traits of Gui-chao into Arkansas rice varieties. This research effort can be a part of that accomplishment.

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Table 1. Yield and yield components from a field experiment with 'Bengal', 'Gui-chao' and 'Lemont' rice conducted at Keiser, Arkansas, in 1994. Grain yields and yield component samples were taken at grain maturity.

Variety	Crop Yield	Culm Density	Panicle Density	Grains/ Panicle	Individual Grain Weight	Harvest Index[z]
	bu/acre	culms/ft^2	panicles/ft^2	no.	mg/grain	no.
Bengal	168 (6)[y]	40 (1)	32 (1)	87 (3)	28.8 (0.2)	0.562 (0.007)
Gui-chao	185 (6)	57 (5)	48 (3)	99 (3)	26.0 (0.3)	0.552 (0.008)
Lemont	132 (7)	46 (3)	36 (3)	76 (4)	26.5 (0.5)	0.497 (0.005)

[z]Harvest index = grain weight/(grain + stubble weight).
[y]Values are means (standard errors of the mean).

Table 2. Individual kernel weights and sucrose synthase activities for three rice varieties grown in the field at Keiser, Arkansas, in 1994

	Individual kernel weights			Sucrose synthase activity per kernel			Sucrose synthase activity per unit of protein		
Anthesis	Bengal	Gui-chao	Lemont	Bengal	Gui-chao	Lemont	Bengal	Gui-chao	Lemont
Days	--------mg/kernel--------			nmoles/kernel/minute			nmoles/mg protein/minute		
7	5.1	4.7	5.8	4.4	1.5	3.5	58.4	48.8	28.6
14	16.2	12.3	13.8	15.5	24.0	16.5	66.5	138.5	56.8
21	22.5	20.3	22.8	7.4	10.0	7.9	43.5	73.1	58.2
28	23.9	20.9	23.5	4.3	4.0	1.8	38.0	126.7	14.7
35	24.8	22.2	24.3	1.9	2.1	0	13.5	29.4	0
42	25.9	23.6	22.3	0.5	2.4	1	0	19.9	0
49	26.9	24.1	23.1	0	1.1	1.1	0	27.8	18.5

SCREENING OF THE USDA/ARS WORLD COLLECTION OF RICE GERMPLASM FOR ALKALINITY TOLERANCE

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ABSTRACT

More than 14,000 accessions of the USDA/ARS rice germplasm collection have been screened for tolerance to high-pH soils (pH > 7.5). Ten seeds of each of the accessions were planted in a Calloway silt loam soil that had been amended with $CaC0_3$ (<100 mesh) to a pH of between 7.5 and 8.0. The criteria set for determining the potential for tolerance to high pH included a minimum of 75% emergence from the high-pH soil and at least 75% of the emerged seedlings asymptomatic for zinc (Zn) deficiency at four weeks after flooding. Four hundred eighty-three accessions were asymptomatic for Zn deficiency in one or more replications of the study. These lines are currently being screened through two more replications to verify their tolerance.

INTRODUCTION

Zinc deficiency is the most common problem found in rice seedlings grown in high-pH soils and has been a problem for many Arkansas rice producers since the 1950s. Symptoms of Zn deficiency are found predominantly on seedling rice growing on silt loam soils with a pH greater than 7.3. It is important to note that in most Arkansas soils, Zn deficiencies are due not to shortages of Zn but to the reduced availability of Zn in high-pH soils. Due to the physical structure and/or chemistry, Zn deficiency is usually not a problem in clay soils. Since groundwater with high levels of calcium bicarbonate (limestone) is used in the large quantities required for rice production, a significant amount of limestone is added to these soils over time. As the pH of these soils increases, the availability of Zn to seedling rice decreases. Pre-plant-incorporated Zn sulfate ($ZnSO_4$) has been used to alleviate Zn deficiency symptoms in silt loam soils known to have high pH's. After Zn deficiency symptoms have appeared, foliar-applied Zn chelate (ZnEDTA) has been the mainstay for any salvage treatment. For many years these fertilizers have been used with great success. However, Zn deficiency problems have resurfaced during the past 5 to 10 years. Some rice producers have decided to cut production costs either by reducing the quantity of Zn fertilizer applied or by halting the application of preplant Zn altogether. An additional problem may lie with the manufacture of new Zn products that may not contain sufficient Zn in forms that are available to the rice seedlings. The development of new rice varieties that can tolerate relatively high-pH soils would allow normal rice production without expensive reclamation processes or application of Zn, which is a heavy metal that could prove toxic in high concentrations, especially if the water source is changed to one with calcium bicarbonate.

MATERIALS AND METHODS

The USDA/ARS rice germplasm collection is being screened for alkalinity tolerance in a soil-based system. The USDA/ARS supplied 5 g of seed from each of the more than 16,000 accessions. The screening process was replicated twice. The first replication was seeded in the order in which the seed arrived. The second replication was randomized with the statistical package MSTAT.

Each accession of the USDA/ARS collection was seeded in a Calloway silt loam soil amended to a pH of 7.5 or greater with finely ground limestone ($CaCO_3$). The soil pH was closely monitored in order to maintain a pH range between 7.5 and 8.0. Twenty-four accessions of rice were seeded in each 33 x 43-cm (13 x 17 in.) plastic Kitty Litter tray filled with a volume of soil that would fill a 12-liter plastic bucket. The soil in the tray was then leveled and compacted. A plexi-glass template, which was designed to divide the tray into 2 columns of 12 rows each, was used as a guide to make furrows in the compacted soil.

Ten good seeds from each accession (following removal of florets that were blank, discolored, misshapen or previously germinated) were placed in each furrow within the template. After the tray was seeded, the template was removed, and the seeds were covered with approximately 2 cm (0.75 in.) of soil. Enough deionized water (approximately 750 ml) was sprayed over each tray to cause the soil pores to seal. An additional 500 to 750 ml of deionized water was applied to each tray just before a 3.5-ml-thick sheet of polyethylene plastic sheeting was placed over the trays to enhance germination and emergence. The plastic sheeting was removed at seeding plus 5 days.

During the 15 days between emergence and flooding, the rice was irrigated with deionized water as needed to maintain a soil moisture suitable for optimum seedling growth. Immediately prior to flooding, the rice seedlings were counted and then fertilized with 45 kg/ha (40 lb/acre) of nitrogen. Seedling counts were taken to document emergence and the number of live seedlings at flooding. Counts of the total number of plants and numbers of symptomatic and asymptomatic plants were made at four weeks after flooding.

RESULTS AND DISCUSSION

To date 14,269 accessions of the more than 16,000 in the USDA/ARS world collection of rice germplasm have been evaluated for tolerance to high-pH soils. Of these more than 14,000 accessions, 483 have demonstrated a relatively high degree of tolerance to high-pH soils in one or more replications. We are presently screening these 483 accessions through two additional replications to determine more precisely which accessions have a high level of tolerance and which might simply have been escapes or accessions where low emergence percentage may have skewed the results. These additional studies will be completed this spring. Additionally, we are running further hydroponic studies to do detailed screening to update our salinity database to include the new rice varieties that have been released since we completed the initial hydroponic studies two years ago.

SIGNIFICANCE OF FINDINGS

The screening of the USDA/ARS rice germplasm collection has identified a significant number of accessions that have demonstrated the potential for tolerating relatively high soil pH's. This pool of germplasm appears to offer good parent material for the development of new varieties tolerant to alkaline soils.

CONTROL, BIOLOGY AND ECOLOGY OF PROPANIL-RESISTANT BARNYARDGRASS

Ronald E. Talbert, V.F. Carey III, Mark J. Kitt, R.S. Helms and Howard L. Black

ABSTRACT

Since its initial confirmation of in Arkansas in 1990, propanil resistance in barnyardgrass (*Echinochloa crus-galli*) has been confirmed in 134 populations in 16 counties. Effective alternatives to propanil for barnyardgrass control in rice include Facet, Bolero or Prowl. Sevin (carbaryl) at 0.1 and 0.3 lb/acre tank-mixed with propanil improved the selective activity on two-leaf, propanil-resistant barnyardgrass in rice. Super Wham and Arrosolo, both applied alone, were superior to Stam M4 but still inadequate for control of resistant barnyardgrass as a single application. Propanil formulations tank-mixed with Prowl or Facet were very effective. Effective herbicides for controlling both biotypes of barnyardgrass in rotational crops were Dual, Lasso, atrazine, Treflan, Prowl, Command, Poast and Select. Propanil-resistant barnyardgrass samples from counties in Arkansas were similar in height, number of tillers, panicles and biomass per plant. Progeny of seeds from moderately resistant barnyardgrass (previously treated with 4 or more lb/acre of propanil to remove susceptible plants), when again treated with propanil, resulted in highly resistant barnyardgrass progeny.

INTRODUCTION

In 1962, propanil was introduced into the United States rice market (Smith, 1965). After the introduction of propanil, rice yields in Arkansas, California, Louisiana, Mississippi and Texas increased 34 to 74% (Brandes, 1962). Since propanil is often used on rice fields up to twice a year, and many growers do not rotate from rice, the potential for development of propanil-resistant weeds exists. In 1990, plants from seeds collected from rice fields in northeastern Arkansas were found to be resistant to rates up to 11 kg/ha of propanil (Smith and Baltazar, 1993).

The mechanism of resistance in propanil-resistant barnyardgrass is similar to the selectivity mechanism in rice (Carey, 1994). Control of the resistant barnyardgrass biotype with a competitive inhibitor was demonstrated; when carbaryl was applied at 1 lb/acre one day before a propanil application at 4 lb/acre, >90% of the propanil-resistant barnyardgrass was controlled (Carey et al., 1992).

Other herbicides controlled propanil-resistant barnyardgrass in rice (Baltazar and Smith, 1994). Propanil in tank mixtures with Prowl or Facet applied post emergence (POST); Facet alone applied delayed-preemergence (PRE) or POST; tank mixtures of Facet with Bolero, Prowl or Arrosolo; Arrosolo applied POST with Prowl or Bolero; and Whip applied to four-leaf rice consistently controlled propanil-resistant barnyardgrass.

Objectives of this research were 1) to evaluate control of propanil-resistant barnyardgrass in rice with aryl acylamidase inhibitors in combination with propanil and rice herbicides and herbicide combinations, 2) to determine if propanil-resistant barnyardgrass can be controlled with rotational-crop herbicides and 3) to investigate whether any multiple or cross resistance to the rotational-crop herbicides exists.

PROCEDURES

Distribution of Propanil-Resistant Barnyardgrass in Arkansas

Rice growers in Arkansas have been encouraged to collect samples from problem fields since 1991 and submit them for propanil resistance testing. The identification of propanil resistance is based on the collection of mature seed from grower fields and comparing the response of propanil-treated seedlings with known susceptible and resistant populations under greenhouse conditions. Rice production practices associated with each sample were obtained through an accompanying questionnaire.

Control of Propanil-Resistant Barnyardgrass in Rice

Field experiments were conducted in 1993 and 1994 to evaluate promising aryl acylamidase inhibitors with propanil and rice herbicides and herbicide combinations for the control of propanil-resistant barnyardgrass at the Rice Research and Extension Center, Stuttgart, Arkansas. Propanil-susceptible and -resistant barnyardgrass was seeded in two separate rows across the plot area.

Percent control of propanil-resistant and -susceptible barnyardgrass and rice injury were visually rated at 7, 14, 28 and 70 days after two-leaf barnyardgrass treatments (DAT). Rough rice yield was determined.

Propanil Formulations Alone and in Combinations With Other Rice Herbicides

An experiment was conducted in 1994 on the Rice Research and Extension Center to compare three formulations of propanil--Super Wham, Stam M4 and Arrosolo--for control of propanil-resistant barnyardgrass at various rates, two- and four-leaf barnyardgrass application timings and combinations with Ordram, Bolero, Prowl and Facet. Propanil-resistant and -susceptible barnyardgrass was seeded in two separate rows across the plot area. A crop oil concentrate at 1% v/v was added to Super Wham alone and Stam M4 alone and all Facet treatments. Percent control of each biotype and rice injury ratings were taken at 7, 14, 28 and 70 DAT. Rough rice yield was determined.

Control of Propanil-Resistant Barnyardgrass in Rotational Crops

A field experiment was conducted at the Main Agricultural Experiment Station at Fayetteville in 1993 and 1994 on a Taloka silt loam. Propanil-resistant and -susceptible barnyardgrass was seeded in separate rows on a shallow bed. Preplant incorporated (PPI), PRE and POST herbicides generally used for grass control in soybeans, corn or sorghum were included at 0.5X and 1X rates in these studies. Percent control ratings of propanil-resistant and -susceptible barnyardgrass were made at 7, 14 and 28 DAT.

Growth Comparisons of Propanil-Resistant Barnyardgrass from Geographic Areas

Experiments were conducted in 1993 and 1994 on the Main Agricultural Experiment Station, Fayetteville, Arkansas, to compare growth characteristics of propanil-resistant barnyardgrass. The samples were collected from Cross, Lafayette, Poinsett, Prairie and St. Francis Counties in Arkansas. Barnyardgrass plants were treated with propanil to ensure that each plant was resistant. Plants were thinned to 16 plants per plot and grown to maturity. Heading date was recorded. Panicle and tiller counts were made, heights measured and dry weights taken.

Dynamics of Propanil Use on Resistance in Barnyardgrass Populations

Three experiments were conducted to study the population dynamics of four resistance categories of barnyardgrass: susceptible (S = 85% control), slightly resistant (SR = 72% control), moderately resistant (MR = 51% control) and highly resistant (HR = 38% control) in 1993 and 1994 at the Main Agricultural Experiment Station, Fayetteville. Seeds from each resistance category were hand-seeded in 6-ft rows. Propanil at 0, 4, 12 and 25 lb/acre plus crop oil concentrate was applied to plants in each resistance category. Seeds from each plot were harvested in 1993 and evaluated for resistance to propanil using the greenhouse assay procedure with propanil at 0, 4, 12 and 25 lb/acre plus crop oil concentrate applied. Response of moderately resistant barnyardgrass seed lots that had been treated with propanil in 1993 were also evaluated in the field at Fayetteville in 1994 using these same rates of propanil.

RESULTS AND DISCUSSION

Distribution of Propanil-Resistant Barnyardgrass in Arkansas

A total of 134 populations of propanil-resistant barnyardgrass have been confirmed from seed samples submitted by Arkansas rice growers, 67 in 1991, 51 in 1992 and 16 in 1993. The number and distribution of propanil-resistant populations in Arkansas can be seen in Fig. 1.

Respondents (143) in 1991 and 1992 indicated that 1) 80% ranked barnyardgrass as their main weed problem; 2) 100% had applied propanil; 3) 82% used propanil in combination with another herbicide; 4) there was better control of barnyardgrass ($P < 0.01$) from fields rotated out of rice for 2 of 3 years than in rice fields with less rotation; and 5) 90% used certified rice seed.

Control of Propanil-Resistant Barnyardgrass in Rice

Earlier findings were generally confirmed with respect to the labeled herbicides for rice (Baltazar and Smith, 1994). Facet, even at reduced rates, continued to be a superior herbicide for the control of propanil-resistant barnyardgrass in these studies. Propanil-resistant barnyardgrass can also be controlled with Prowl, Bolero or thiazopyr, a promising, new unlabeled herbicide, either alone or in some combination with propanil or Arrosolo. Propanil-resistant barnyardgrass control can be improved by mixing aryl acylamidase inhibitors, such as carbaryl, with propanil on two-leaf barnyardgrass or by phenmedipham applied 5 days prior to propanil (Table 1). Rice injury and yield reductions from carbaryl plus propanil treatments can be minimized by using carbaryl at 0.1 lb/acre with propanil (Tables 1 and 2).

Propanil Formulations Alone and in Combinations With Other Rice Herbicides

Control of propanil-resistant barnyardgrass was improved with Super Wham at 8 lb ai/acre or Arrosolo at 12 lb ai/acre (8 lb propanil + 4 lb molinate) on two-leaf barnyardgrass or Super Wham at 4 lb/acre or Arrosolo at 6 lb/acre (4 lb propanil + 2 lb molinate) applied sequentially on two- and four-leaf barnyardgrass, as compared to similar treatments with Stam M4 (Fig. 2). There were fewer differences among these propanil formulations when tank mixed with Ordram, Bolero, Prowl and Facet (Figure 3). Super Wham, Stam M4 and Arrosolo applied with Facet at 0.25 lb/acre on two- or four-leaf barnyardgrass gave greater than 95% full-season control of propanil-resistant barnyardgrass. These formulations applied with Prowl at 1 lb/acre on two-leaf barnyardgrass gave greater than 92% full-season control of propanil-resistant barnyardgrass. Bolero was slightly less effective, and Ordram was much less effective than Facet or Prowl. Rice injury was minimal, and yields were generally high from these treatments.

Control of Propanil-Resistant Barnyardgrass in Rotational Crops

No cross or multiple resistance was observed in propanil-resistant barnyardgrass to the rotational crop herbicides evaluated, and no control differences were observed for either biotype to these rotational-crop herbicides (detailed data not shown). Herbicides that gave greater than 95% control of both barnyardgrass biotypes at half rates were Treflan and Prowl applied PPI; Dual, Lasso, Command and atrazine applied PRE; and Poast and Select applied POST. Sencor and Scepter applied PRE and Pursuit, Fusilade 2000, Assure II and Whip applied POST at half rates gave less than 90% control of barnyardgrass.

Growth Comparisons of Propanil-Resistant Barnyardgrass from Geographic Areas

There was more variation in the growth and development within the various populations of propanil-resistant barnyardgrass lots than among lots from the various counties (detailed data not shown). The propanil-resistant barnyardgrass appears to be morphologically similar to propanil-susceptible barnyardgrass.

Dynamics of Propanil Use on Resistance in Barnyardgrass Populations

The progeny of moderately resistant plants previously treated with 4 or more lb/acre of propanil were then highly resistant to propanil (Table 3). Propanil treatment apparently removed the susceptible plants from the population, and the progeny were then all resistant, indicating that the moderately resistant barnyardgrass sample was a mixture of susceptible and resistant barnyardgrass.

SIGNIFICANCE OF FINDINGS

Propanil-resistant barnyardgrass is becoming a more widespread and intense problem in Arkansas. A number of practices appear useful for managing this problem, including the use of effective grass herbicides in rotations to other crops, the use of alternatives to propanil for grass control in rice and the use of certified rice planting seed. As the result of our presenting this information in 1994, the Arkansas State Plant Board ruled that barnyardgrass is a noxious weed in seed rice, and none is now allowed in any certified rice seed.

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Table 1. Percent control of propanil-resistant barnyardgrass and rice injury from the use of aryl acylamidase inhibitors with propanil.

Combination with propanil at 3 lb/acre	Rate	Resistant-barnyardgrass control	Rice injury
	lb/acre	------------- % -------------	
carbaryl	1.0	93	28
carbaryl	0.3	97	12
carbaryl	0.1	80	4
phenmedipham	1.0	90	2
propanil (alone)	3.0	29	1
LSD $_{(0.05)}$		20	18

Table 2. Rough rice yield as affected by aryl acylamidase and propanil-resistant barnyardgrass.

Combination with		Rough rice yield	
propanil at 3 lb/acre	Rate	1993	1994
	------------------------- lb/acre -------------------------		
carbaryl	1.0	2670	5100
carbaryl	0.3	3110	5390
carbaryl	0.1	4730	5180
phenmedipham	1.0	4740	5510
propanil (alone)	3.0	3870	5180
LSD $_{(0.05)}$		1160	

Table 3. Response of four populations of barnyardgrass to selection pressure from propanil at 4.5 kg/ha.

			Greenhouse assay of progeny previously	
Classification	Greenhouse Assay	Field Response	Untreated	Treated
	------------------------- % control -------------------------			
Susceptible standard	85	86	89	87
Slightly resistant	72	89	89	90
Moderately resistant	51	83	45	10
Highly resistant	38	26	3	4

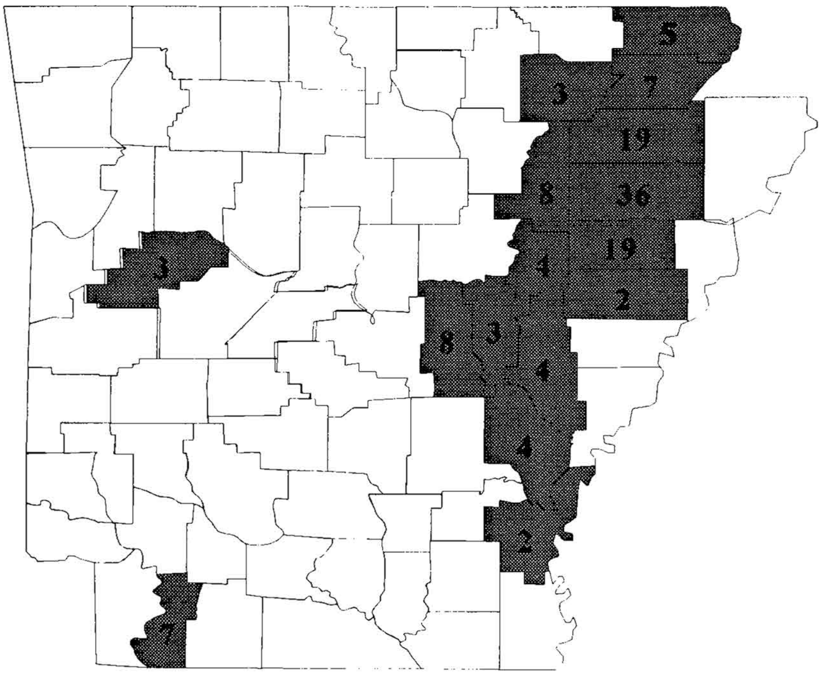

Figure 1. Number of confirmed propanil-resistant barnyardgrass populations by county in Arkansas (1991-1993).

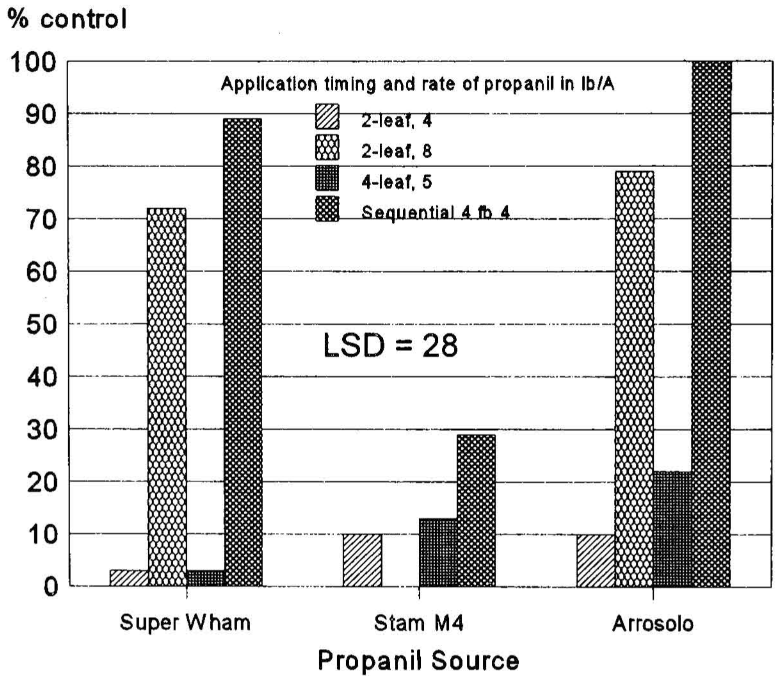

Figure 2. Percent control of propanil-resistant barnyardgrass at 28 DAT by various propanil formulations at various rates and timings. LSD = 28.

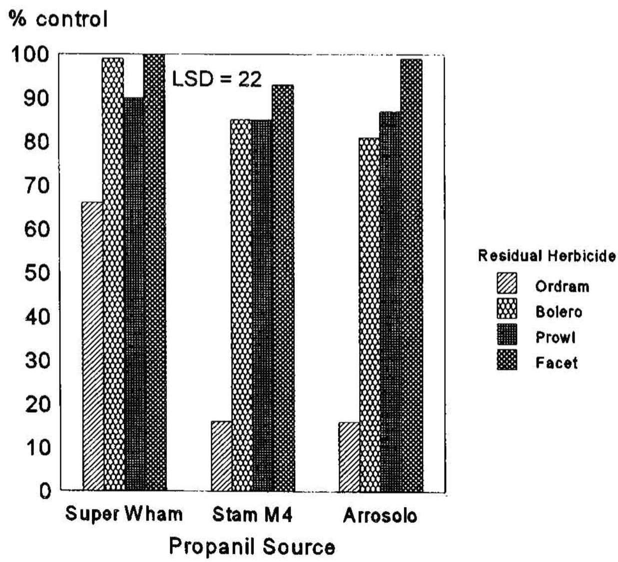

Figure 3. Percent control of propanil-resistant barnyardgrass at 28 DAT by propanil formulations tank mixed with residual rice herbicides. LSD = 22.

A CONSOLIDATED APPROACH TO WEED MANAGEMENT IN RICE (FINAL REPORT)

F.L. Baldwin

ABSTRACT

Weed control research for this portion of the project was conducted on land belonging to the University of Arkansas at Pine Bluff, located north of Lonoke. Six large, applied research and demonstration trials were conducted. The site has a severe infestation of broadleaf signalgrass and a light to moderate infestation of several broadleaf and aquatic species. The objective of one study was to compare the rice injury potential of Prowl, applied delayed preemergence, on broadcast versus drill-seeded rice. There was no difference in weed control and crop injury with the two seeding methods. Broadcast-seeded rice was added to the Prowl label for 1995.

The objective in another study was to compare different formulations of propanil, alone and in tank mixture, with other herbicides in a dense infestation of broadleaf signalgrass. Conditions for herbicide activity were outstanding, and there was little difference in control or rice injury among Stam M-4, Stam 80 EDF, Super Wham and Arrosolo. All treatments performed very well.

Two studies were conducted in an effort to support reduced rate recommendations for Facet combinations to be added to the MP-44 (annual weed control publication). In the delayed preemergence study, reduced rate combinations of Facet + Prowl and Facet + Bolero performed equivalent to the labeled rate standards. Based upon these studies and those conducted over several years by Dr. Ronnie Helms and Dr. Charlie Guy, reduced rate recommendations were added to the MP-44 for 1995. In the postemergence study, reduced rates of Facet,

in combination with labeled and reduced rates of propanil or Arrosolo, also performed as well as labeled rate standards. However, due to a label change requiring the use of a drift control agent with all Facet applications in 1995, reduced rate recommendations cannot be added to the MP-44 without further research.

Two other studies were conducted to evaluate weed control programs in which the weed spectrum included heavy infestations of both grass and broadleaf weeds. In these studies, conditions were near perfect at the time of application, and excellent control was achieved with most of the treatments. Good control ratings were obtained for sicklepod. While sicklepod is not a major rice weed, the number of calls on it increases each year. Propanil, Facet and several of the tank mix combinations of other herbicides with propanil provided excellent control. The sicklepod studies will be repeated in 1995, and the weeds will be treated at larger growth stages to simulate a levee treatment timing.

INTRODUCTION

With the retirement of Dr. R.J. Smith Jr., the applied research in rice weed control has been spread among Ronnie Helms, Charlie Guy, Ron Talbert and Ford Baldwin. Each investigator is working at a separate location with a range of soil textures and differing weed problems. However, the individual efforts are coordinated into a team approach. This investigator's responsibility is to conduct applied research and demonstration trials on a silt loam soil north of Lonoke, Arkansas. The site is on land owned by the University of Arkansas at Pine Bluff and has a severe infestation of weeds common to rice grown in that area of the state. The research and demonstration projects conducted at this location are for the purpose of providing a rapid turn around of information to answer grower questions and to contribute to the rice weed control recommendations in the MP-44 (annually updated weed control recommendations).

PROCEDURES

Six studies were conducted in 1994. All studies were randomized complete block designs with four replications. 'Alan' rice was drill seeded and maintained according to University of Arkansas recommendations. The single exception was in the broadcast-seeded rice study in which the seed were dropped on the soil surface and covered with an s-tine field cultivator. All herbicide treatments were applied with a backpack sprayer.

The first study compared Prowl applied delayed preemergence to broadcast- and drill-seeded rice. Rainfall occurred to seal the soil, and the delayed preemergence treatments of Prowl or Prowl + Facet were applied 5 days after planting, and the plots were flushed 5 days after treatment. A propanil + Prowl postemergence treatment was applied as a standard for comparison. Broadleaf signalgrass control ratings, crop injury ratings and yield data were collected.

The second test was a 30-treatment delayed preemergence study to evaluate labeled versus reduced rates of Bolero, Facet, Prowl and their combinations. Rice was seeded on 11 May 1994, and 5 to 6 in. of rainfall occurred on 12 and 13 May. The treatments were applied to a wet soil on 16 May and flushed for activation on 21 May. Broadleaf signalgrass control ratings, crop injury ratings and yield data were collected.

The third test, a 30-treatment, postemergence study, was conducted to compare some of the various formulations of propanil (Stam M-4, Stam 80 EDF, Super Wham and Arrosolo) alone and in combination with Prowl, Facet and Bolero. The rice was seeded 11 May 1994, and the treatment dates were 31 May and 7 June. Visual rating data were taken for broadleaf signalgrass and morningglory control and for crop injury. Yield data were also taken.

The fourth test, a similar 30-treatment study, was conducted to evaluate labeled and reduced rates of Stam and Arrosolo alone and in combination with labeled and reduced rates of Facet. Seeding and application dates and the data collected were the same as in the previous study.

The fifth test, a 30-treatment, program-approach study, was conducted to compare various combinations of grass and broadleaf herbicides for control of broadleaf signalgrass, hemp sesbania and sicklepod. The rice was seeded 11 May 1994 and immediately flushed to seal the soil for application of the delayed preemergence herbicides. Before flushing was complete, 5 to 6 in. of rainfall occurred over the next two days. Delayed preemergence treatments were applied 16 May and flushed 21 May. Postemergence treatments were applied 31 May and 7 June. Weed control and crop injury ratings and crop yield data were collected.

The sixth test, a similar 30-treatment study, was conducted to evaluate various combinations of propanil or Arrosolo with Grandstand, Buctril, Londax or Facet for control of hemp sesbania, morningglories, sicklepod and broadleaf signalgrass. Planting dates, application dates and data collected were similar to those in the previous study.

RESULTS AND DISCUSSION

In the study comparing Prowl applied delayed preemergence in broadcast- versus drill-seeded rice, there was a trend toward lower yields in the broadcast rice in general. However, there were no apparent differences in rice injury or yield due to the Prowl applied as a delayed preemergence versus postemergence treatment. Supporting data are shown in Table 1.

In the delayed preemergence study, Prowl applied alone provided approximately 50% control of broadleaf signalgrass, and the Bolero-alone treatments were weak, as expected. Selected data are shown in Table 2. The higher rates of Facet alone and all rates of Prowl and Bolero plus Facet provided excellent grass control and high rice yields. These data support both the labeled and new reduced rate combinations in MP-44. All data from this trial and those to follow are available in the publication *1994 Weed Control Demonstrations*, available from the University of Arkansas Cooperative Extension Service.

In the study to compare the applications of various formulations of propanil, excellent conditions for herbicide activity were present at the time of application. Comparing Stam M-4, Stam 80 EDF, Super Wham and Arrosolo alone and in combination with Facet, Bolero and Prowl, there were essentially no differences in weed control or crop injury due to propanil formulation. All treatments provided excellent control of broadleaf signalgrass and resulted in high rice yields. The rice yield in the weedy check was 127 bu/acre, and yields in the treated plots were in the 180-bu/acre range (data not shown).

The study to compare the reduced rates of Stam and Arrosolo plus Facet was conducted to extend the database for recommending reduced rates of those herbicides in the MP-44. Excellent weed control and rice yields were achieved with the reduced rate combinations. However, the treatments did not include a drift control agent because the new Facet regulations were not anticipated. The 1995 studies will include a drift control agent in an effort to build a database that will allow for reduced rate recommendations in the future.

The program approach and grass/broadleaf weed combination studies were conducted to compare various herbicide programs on broadleaf signalgrass, hemp sesbania (coffeebean), sicklepod and morningglories. Due to the excellent environmental conditions at the time of application, most of the treatments provided excellent control. Combinations of Stam or Arrosolo with Facet, Grandstand, Storm or Londax provided excellent overall weed control (data not shown).

SIGNIFICANCE OF FINDINGS

This research extended the weed science for rice database. Adding of broadleaf signalgrass data also contributed to the new reduced rate recommendations for delayed preemergence treatments added to the 1995 MP-44. The reduced rate combination treatments allow the grower to use a broader spectrum mixture for a cost comparable to labeled rates of the single herbicide component. This resulted in improved over-all better weed control, often at lower over-all herbicide costs, and increased rice yields. Other significant findings were the data collected for sicklepod control and a better database on broadleaf signalgrass--the most common grass weed in many rice fields in central Arkansas.

Table 1. Response of broadcast- or drill-seeded 'Alan' rice to Prowl.

	Rice Injury (%)[z]		
Trt. Name/No.	5/31/94	7/20/94	Yield bu/acre
1. Drill Seed Stam + Prowl 2-3 lf rice	0	0	150
2. Broadcast Seed Stam + Prowl 2-3 lf rice	0	0	144
3. Drill Seed Prowl Delayed pre fb Stam 2-3 lf rice	0	0	159
4. Broadcast Seed Prowl + Delayed pre fb 2-3 lf rice	0	0	145
5. Drill Seed Prowl + Facet Delayed pre	14	0	150
6. Broadcast Seed Prowl + Facet Delayed pre	0	0	144
$LSD_{(0.05)}$	7	0	18

[z]Visual estimates.

Appendix Table 2. Response of 'Alan' rice and broadcast signalgrass to delayed preemergence herbicide treatments

Trt. Name/No.	Rate (lb ai/acre)	Broadleaf Signalgrass Control (%)[z] 6/4/94	9/8/94	Yield (bu/acre)
1. Weedy Check		0	0	121
2. Prowl	1.0	61	45	148
3. Bolero	4.0	40	0	133
4. Facet	0.25	85	88	160
5. Facet	0.375	96	100	175
6. Prowl	1.0			
Facet	0.188	96	100	157
7. Prowl	1.0			
Facet	0.25	98	99	166
8. Bolero	2.0			
Facet	0.188	86	84	181
9. Bolero	2.0			
Facet	0.25	86	88	157
$LSD_{(0.05)}$		8	12	25

[z]Visual estimates.

WEED CONTROL AND CROP TOLERANCE TO HERBICIDES

C.B. Guy, Jr., R.S. Helms and R.W. Ashcraft

ABSTRACT

Twenty-six studies were conducted at the Southeast Branch Experiment Station near Rohwer, Arkansas, in 1994. Data from 1992-1994 indicate that 2,4-D amine caused rice injury when applied immediately before seeding in two of three years. In one year, injury from 2,4-D amine at 0.5 and 1.0 lb active ingredient (ai)/acre occurred when applied at one and three weeks prior to seeding. Rice tolerance to Grandstand was affected by rate and application timing but not by variety ('Cypress', 'Jodon', 'Kaybonnet', 'LaGrue'). Grandstand at 0.38 lb ai/acre did not affect rice yield when applied from the five-leaf growth stage to panicle differentiation. Applications later than panicle differentiation reduced yield at both 0.38 and 0.75 lb ai/acre. Reduced rate combinations of Facet plus propanil were more effective when applied to two-leaf rather than to four- or five-leaf barnyardgrass. When applied to two-leaf grass, rates as low as 0.188 + 1.0 lb ai/acre of Facet + propanil provided adequate control and yield protection. Cotton tolerance to drift rates of Facet was better if application was made prior to bed knockdown compared to application immediately after planting (preemergence).

INTRODUCTION

Weed management in rice is changing as production practices change. The introduction of reduced-tillage plantings has increased the need for information about preplant herbicides, including rice tolerance. 2,4-D is an inexpensive herbicide option for preplant broadleaf control, but it has potential to injure rice when soil applied. In-season broadleaf weed control is important not only to protect yield, but also to prevent dockage in the harvested grain. Grandstand has provided good control of morningglories, hemp sesbania and northern jointvetch; however, it has been shown to injure rice and reduce yields depending on water management, application timing and rice variety. Thus, as new varieties such as 'Kaybonnet' are introduced, they need to be screened for herbicide tolerance.

Barnyardgrass is the number one grass weed problem in rice. Facet is a new herbicide that has proven to be very effective on barnyardgrass; however, it is expensive. Thus producers are interested in information on reduced rates of Facet applied with reduced rates of propanil.

Facet has been shown to injure cotton at drift rates, and application is restricted to $\geq$ 1/4 mile from cotton. In some years when rice is planted early, Facet may be applied before cotton planting. Information is needed on cotton tolerance to drift rates of Facet applied at selected times prior to cotton planting.

PROCEDURES

Rice Response to Preplant Herbicides

Tests were conducted in 1992, 1993 and 1994 at the Southeast Branch Experiment Station near Rohwer, Arkansas, on Perry silty clay with 3.7% organic matter (OM), 43% clay, 46% silt, 11% sand, pH 6.4 and cation exchange conductivity (CEC) 16.5. Herbicides tested were 2,4-D amine, 2,4-D LV ester, Harmony Extra (thifensulfuron + tribenuron) and Grandstand (triclopyr). Herbicide rates were 1X and 2X the full labeled rate, except for 2,4-D, which was applied at 1/2X and 1 X the full rate. Herbicides were applied at 6, 4, 1 and 0 weeks prior to seeding 'Lemont' rice in 1992 and 1994 and 'Alan' in 1993. Immediately prior to planting, the soil was lightly (< 2 in.) tilled with a PTO-driven tiller. Data recorded included visual injury, stand counts and yield.

Response of Cypress, Jodon, Kaybonnet and LaGrue to Grandstand Applied at Selected Growth Stages

'Cypress', 'Jodon', Kaybonnet and 'LaGrue' were drill-seeded (40 seed/ft^2) on a silty clay. Grandstand (triclopyr) was applied with a backpack sprayer at 0.38 and 0.75 lb ai/acre, 1X and 2X the labeled rate. A nonionic surfactant was used at 0.25% v/v, and the herbicides were applied at 10 gpa. Application timings were five-leaf, mid-tiller, late-tiller, panicle initiation, panicle differentiation, panicle differentiation plus seven days and early booting of the rice. Data recorded included visual injury, visual heading estimates and rough rice yield.

Barnyardgrass Control with Reduced Rate Combinations of Facet Plus Propanil

Lemont rice was seeded in 1993 and Millie in 1994 on a silt loam that was over-seeded with barnyardgrass. Herbicide combinations were applied to two- and four-leaf barnyardgrass. All possible combinations of 0, 1, 2 and 3 lb ai/acre propanil and 0, 0.125, 0.188, 0.25 and 0.375 lb ai/acre Facet (quinclorac) were tested. Crop oil (1% v/v) was added only to those treatments with no propanil. Data collected included estimates of barnyardgrass control and rough rice yield.

Cotton Response to Drift Rates of Facet Applied Prior to Planting

Facet (quinclorac) was applied in 1994 at 0, 0.005, 0.05, 0.25 and 0.5 lb ai/acre to hipped cotton beds before knockdown and preemergence. Two timings were evaluated prior to knockdown with one set of treatments applied 25 April and another set applied 12 May. Three rainfall events totalling 2.28 in. occurred after the 25 April application but prior to planting. Immediately after (about 5 hours) the 12 May application, the beds were knocked down with a do-all for planting. 'DPL 51' cotton was planted 12 May, and a set of preemergence treatments of Facet was applied. The soil was a silt loam with 1.2% OM, 21% sand, 68% silt, 11% clay, pH 6.3 and CEC 4.8. On 14 and 15 May, a total of 1.42 in. of rain was received. Data collected included visual injury, stand counts, nodes above white flower counts, seedcotton yield and fiber quality via HVI analysis.

RESULTS AND DISCUSSION

Rice Response to Preplant Herbicides

Rice sensitivity to the herbicides evaluated was in the following order: Grandstand > 2,4-D ester ≥ 2,4-D amine > Harmony Extra (Table 1). Herbicide application timing as well as environmental conditions affected rice response. For example, in 1992, 2,4-D ester or amine at 0.5 and 1.0 lb ai/acre did not reduce rice stand or produce visual injury when applied 6 weeks prior to planting (Table 2). However, injury was observed when 2,4-D ester or amine was applied at 3, 1 and 0 weeks prior to planting. Injury ranged from 0 to 55%, depending upon rate and application timing. Generally, stand reductions occurred when injury was observed (data not shown). Lack of rainfall during this time frame resulted in little herbicide degradation and probably increased herbicide injury potential. Only 0.46 in. of rain was received from the time the 3-week preplant application was made until seeding, and the day after planting 0.72 in. of rain fell. Rough rice yield was not reduced by any treatment, indicating the ability of rice to overcome early injury and stand reductions.

In 1993 only Grandstand at 0.75 lb ai/acre applied 1 and 0 weeks prior to seeding resulted in noticeable injury, 38 and 53% injury at 23 days after planting, respectively. 2,4-D amine at 0.5 and 1.0 lb ai/acre and Harmony Extra at 0.023 and 0.046 lb ai/acre did not cause visual injury regardless of application timing (data not shown).

In 1994 the only treatments that caused injury when applied one week prior to seeding were Grandstand at 0.375 and 0.75 lb ai/acre. 2,4-D amine and Grandstand were the only herbicides that produced a visual injury response when applied immediately prior to planting. None of the herbicides, including Harmony Extra, resulted in injury when applied 4 and 6 weeks before seeding. Table 2 shows rice injury evident 23 days after seeding. Sufficient rainfall for herbicide degradation prior to planting was probably responsible for the lack of injury noted with herbicide application at 1, 4 and 6 weeks before planting. Rainfall records indicate 5.0 in. between the 6-week preplant application and planting, and 2.42 and 1.42 in. for the 1- and 4-week preplant application and planting, respectively. None of the herbicide treatments affected rice yield (data not shown).

Response of Cypress, Jodon, Kaybonnet and LaGrue to Grandstand Applied at Selected Growth Stages

This test is a continuation of the screening program for reaction of new rice varieties to Grandstand. Past research with 11 rice varieties indicated that growth stage at application was the only factor contributing to injury and subsequent yield reduction. However, this year is the first year that a response to Grandstand rate was observed. Table 3 shows the effect of Grandstand rate and rice growth stage at application on rice yield. It is important to note that the window for application for Grandstand is from the four-leaf stage until panicle differentiation. Grandstand did not affect yield within this window except when applied at 0.75 lb ai/acre (2X rate) at mid-tiller, late tiller and panicle differentiation growth stages. Both rates of Grandstand reduced rice yield. when applied at panicle differentiation plus seven days and at booting.

Barnyardgrass Control With Reduced Rate Combinations of Facet Plus Propanil

Tables 4 and 5 show barnyardgrass control and rice yield from treatments applied to two- and four-leaf barnyardgrass, respectively. In 1993 the application timing to four-leaf barnyardgrass was missed, and application was actually made to five-leaf grass that was starting to tiller. When application was to small (two-leaf) barnyardgrass, rate combinations as low as 0.188 lb ai/acre Facet plus 1 lb ai/acre propanil provided effective control. Data from the five-leaf barnyardgrass application indicate poor control even with full rate combinations, Facet + propanil at 0.38 + 3 lb ai/acre. When application was made to four-leaf grass, effective rate combinations included Facet + propanil at 0.188 + 3 lb ai/acre and at 0.38 + 1 lb ai/acre.

Cotton Response to Drift Rates of Facet Applied Prior to Planting

Preemergence applications of Facet at rates of 0.25 and 0.50 were more phytotoxic than applications made just prior to bed knockdown (Table 6). Facet applied preemergence at 0.05 lb ai/acre and greater reduced seed cotton yield. When Facet was applied before bed knockdown without rainfall, yield was not reduced at any rate. When rainfall (2.28 in.) occurred between application and bed knockdown, injury was observed with Facet rates of 0.25 and 0.5 lb ai/acre (data not shown), but only the 0.5-lb ai/acre rate reduced seedcotton yield. None of the treatments affected fiber length, strength or uniformity (data not shown).

SIGNIFICANCE OF FINDINGS

Conservation (reduced) tillage is increasing, and with this the need for preplant herbicides will increase. 2,4-D is an inexpensive broadleaf herbicide. Our data indicate that 2,4-D amine is safe to apply if used at least three weeks prior to seeding rice. Grandstand on rice received federal registration in 1995 and is a good alternative to in-season 2,4-D because of less injury potential to off-target crops. Under Section 18 label use, Grandstand has caused minor crop injury problems. Our data indicate that application timing, but not variety, affects rice tolerance to Grandstand. Barnyardgrass is the major grass weed in rice. Unfortunately, controlling barnyardgrass can cost as much as $50/acre. Our reduced rate research with Facet plus propanil shows great promise for reducing barnyardgrass control costs. Reduced rate recommendations for Facet plus propanil have been delayed because we do not know how drift control agents will affect control. Research will be conducted in 1995 to address this issue. In many delta areas of Arkansas, cotton and rice are grown in adjacent fields. Off-target herbicide movement often causes injury to cotton. Facet has the potential to injure cotton and reduce yield. Our research indicates that Facet can be safely used adjacent to cotton if applied before bed knockdown.

Table 1. Rice injury resulting from preplant applications of 2,4-D amine, Grandstand and Harmony Extra (1994).

		Application (weeks prior to seeding)			
Herbicide	Rate	6	4	1	0
	(lb ai/acre)	--------------------% injury[z]--------------------			
2,4-D amine	0.5	0	3	0	30
2,4-D amine	1.0	0	0	0	40
Grandstand	0.375	3	5	23	48
Grandstand	0.75	13	0	58	60
Harmony Extra	0.023	0	0	0	0
Harmony Extra	0.046	0	0	0	8
$LSD_{(0.05)}$ = 12					

[z]Rating made 23 days after seeding.

Table 2. Rice injury resulting from preplant applications of 2,4-D (1992).

		Application (weeks prior to seeding)			
Herbicide	Rate	6	3	1	0
	(lb ai/acre)	--------------------% injury[z]--------------------			
2,4-D ester	0.5	0	35	21	41
2,4-D ester	1.0	0	50	55	43
2,4-D amine	0.5	0	5	15	29
2,4-D amine	1.0	0	31	36	40
$LSD_{(0.05)}$ = 30					

[z]Rating made 15 days after seeding.

Table 3. Effect of plant growth stage of rice and Grandstand rate on average grain yield in 1994 ('Cypress', 'Jodon', 'Kaybonnet' and 'LaGrue' combined).

	Grandstand rate (lb ai/acre)	
Rice Growth Stage	0.38	0.75
	----Rough rice yield (lb/acre)----	
Untreated Check	6880[z]	7033[z]
Five-leaf	7044	7376
Mid-tiller	6349	5991
Late-tiller	6857	5800
Panicle initiation	6756	6969
Panicle differentiation	6832	6410
Panicle differentiation + 7 days	6303	5651
Booting	4007	3575
$LSD_{(0.05)}$ = 569		

[z]No Grandstand applied to untreated checks.

Table 4. Reduced rate combinations of Facet plus Propanil applied to two-leaf barnyardgrass (BYG).

		1993 'Millie'		1994 'Lemont'	
Herbicide	Rate	BYG[z]	Yield	BYG[1]	Yield
	(lb ai/acre)	(% control)	(lb/acre)	(% control)	(lb/acre)
Untreated		0	150	0	0
Propanil	1	13	1215	0	0
Propanil	2	55	2470	15	872
Propanil	3	58	2648	23	1192
Facet	0.125	79	3746	59	3460
Facet	0.125	84	3889	81	5406
+ Propanil	1				
Facet	0.125	92	4456	79	5460
+ Propanil	2				
Facet	0.125	93	4894	74	4961
+ Propanil	3				
Facet	0.188	93	4476	69	4133
Facet	0.188	99	4356	85	5601
+ Propanil	1				
Facet	0.188	97	4951	90	5350
+ Propanil	2				
Facet	0.188	98	4758	91	5794
+ Propanil	3				
Facet	0.25	99	5267	93	5644
Facet	0.25	99	4684	93	5762
+ Propanil	1				
Facet	0.25	99	5241	93	5945
+ Propanil	2				
Facet	0.25	99	5005	88	5788
+ Propanil	3				
Facet	0.38	99	4821	96	5710
Facet	0.38	99	4306	98	6102
+ Propanil	1				
Facet	0.38	100	4007	98	5750
+ Propanil	2				
Facet	0.38	97	5252	95	6274
+ Propanil	3				
LSD (0.05) =		13	1325	14	1169

[z]End of season rating.

Table 5. Reduced rate combinations of Facet plus Propanil applied to four-leaf (1994) and five-leaf (1993) barnyardgrass (BYG).

		1993 'Millie'		1994 'Lemont'	
Herbicide	Rate	5-leaf BYG[z]	Yield	4-leaf BYG[z]	Yield
	(lb ai/acre)	(% control)	(lb/acre)	(% control)	(lb/acre)
Untreated		0	366	0	0
Propanil	1	18	2325	0	0
Propanil	2	20	2447	25	1231
Propanil	3	28	2779	24	1292
Facet	0.125	25	1694	8	0
Facet + Propanil	0.125 1	58	4139	45	3619
Facet + Propanil	0.125 2	43	2722	30	2563
Facet + Propanil	0.125 3	54	3397	43	3394
Facet	0.188	43	2672	33	1215
Facet + Propanil	0.188 1	64	3477	34	2370
Facet + Propanil	0.188 2	61	3857	59	4209
Facet + Propanil	0.188 3	61	4408	84	6602
Facet	0.25	63	2799	25	1212
Facet + Propanil	0.25 1	69	4302	71	5091
Facet + Propanil	0.25 2	66	4116	76	4935
Facet + Propanil	0.25 3	63	3647	80	5900
Facet	0.38	58	3952	43	2145
Facet + Propanil	0.38 1	75	4479	91	6087
Facet + Propanil	0.38 2	70	3920	92	5622
Facet + Propanil	0.38 3	68	4226	91	5813
$LSD_{(0.05)}$ =		19	1364	27	1903

[z] End of season rating.

Table 6. Effect of application timing and Facet rate on cotton yield.

	Application timing		
	Before bed knockdown		
Facet rate (lb ai/acre)	With rainfall	Without rainfall	Preemergence
	------------------lb seedcotton/acre------------------		
0	4526	4278	4732
0.5	3921	4003	550
0.25	4044	4141	1816
0.05	4093	4244	4072
0.005	4471	4712	4202

$LSD_{(0.05)}$ = 558 within and between columns.

WEED MANAGEMENT IN RICE

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ABSTRACT

Experiments were conducted to develop a database on the potential for reduced herbicide rate recommendations in rice. Currently in Arkansas, rice herbicide recommendations generally adhere to the label rate recommendations. However, recent research with Facet and Facet tank-mixes with Bolero, Prowl, propanil or Arrosolo has demonstrated that effective weed control can be obtained with only one-half to two-thirds the recommended herbicide label rate. Delayed preemergence (DPRE) reduced-rate applications of Facet controlled both propanil-susceptible and -resistant barnyardgrass (BYG). Reduced-rate tank-mixes of Facet and Bolero or Facet and Prowl applied DPRE controlled both BYG and bearded sprangletop (BST). Reduced rate applications of Facet alone (0.19 or 0.25 lb active ingredient (ai)/acre) and tank-mixed with propanil (1, 2 or 3 lb ai/acre) or with Arrosolo (1.5, 3.0 or 4.5 lb ai/acre) controlled both two- and four-leaf BYG applied early postemergence (POST). Additional experiments were conducted to determine the effects of water management on rice injury from triclopyr. Studies initiated in 1992 and continued through 1994 indicate that triclopyr injury to rice can be minimized with correct water management techniques. Funding for this research has been provided by grower check-off funds administered by the Rice Research and Promotion Board and the University of Arkansas.

INTRODUCTION

Weed management is a critical part of rice production. Weeds must be controlled in rice because they reduce grain yields and milling quality and decrease harvest efficiency. However, with the current economics of rice farming, weed management costs need to be minimized while maintaining effective weed control. The University of Arkansas Cooperative Extension Service has been a national leader in reduced-rate herbicide recommendations in soybeans. The reduced-rate herbicide approach in soybeans has reduced herbicide cost, increased profit potential and yet maintained effective weed control in soybeans. The reduced-rate herbicide approach in rice must be implemented to decrease production cost and increase profit potential because of the potential of reduced rice subsidies and the national pesticide reduction initiative. Reduced herbicide rate technology means more than just reducing the herbicide rate. Management must be increased to maintain the effectiveness of the herbicide by flushing to activate residual herbicides and/or applying at the proper weed size. The reduced herbicide rate approach must also be evaluated in rice grown utilizing the conservation tillage approach. In this system burndown herbicides replace tillage operations. Profit potential in conservation-tillage system rice is high because of reduced tillage operations, timely seeding, effective use of labor and equipment and improved seedbeds in some soil types.

PROCEDURES

Herbicide treatments were compared in replicated field experiments conducted in 1994 at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas. Labeled and reduced rates of herbicides were applied alone, in tank-mixes or in sequential combinations at various rates, times and methods of application. Treatments were evaluated in terms of weed control efficacy and effect on crop growth. Generally effective treatments were those that provided $\geq$ 80% weed control and $\leq$ 30% injury to rice from which rice recovered in a reasonable period of time without significant grain yield reduction.

Barnyardgrass and Sprangletop Study

Field studies were initiated in 1993 and continued in 1994 to evaluate reduced rates of Facet (0.19 or 0.25 lb ai/acre) compared to the full labeled Facet rate (0.38 lb ai/acre) alone or tank-mixed with Bolero (2 or 3 lb ai/acre) or Prowl (1 lb ai/acre) applied DPRE. Prowl (1 lb ai/acre) or Bolero (4 lb ai/acre) applied DPRE were also evaluated in this study. Standard postemergence herbicide treatments in this study were Arrosolo (6 lb ai/acre) or propanil (4 lb ai/acre) tank-mixed with Bolero (3 lb ai/acre) or Prowl (1 lb ai/acre) applied at the two-leaf barnyardgrass growth stage.

Propanil-Resistant Barnyardgrass Study

Propanil-resistant BYG collected in Poinsett County, Arkansas, was over-seeded in the experimental area at RREC. Post-emergence herbicide treatments that were evaluated for control of propanil-resistant BYG included sequential applications of propanil (4 lb ai/acre followed by (fb) 4 lb ai/acre), propanil tank-mixed with Prowl (3 + 1 lb ai/acre), sequential applications of Arrosolo (6 lb ai/acre fb 6 lb ai/acre) and Arrosolo tank-mixed with Prowl (4.5 + 1 lb ai/acre). Herbicide treatments applied DPRE that were evaluated for control of propanil-resistant BYG included Facet (0.19, 0.25 and 0.38 lb ai/acre) alone and tank-mixed with Bolero (2 or 3 lb ai/acre) or Prowl (1 lb ai/acre) and Prowl alone (1 lb ai/acre).

Facet, Propanil, Arrosolo Tank-mix Study

Field studies were initiated in 1993 and 1994 to evaluate reduced rate postemergence applications of Facet, propanil or Arrosolo alone or Facet tank-mixed with propanil or Arrosolo. The Facet rates in this study were 0.38 lb ai/acre (labeled rate) and 0.25 or 0.19 lb ai/acre (reduced rates). The propanil rates were 1, 2 or 3 lb ai/acre. Arrosolo rates were 1.5, 3.0 or 4.5 lb ai/acre. All treatment combinations of Facet, propanil or Arrosolo alone or Facet tank-mixed with propanil or Arrosolo were applied at the two-leaf or four-leaf barnyardgrass growth stage.

Grandstand (Triclopyr) Water Management Study

Field studies were initiated in 1992 and continued through 1994 to determine the effects of water management on Grandstand injury in rice. Grandstand was applied to rice at the four- to five-leaf, mid-tillering or panicle initiation growth stages at 0.25, 0.38 or 0.75 lb ai/acre. The water management regimes in this study were: (1) at the four- to five-leaf growth stage establish the flood 24 or 72 hours after Grandstand application, (2) at the mid-tillering or panicle initiation growth stages apply Grandstand to rice in an established flood compared to removing the flood 48 hours before applying Grandstand.

Conservation Tillage Systems in Rice

Two weed management studies were initiated in 1994. The experimental area was disked and land planed in the fall of 1993. The studies were (1) apply burndown herbicides (Gramoxone (2 pints product/acre) or Roundup DPAK (20 oz product/acre)) then plant rice or (2) plant rice then apply the same burndown herbicides. The herbicide treatments included Facet (0.38 lb ai/acre) applied preemergence (PRE)/DPRE, Prowl DPRE (1 lb ai/acre), Bolero DPRE (4 lb ai/acre), Facet tank-mixed with Bolero DPRE (0.25 + 3.0 lb ai/acre), Facet tank-mixed with Prowl DPRE (0.25 + 1 lb ai/acre) or propanil tank-mixed with Bolero POST (3.0 + 3.0 lb ai/acre).

RESULTS AND DISCUSSION

Barnyardgrass and Sprangletop Study

The results of the field studies conducted in 1993 and 1994 indicated that delayed preemergence (DPRE) applications of Facet at labeled rates (0.38 lb ai/acre) and reduced rates (0.19 or 0.25 lb ai/acre) provided effective season-long BYG control compared to standard herbicide treatments. Bearded sprangletop (BST) control with the Facet treatments was unacceptable. Reduced rate tank-mixes of Facet and Bolero or Facet and Prowl provided effective control for both BYG and BST. Bolero applied DPRE controlled BST but not BYG. Prowl applied DPRE controlled both BST and BYG. These results have been incorporated into the MP-44 for reduced rate recommendations for BYG and BST in rice.

Propanil-Resistant Barnyardgrass Study

Sequential applications of propanil (4 lb ai/acre followed by 4 lb ai/acre) failed to control the propanil-resistant BYG. The tank-mix of propanil and Prowl applied when the BYG was at the two-leaf growth stage was also ineffective on propanil-resistant BYG. However, a tank-mix of Arrosolo plus Prowl and Arrosolo followed by Arrosolo provided effective control of propanil-resistant BYG. Other herbicide treatments that controlled propanil-resistant BYG ($\geq$ 90% control) included DPRE applications of Facet (0.19, 0.25 and 0.38 lb ai/acre), tank mixes of Facet and Bolero, Facet and Prowl and Prowl alone.

Facet, Propanil, Arrosolo Tank-mix Study

Field studies initiated in 1993 and continued in 1994 demonstrated that reduced rates of Facet tank-mixed with propanil or Arrosolo could provide effective weed control. The Facet label rate for postemergence applications is 0.38 lb ai/acre. The results of this study indicate that two- and four-leaf BYG could be effectively controlled with Facet rates as low as 0.19 lb ai/acre tank-mixed with 2-3 lb ai/acre propanil or 3-4.5 lb ai/acre of Arrosolo. These studies were to be used as a database for reduced rate recommendations for post applications of Facet. However, changes in the 1995 Arkansas Facet label state that drift control agents must be used with all applications of Facet. Since we have no information on the effects of drift control agents on the efficacy of reduced rates of Facet, reduced rate recommendations for post applications were not included in the MP-44 in 1995.

Grandstand (Triclopyr) Water Management Study

Results from these studies indicate that delaying the flood three days after preflood Grandstand applications will minimize rice injury from Grandstand. When postflood applications of Grandstand were made, rice injury was minimized when the flood was lowered to expose broadleaf weeds. However, the soil should not be exposed (do not remove flood completely).

Conservation Tillage Systems in Rice

The Facet applied PRE/DPRE or Facet and Bolero or Facet and Prowl DPRE were equal to the standard propanil and Bolero POST treatment for BYG control. These results demonstrate that reduced rates of Facet tank-mixed with Bolero or Prowl were equal to early post treatments of propanil and Bolero in rice grown in a conservation-tillage system. In these studies other problem weeds such as smartweed and nutsedge were not present.

SIGNIFICANCE OF FINDINGS

The reduced rate DPRE applications of Facet and Facet and Bolero or Prowl tank-mixes provide effective control of BYG and BST. These results indicate that with proper water management (flooding) to keep the herbicide active, weed control cost in rice production may be reduced. The DPRE applications also provided effective control of propanil-resistant BYG. These results were incorporated into the University of Arkansas Rice Weed recommendations published in the 1995 MP-44. The Grandstand Water Management Study effectively demonstrated the relationship between water management and rice injury from Grandstand. This information is on the Section 3 Grandstand label to minimize Grandstand injury in rice.

Conservation-tillage systems in rice continue to increase in Arkansas. The current database for weed management in conservation-tillage systems indicates that reduced rates of Facet and Bolero or Prowl provide effective weed control in this system. Additional studies are needed to address situations with problem weeds such as smartweed and nutsedge along with BYG and propanil-resistant BYG for complete weed management recommendations in this system.

ENVIRONMENTAL IMPLICATIONS OF PESTICIDES IN RICE PRODUCTION

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ABSTRACT

There are still many unknowns involved with water quality evaluation; therefore, monitoring for pesticides in water sources and supplies must continue. Determining the type, concentration and characteristics of pesticides present in water supplies is essential to the overall assessment of water quality. Although corn and soybean pesticides have received the most attention, some rice pesticides have also been detected in surface waters within the rice producing regions of the U.S.

Three independent locations implementing contained water management systems and recycling water were monitored in 1994. Irrigation, runoff and pond water samples were collected every 10 to 14 days between permanent flood establishment and draining for harvest. Samples were transported to the laboratory and extracted for 16 pesticides using solid phase extraction (SPE) techniques. Quantification and confirmation of pesticide residues were obtained by High Performance Liquid Chromatography (HPLC) and Gas Chromatography/Mass Spectrometry (GC/MS) analysis. The lower limit of quantitation was 2 μg/L in water. Pesticides selected for monitoring were determined from Cooperative Extension Service recommendations (MP-44, MP-144, etc.) and analytical capabilities. Those included were Benlate, Londax, Sevin, Furadan, 2,4-D, Whip, Rovral, Malathion, MCPA, Methyl parathion, Ordram, Prowl, Stam, Tilt, Facet and Bolero.

Since each location was independently managed, individual results are site specific. 2,4-D, Benlate, Ordram, Stam, Facet and Bolero were

the pesticides actually applied during the season. These pesticides were detected, usually at trace levels, in tailwaters shortly after application but did not appear to build up in the reservoirs. Facet residues in the tailwaters were more persistent (6 to 8 weeks) than the other detected compounds (less than 2 weeks). Prowl residues were also detected but probably resulted from neighboring soybean fields.

INTRODUCTION

In recent years, both public awareness of and concern about water quality have increased. Reported findings of numerous pesticides in water supplies have caused some agricultural production systems to be questioned. Although many of these reports involve corn and soybean pesticides, it is important to note that inputs from many agricultural systems have the potential to adversely affect the environment. Detections of both Ordram and Bolero residues in the Sacramento River have resulted in restrictions for California rice producers, requiring them to hold the flood waters on site for several days prior to release (Ross and Sava, 1986). Closer to Arkansas, Ordram and Bolero residues have also been detected in the Mississippi River and its tributaries (Pereira and Hostettler, 1993). With current methods and analytical capabilities, it is not unlikely that instances of detectable levels of pesticides can be found in water, especially in regions of intense agricultural production (CAST, 1994). The difficulty, though, rests in assessing the significance of trace level detections. Although pesticide risk assessment involves many assumptions and is not an exact science, it is essential to continue monitoring the environment to aid in determining any potential problems before they become severe.

The overall objective of this research is to assess the extent of pesticides present in tailwater runoff from rice fields and to promote appropriate management practices that will maintain high water quality. Specific goals are 1) to monitor tailwaters and confined surface water irrigation sources for pesticide residues and to determine the dissipation trends of any detected pesticide and 2) to determine the contributions and significance of suspended sediment on the transport of persistent pesticides found during the monitoring component of objective 1.

PROCEDURES

Four sampling sites were identified in the rice producing region of Arkansas. These locations utilized water management systems with the potential to pump and recycle irrigation water from confined reservoirs that collect tailwater drainage from the field. Tailwater, pond water and irrigation water samples were collected on a bimonthly schedule that began with the establishment of permanent flood. Water samples (900 mL) were transported, on ice, from the sampling locations to the Altheimer Laboratory at Fayetteville for extraction and analysis. At the time of sample collection, field-fortified solutions were also prepared from each location to monitor the stability of the selected pesticides in water during transport. Based on Cooperative Extension Service recommendations and our analytical capabilities, the following 16 pesticides were selected for analysis: Benlate, Londax, Sevin, Furadan, 2,4-D, Whip, Rovral, Malathion, MCPA, Methyl parathion, Ordram, Prowl, Stam, Tilt, Facet and Bolero. From this screening list, Benlate, 2,4-D, Ordram, Stam, Facet and Bolero were actually applied at one or more locations during 1994. All samples were prefiltered through Whatman GF/F filter paper (0.7-µm particle retention) to remove any suspended sediment. Filtered water (250 mL) was extracted using a 47-mm vacuum extraction manifold equipped with Empore C-18 extraction disks. Analytes were eluted with ethyl acetate and concentrated to the desired volume under a stream of dry nitrogen. An aliquot of the final extract was evaporated to dryness and resuspended in acetonitrile/water for HPLC analysis. Samples resulting in a positive detection from HPLC were then subjected to GC-MS analysis for final confirmation.

RESULTS AND DISCUSSION

Since each location was independently managed, results from each system are site specific and will be discussed separately.

Arkansas County

This system used a modified recycling system for the water. Since the growing season provided frequent and plentiful rains, irrigation water was pumped from a nearby bayou instead of pumping from the pond. Since this bayou neighbored several adjoining rice fields, water from it may have contained pesticide residues from other adjacent sites. Permanent flood was established in late May. Stam and Bolero were applied preflood; Ordram and 2,4-D were applied postflood. Samples from 20 August represented the final water conditions after draining.

Conway County

Both sites were actually at the same location. These sites utilized true recycling systems for the water. However, two slightly different water management systems were used. Runoff from the East site entered the reservoir directly (<100 ft separation). In contrast, the West site required a drainage ditch (about 0.25 to 0.5 mi in length) to recycle the runoff back to the reservoir. This ditch contained some vegetative growth, which provided additional filtering of the water. Permanent floods were established just prior to 6 June, and draining occurred around 18 August. Both sites received preflood applications of Stam and Bolero; 2,4-D was applied postflood. At this location, very little tailwater was observed flowing from the fields.

Faulkner County

This site pumped irrigation water from a retaining pond but did not collect and recycle their tailwaters. Runoff entered a drainage canal that led to a nearby creek. This field was planted later than the other three sites. Permanent flood was not established until 13-14 June. The water sample collected on 6 June was runoff resulting from flushing the field. Facet and Bolero were applied preflood; 2,4-D and Benlate were applied postflood. This system consistently had some water flowing from the field.

RESULTS

2,4-D residues were detected in tailwaters shortly after application (less than 12 hour) at Faulkner County but were not detected at the next sampling time in any of the water samples (Table 1). A trace level 2,4-D detection was also observed in the pond sample at Conway County (East) on 12 July. Ordram was detected in the tailwater samples from Arkansas County approximately 2-3 days after application, but similar to 2,4-D, it was not detected 13 days later at the next sampling time (Table 2).

Facet and Bolero residues in Faulkner County were highest at the time of flushing (Tables 3 and 4). Bolero concentrations dissipated to <2 ppb within 10 days. Low-level Facet residues persisted for about 8 weeks in the levee seepage and tailwaters (Table 3). Since Facet was not applied at this Arkansas County location, trace level concentrations probably resulted from irrigation water pumped from the bayou containing runoff from neighboring fields.

Low-level Stam residues were detected at all locations early in the season (Table 5). Stam concentrations at Faulkner County may have resulted from application to other rice fields on the same farm. In the past we have stated that Stam is rapidly hydrolyzed in water and does not persist. Findings from this year indicate that persistence at very low concentrations may occur. Since Prowl was not applied to any of the rice fields being studied, detectable residues of this compound probably resulted due to runoff from neighboring soybean fields (Table 6). Benlate was not detected in any of the water samples collected.

The effect of suspended sediment varied among the pesticides screened. Pesticide recoveries from field-fortified samples appear to indicate that Bolero, Rovral, Whip and Prowl concentrations in surface water were reduced by up to 40-50% following the prefiltering procedure. This indicates that a significant fraction of these compounds may be adsorbed to the sediment and not truly dissolved in the water. Extraction of the filtered sediment fraction did not recover significant amounts of these pesticides and indicates that these residues are probably bound very tightly to the sediment. Since sediment appears to represent a significant sink for these particular pesticide residues, water management systems that reduce sediment load should be effective in reducing the transport of these pesticides into surface waters.

SIGNIFICANCE OF FINDINGS

Even though pesticides were detected in the tailwaters, we have provided no evidence to show that pesticide concentrations build up in the reservoirs. In many cases, it appears that pesticide dissipation from water is very rapid. This is evident from observing residues at one sampling time and not detecting the pesticide two weeks later. As one would expect, the period of highest pesticide concentration in water occurs shortly following pesticide application. Therefore, containment of water on the field should be emphasized immediately following postemergence applications to flooded rice. These studies indicate that periods of flushing early in the season are most likely to cause loss of pesticides from preflood applications.

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Table 1. 2,4-D detections in various rice producing systems (ppb).[z]

	Date of Collection							
Water Source	6/6	6/15	6/29	7/12	7/27	8/10	8/20	9/6
			ARKANSAS COUNTY					
Irrigation	nd	nd	nd	nd	nd	nd	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	nd	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
			CONWAY COUNTY - EAST SITE					
Irrigation	nd	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	NC	NC
Pond	nd	nd	nd	7	nd	nd	nd	NC
			CONWAY COUNTY - WEST SITE					
Irrigation	NC	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	nd	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
			FAULKNER COUNTY					
Irrigation	NC	nd	nd	nd	nd	nd	<2	NC
Tailwater	nd	nd	nd	1128	nd	nd	nd	nd
Levee Seepage	NC	nd	nd	270	nd	NC	nd	NC
Pond	NC	nd	nd	28	nd	nd	NC	NC

[z]NC = not collected, nd = not detected, Health Advisory Level (HAL) = 70 ppb, Limit of quantitation = 2 ppb.

Table 2. Ordram detections in various rice producing systems (ppb).[z]

	Date of Collection							
Water Source	6/6	6/15	6/29	7/12	7/27	8/10	8/20	9/6
			ARKANSAS COUNTY					
Irrigation	nd	nd	nd	nd	nd	nd	NC	NC
Tailwater	nd	nd	40	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	<2	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
			CONWAY COUNTY - EAST SITE					
Irrigation	nd	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	NC	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
			CONWAY COUNTY - WEST SITE					
Irrigation	NC	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	nd	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
			FAULKNER COUNTY					
Irrigation	NC	nd	nd	nd	nd	nd	nd	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	nd
Levee Seepage	NC	nd	nd	nd	nd	NC	nd	NC
Pond	NC	nd	nd	nd	nd	nd	NC	NC

[z]NC = not collected, nd = not detected, Health Advisory Level (HAL) = not available, Limit of quantitation = 2 ppb.

Table 3. Facet detections in various rice producing systems (ppb).[z]

Water Source	Date of Collection							
	6/6	6/15	6/29	7/12	7/27	8/10	8/20	9/6
	ARKANSAS COUNTY							
Irrigation	nd	<2	nd	nd	nd	nd	NC	NC
Tailwater	nd	<2	nd	nd	nd	nd	nd	NC
Drainage Canal	<2	<2	nd	nd	<2	nd	nd	NC
Pond	<2	<2	nd	nd	nd	nd	nd	NC
	CONWAY COUNTY - EAST SITE							
Irrigation	nd	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	NC	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
	CONWAY COUNTY - WEST SITE							
Irrigation	NC	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	nd	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
	FAULKNER COUNTY							
Irrigation	NC	nd	nd	nd	nd	nd	nd	NC
Tailwater	176	11	13	14	<2	nd	nd	<2
Levee Seepage	NC	58	36	11	9	NC	<2	NC
Pond	NC	<2	nd	nd	nd	nd	NC	NC

[z]NC = not collected, nd = not detected, Health Advisory Level (HAL) = not available, Limit of quantitation = 2 ppb.

Table 4. Bolero detections in various rice producing systems (ppb).[z]

Water Source	Date of Collection							
	6/6	6/15	6/29	7/12	7/27	8/10	8/20	9/6
	ARKANSAS COUNTY							
Irrigation	nd	nd	nd	nd	nd	nd	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	nd	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
	CONWAY COUNTY - EAST SITE							
Irrigation	nd	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	NC	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
	CONWAY COUNTY - WEST SITE							
Irrigation	NC	nd	nd	nd	nd	NC	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	nd	nd	nd	nd	nd	NC
Pond	nd	nd	nd	nd	nd	nd	nd	NC
	FAULKNER COUNTY							
Irrigation	NC	nd	nd	nd	nd	nd	nd	NC
Tailwater	145	<2	nd	nd	nd	nd	nd	nd
Levee Seepage	NC	<2	nd	nd	nd	NC	nd	NC
Pond	NC	<2	nd	nd	nd	nd	NC	NC

[z]NC = not collected, nd = not detected, Health Advisory Level (HAL) = not available, Limit of quantitation = 2 ppb.

Table 5. Stam detections in various rice producing systems (ppb).[z]

	Date of Collection							
Water Source	6/6	6/15	6/29	7/12	7/27	8/10	8/20	9/6
	ARKANSAS COUNTY							
Irrigation	<2	<2	nd	nd	nd	nd	NC	NC
Tailwater	<2	<2	nd	nd	nd	nd	nd	NC
Drainage Canal	<2	<2	nd	<2	nd	nd	nd	NC
Pond	<2	<2	nd	nd	nd	nd	nd	NC
	CONWAY COUNTY - EAST SITE							
Irrigation	nd	<2	<2	<2	<2	NC	NC	NC
Tailwater	nd	<2	<2	nd	nd	nd	NC	NC
Pond	<2	<2	<2	nd	nd	nd	nd	NC
	CONWAY COUNTY - WEST SITE							
Irrigation	NC	<2	nd	nd	nd	NC	NC	NC
Tailwater	<2	<2	nd	nd	nd	nd	nd	NC
Drainage Canal	<2	<2	nd	nd	nd	nd	nd	NC
Pond	<2	<2	nd	nd	nd	nd	nd	NC
	FAULKNER COUNTY							
Irrigation	NC	<2	nd	nd	nd	nd	nd	NC
Tailwater	<2	<2	nd	nd	nd	nd	nd	nd
Levee Seepage	NC	<2	nd	nd	nd	NC	nd	NC
Pond	NC	<2	<2	nd	nd	nd	NC	NC

[z]NC = not collected, nd = not detected, Health Advisory Level (HAL) = not available, Limit of quantitation = 2 ppb.

Table 6. Prowl detections in various rice producing systems (ppb).[z]

	Date of Collection							
Water Source	6/6	6/15	6/29	7/12	7/27	8/10	8/20	9/6
	ARKANSAS COUNTY							
Irrigation	nd	nd	nd	nd	nd	nd	NC	NC
Tailwater	nd	nd	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	nd	<2	<2	nd	nd	nd	NC
Pond	nd	<2	nd	nd	nd	nd	nd	NC
	CONWAY COUNTY - EAST SITE							
Irrigation	nd	<2	nd	nd	nd	NC	NC	NC
Tailwater	nd	<2	<2	nd	nd	nd	NC	NC
Pond	<2	<2	<2	nd	nd	nd	nd	NC
	CONWAY COUNTY - WEST SITE							
Irrigation	NC	<2	nd	<2	nd	NC	NC	NC
Tailwater	nd	<2	nd	nd	nd	nd	nd	NC
Drainage Canal	nd	<2	<2	nd	nd	nd	nd	NC
Pond	<2	<2	nd	nd	nd	nd	nd	NC
	FAULKNER COUNTY							
Irrigation	NC	nd	nd	<2	nd	nd	nd	NC
Tailwater	nd	<2	nd	<2	nd	nd	nd	nd
Levee Seepage	NC	<2	nd	nd	nd	NC	nd	NC
Pond	NC	<2	nd	nd	nd	nd	NC	NC

[z]NC = not collected, nd = not detected, Health Advisory Level (HAL) = not available, Limit of quantitation = 2 ppb.

SCREENING FOR RICE STINK BUG RESISTANCE

J.L. Bernhardt, K.A.K. Moldenhauer and K.A. Gravois

ABSTRACT

The evaluation of advanced rice lines in the Arkansas rice breeding program for susceptibility to rice stink bug feeding is a major part of the entomology research program. The objective of the program is to safeguard against the release of varieties more susceptible than those existing at the present time. Two advanced lines, later released as 'Katy' and 'Kaybonnet', were found to have less damage (pecky rice) than other long-grain rice varieties in the mid-season and short-season maturity groups, respectively, of the Arkansas Rice Performance Trials (ARPT). What remains is to find a line from the very-short-season maturity group that is less susceptible to rice stink bug damage than current varieties. Results from tests in 1994 indicate that three lines in the very-short-season maturity group had substantially less pecky rice than the check varieties.

INTRODUCTION

The rice stink bug, *Oebalus pugnax* (F.), is an insect pest commonly found in Arkansas rice fields. The adults and nymphs pierce the hull and feed on the developing kernel by removing the fluid contents. After the hull is pierced, pathogens often gain entry into the kernel and cause kernel discoloration. Discolored kernels are called pecky rice. Only after the grain is hulled does the extent of discoloration become evident. The amount of pecky rice often influences the acceptability and value of the rough rice.

A major part of the entomology research program in rice is the evaluation of rice lines for susceptibility to rice stink bug feeding by the assessment of the amount of discolored kernels. The overall objective is to safeguard against the release of more susceptible varieties than exist at the present time. To accomplish the objective, rice grain samples are obtained from several sources and evaluated for the amount of discolored kernels caused by rice stink bugs. Results from the evaluations of rice lines are compared and conclusions made as to the relative susceptibility of rice lines to rice stink bug damage. Rice lines with consistently less damage are called resistant. This report is a summary of evaluations of rice lines for resistance to the rice stink bug.

PROCEDURES

Rice samples from the following sources and years were evaluated: 1) rice lines from the rice breeding program of the University of Arkansas placed in the Arkansas Rice Performance Trials (ARPT) (1988-1994); 2) rice lines from breeding programs of other universities and private seed companies tested in the ARPT (1988-1994); and 3) advanced rice lines placed in the Uniform Regional Rice Nursery (URRN) (1993-1994). Locations of the ARPT were the Rice Research and Extension Center, Stuttgart, Arkansas (RREC, Arkansas County); the Cotton Branch Experiment Station, Marianna, Arkansas (CBES, Lee County); a county in northeastern Arkansas (Jackson or Clay County); and/or the Southeast Branch Experiment Station, Rohwer, Arkansas (SEBS, Desha County). The number of rice lines, replications and locations for the ARPT and URRN evaluations are given in Table 1. Varieties are among entries in the ARPT and URRN and are used as checks for comparisons.

The uncleaned rough rice was hulled, and the brown rice was passed through an electronic sorting machine that separated discolored kernels. The discolored kernels were examined under a dissecting microscope to determine the cause of the discoloration. The categories of discolored kernels were 1) kernels discolored by rice stink bug feeding, 2) kernels infected with kernel smut and 3) all other discolorations, of which many have discoloration confined to the bran layer. The amount of discolored kernels in a category was weighed and is expressed as a percentage of the total weight of brown rice.

RESULTS AND DISCUSSION

Among the rice lines tested in the ARPT from 1988 to 1993 seven were released for certified seed production. These lines were RU8601179 ('Katy'), RU8701105 ('Millie'), RU8701084 ('Alan'), RU8801121 ('Orion'), RU9001007 ('Adair'), RU9001096 (LaGrue') and RU9101142 ('Kaybonnet'). These lines were released because each was found to have advantages over other varieties in the same maturity group. The advantage Katy and Kaybonnet have over other lines was resistance to the rice blast disease. In addition, our evaluations found that Katy and Kaybonnet consistently have low levels of pecky rice (Table 2).

The occurrence of rice varieties with both blast and rice stink bug resistance is indeed fortuitous. The Arkansas rice breeding program has sought to add the rice blast resistance gene to other rice lines. Therefore, advanced rice lines with Katy as one parent have been evaluated to see if rice stink bug resistance also was transferred. Kaybonnet, which contains Katy germplasm, had lower amounts of pecky rice than did other long-grain lines except LaGrue in the short-season maturity group.

Other advanced lines that had Katy as one parent were evaluated in 1994 (Table 3). Among the eight lines in the mid-season maturity group of the ARPT, five had a percentage of pecky rice only slightly higher than the standard, Katy. Among the seven lines in the short-season group, four had a percentage of pecky rice comparable to the standard, Kaybonnet. Only three lines were in the very-short-season group. All had less pecky rice than did the check varieties, and RU9301102 and RU9401090 had 40 to 60% less peck than did Adair or Alan.

The evaluation of rice lines in the URRN provided a good comparison of the susceptibility of many varieties and advanced lines from breeding programs in Arkansas, Louisiana, Mississippi and Texas. Varieties such as Katy, Kaybonnet, LaGrue and 'Mars' had lower amounts of pecky than most other varieties. Several lines from Texas (RU9303012, RU9303012, RU9103049, RU9303166, RU9003092, RU9303043, RU9403066) and Louisiana (RU9402005, RU9102085, RU9402048, RU9302065) also had low amounts of pecky rice.

SIGNIFICANCE OF FINDINGS

Evaluation of advanced rice lines provides rice breeders with information on the susceptibility of lines to rice stink bug damage. Breeders can then use the information in the selection of lines for further tests and the elimination of lines that are clearly more susceptible to damage than presently grown varieties. Examples of lines that have been found to have less susceptibility to rice stink bug damage are Katy and Kaybonnet. With the release of Katy in the mid-season maturity group and Kaybonnet in the short-season maturity group, growers now have the opportunity to choose a line that will help minimize pecky rice.

The very-short-season maturity group is the only group without a line less susceptible to rice stink bug damage. However, three lines tested in this maturity group in 1994 have Katy as one parent and had less pecky rice than the check varieties.

Evaluation of rice lines in the URRN also has benefits to Arkansas rice growers. Often a variety is released from another state without much information on how that variety will perform in Arkansas. The URRN contains advanced rice lines from other states. When these lines are evaluated, the susceptibility to rice stink bug damage can be assessed before that line is released as a variety.

All of the yearly evaluations help prevent the release of lines highly susceptible to damage by the rice stink bug or give information on the expected susceptibility to rice stink bug damage.

Table 1. Number of locations, rice lines and replications for evaluations of rice samples from the Arkansas Rice Performance Trials (ARPT) and the Uniform Regional Rice Nursery (URRN) grown at Stuttgart.

	ARPT							URRN	
Item	1988	1989	1990	1991	1992	1993	1994	1993	1994
	number								
Locations	3	4	4	3	3	3	3	1	1
Rice Lines	36	36	36	36	63	63	60	80	80
Replications	4	4	4	4	3	3	3	3	3

Table 2. Average percent, by weight, of pecky rice in brown rice samples of rice varieties in the Arkansas Rice Performance Trials (ARPT).

Maturity Group	Grain	Year						
and Variety	Type	1988	1989	1990	1991	1992	1993	1994
Mid-Season								
Cypress	L	-	-	-	-	0.44	1.30	0.59
Newbonnet	L	0.88	0.14	0.80	0.79	0.44	1.50	0.64
Lemont	L	0.54	0.17	0.64	0.45	0.30	1.14	0.43
Katy	L	0.48	0.09	0.40	0.31	0.21	0.98	0.41
Short-Season								
Gulfmont	L	0.64	0.19	0.70	-	0.37	-	-
Mars	M	0.92	0.17	0.98	0.90	0.60	1.48	0.63
Orion	M	0.81	0.22	0.96	0.81	0.71	1.98	0.82
Bengal	M	-	-	-	-	1.24	2.36	1.42
Kaybonnet	L	-	-	-	-	0.31	0.92	0.28
LaGrue	L	-	-	-	0.36	0.30	0.78	0.31
Very-Short-Season								
Tebonnet	L	-	0.17	0.90	0.72	0.39	1.07	-
Maybelle	L	-	0.19	0.70	0.71	0.32	0.92	0.78
Millie	L	0.65	0.18	0.68	0.58	0.36	1.15	0.54
Alan	L	1.22	0.27	1.20	0.69	0.56	1.65	0.84
Adair	L	-	-	0.83	0.79	0.50	0.70	0.67
Jackson	L	-	-	-	0.51	0.37	0.99	0.69

RICE WATER WEEVIL INFESTATION IN WATER- AND DRILL-SEEDED RICE

J.L. Bernhardt

ABSTRACT

An experiment was conducted to determine if rice water weevils responded differently to methods of rice culture. Water seeding with continuous flood and drill seeding methods were compared. Rice water weevil adults and larval infestation differed in the two seeding and rice culture methods. Infestation pattern was normal for drill-seeded rice, i.e., peak infestation about 3 weeks after permanent flood and a steady decline thereafter. Water-seeded rice had a different pattern. Rice water weevil adults located, infested and deposited eggs in water-seeded rice with continuous flood very soon after the plants emerged from the water. A high level of infestation continued for 4 weeks and then started a decline. The steady level of larval infestation perhaps indicated multiple flights of adults infesting water-seeded plots. Grain yield was lower in the water-seeded plots. Damage due to rice water weevil infestation over several weeks may have contributed to yield loss. Although not quantified, slightly lower plant stand is believed also to have contributed to lower yields in the water-seeded plots. Growers who wish to water-seed rice and then maintain a continuous flood should be aware of potential problems with the rice water weevil. Serious problems could arise if fields on a farm are water-seeded and the adjacent fields are drill-seeded. This would isolate the water-seeded fields and concentrate rice water weevils. Application of carbofuran (Furadan) for rice water weevil control is more likely to be needed in water-seeded rice with continuous flood than in drill-seeded rice.

INTRODUCTION

The rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, is an insect pest found in all Arkansas rice fields. Although feeding on leaves by overwintered adults is commonly found on non-flooded rice, adults are attracted to flooded rice, and oviposition occurs only in flooded rice. Eggs are placed inside a submerged portion of the leaf sheath. Larvae must exit the leaf sheath, sink, enter the soil and find rice roots. Severe root-pruning results in stressed plants that are unable to receive nutrients from the soil until new roots appear; the plants do not achieve normal growth, have delayed heading and usually have reduced grain yield.

Drill-seeding of rice provides an opportunity for rice plants to achieve four to five leaves and a root system sufficient in size to receive nutrients and supplemental nitrogen before application of permanent flood. In contrast, water-seeded rice with continuous flood may provide the rice water weevil submerged, small plants with a less developed root system. Water-seeded rice could have an earlier infestation of rice water weevils and suffer severe root damage to the small root system. In addition, water-seeded rice could attract rice water weevils over a longer period of time interval. Rolston and Rouse (1964) found 3.5 and 8.5 times as many weevil larvae in water-seeded plots as in drill-seeded plots 4 and 8 weeks, respectively, after permanent flood in the drill-seeded plots. An explanation for higher numbers of rice water weevils in water-seeded rice was provided by Bang and Tugwell (1976). They found that rice water weevil adults preferred rice plants younger than 35 days. More weevils over a longer period of time may prove too much for the rice plants to overcome for normal grain yield in water-seeded rice with continuous flood.

The objective of this study was to compare the infestation levels of rice water weevils in drill-seeded rice and water-seeded rice with continuous flood and measure any influence of infestation on grain yield.

PROCEDURES

The comparison of rice water weevil infestation in water- and drill-seeded rice was conducted at the Rice Research and Extension Center near Stuttgart, Arkansas. Plot areas for the water-seeded rice were cultivated, nitrogen (150 lb N/acre as urea) incorporated, grooved to prevent seeds from wind or wave dispersal and treated with thiobencarb (Bolero) at 3 lb active ingredient (ai)/acre. Pre-sprouted 'Lemont' rice (150 grams) was broadcast into water over each 4.7 x 24-ft area on 13 May. After 4 days the water level was lowered to allow seedling establishment. The water depth was gradually increased to 4 to 5 in. by 31 May. A single supplemental nitrogen application of 30 lb N/acre as urea was made on 6 July to the water-seeded plots.

Plots similar in size to water-seeded plots were drill-seeded 28 April with Lemont rice at a rate of 90 to 100 lb/acre. Rice emerged 9 May. A single application of propanil (Stam, 3 lb ai/acre), thiobencarb (Bolero, 2 lb ai/acre) and bentazon (Basagran, 1 lb ai/acre) tank mix was applied to the drill-seeded rice 17 May. A three-way split of nitrogen (120-30-30 lb N/acre as urea) was applied 2 June preflood, 6 July and 19 July, respectively.

Rice water weevil larvae were monitored each sample date by removing five soil/plant cores (4 in. diameter x 4 in. depth) from each plot. Soil surrounding the roots was washed into 40-mesh sieves. The sieves were immersed in salt water, which caused the rice water weevil larvae to float. Each of the five samples from each plot was examined for the presence and number of rice water weevil larvae and pupae. Samples in the water-seeded plots were taken 17 June, about 4 weeks after rice plants emerged from the water, and continued weekly for 5 weeks. Samples were taken 24 June, about 3 weeks after permanent flood, in the drill-seeded plots and continued weekly for 4 weeks.

Prior to harvest, the number of panicles/ft^2 was counted in each plot. Twenty feet of the center four rows of each drill-seeded plot and a comparable area (41.9 ft^2) in the water-seeded plots was harvested with a small plot combine on 9 and 14 September, respectively. Recorded yields were corrected to 12% moisture.

RESULTS AND DISCUSSION

Rice Water Weevil Populations

Rice water weevil larvae found in the first samples taken in the water-seeded rice with continuous flood on 17 June included all sizes (Table 1). The presence of the pupae and many large larvae about 4 weeks after rice plants emerged above the water indicated that adults did infest and oviposit in the young water-seeded rice.

The infestation of rice water weevil larvae was the greatest in samples taken 3 weeks after permanent flood in the drill-seeded plots (Table 2) and declined steadily each week thereafter. This is the normal pattern for rice water weevil infestation in drill-seeded rice.

The pattern of infestation in water-seeded rice was different from that of the drill-seeded rice. The infestation remained nearly the same for the first three sample dates. Not until 8 weeks after plants emerged from the water did the level of rice water weevil infestation begin to decline significantly.

Grain Yields

Significant differences were found between the two rice culture methods (Table 2). The drill-seeded plots averaged 2660 lb/acre more than the water-seeded plots. Not all of the yield reduction may have been a result of rice water weevil damage. The number of panicles per square foot was 26 in the drill-seeded rice and 24 in the water-seeded rice. However, it was noted that some of the panicles in the water-seeded rice were from tillers that indicated a lower stand count than in the drill-seeded plots. Panicles from tillers are usually smaller than the main culm panicle. A small portion of the yield difference could be attributed to low plant stands in the water-seeded plots.

SIGNIFICANCE OF FINDINGS

Rice water weevil adults responded differently to the two seeding and rice culture methods. Rice water weevil adults located, infested and deposited eggs in water-seeded rice with continuous flood very soon after the plants emerged from the water. A high level of infestation continued for 4 weeks, then started a decline. The steady level of larval infestation perhaps indicated multiple flights of adults infesting water-seeded plots. Grain yield was lower in the water-seeded plots.

Growers who wish to water-seed rice and then maintain a continuous flood should be aware of potential problems with the rice water weevil. Application of carbofuran (Furadan) for rice water weevil control is more likely to be needed in water-seeded rice with continuous flood than in drill-seeded rice.

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Table 1. Percentage size distribution of immature rice water weevils from plots of water-seeded (WS) and drill-seeded (DS) rice, Stuttgart, Arkansas, 1994.

Size or stage of rice water weevil immatures	Date of samples								
	6/17	6/24		7/1		7/8		7/15	
	WS	WS	DS	WS	DS	WS	DS	WS	DS
Very Small	3.3	4.3	1.6	17.0	3.9	15.0	12.1	9.8	14.3
Small	33.5	22.6	17.2	29.2	13.2	14.2	21.5	12.1	14.3
Medium	28.5	16.9	24.0	18.9	14.3	25.7	14.0	21.2	21.4
Large	30.9	34.9	51.7	24.2	34.9	35.8	27.1	43.2	39.3
Pupae	3.8	21.3	5.5	10.7	33.7	9.3	25.3	13.7	10.7

Table 2. Average number of rice water weevil larvae per sample and yields taken from plots of two rice culture methods at Stuttgart, Arkansas, 1994.

	Date of Samples					Yield
Seeding method	6/17	6/24	7/1	7/8	7/15	(lb/acre)
Water-Seeded	16.4	15.1	15.9	11.3	6.6	5456
Drill-Seeded		19.2	12.9	5.4	2.8	8116

PEST MANAGEMENT: Disease Control

THE RELATIONSHIP BETWEEN RACE AND DNA FINGERPRINT GROUPS IN THE RICE BLAST PATHOGEN

J.C. Correll and F.N. Lee

ABSTRACT

A project was initiated in 1993 to examine race diversity in populations of the rice blast fungus (*Pyricularia grisea*) in Arkansas. The data indicate that eight genetically distinct "families" (MGR-DNA fingerprint groups) of the rice blast pathogen occur in Arkansas, but only four of the eight groups occur in the contemporary (i.e., after 1992) pathogen population. Two races (IC-17 and IB-49) apparently predominate in the contemporary population. In 1994, blast samples were collected from 30 locations from nine cultivars and 10 counties in the state. Isolates also have been collected from the highly susceptible cultivar 'M204' from seven counties in the state. In addition, over 500 monoconidial isolates have been recovered from 20 rice cultivars from a single location in White County. Isolates are currently being examined for race and DNA fingerprints. Preliminary data indicate that all four DNA fingerprint groups are common throughout the state. Again, similar to 1993, IC17 and IB49 predominate in the population. However, isolates collected from several cultivars, including 'Katy' and 'Kaybonnet', have been examined more extensively. Virulence tests have confirmed that several monoconidial isolates were pathogenic on the cultivars Katy and Kaybonnet in greenhouse inoculations, indicating that a unique race may be emerging in commercial rice fields. Preliminary DNA fingerprinting data indicate that isolates with this unique virulence phenotype are in one of the four common DNA fingerprint groups found in the state. Race diversity has previously been detected within this particular DNA fingerprint group.

INTRODUCTION

Breeding for stable resistance to rice blast is dependent on several variables, including the genetic diversity of regional blast pathogen populations and the appearance of new races capable of attacking previously resistant cultivars (Ou, 1985). Race stability, sources of new races and mechanisms by which new races of *P. grisea* appear that attack newly deployed resistance genes in popular rice cultivars are largely unknown (Ou, 1985). Addressing race stability and the origin of new races in the blast pathogen population in Arkansas is contingent on the availability of stable genetic markers to examine the genetic relatedness among races over time (Xia and Correll, 1995).

Information on the relationship between race and fungal genotype (DNA fingerprint) should provide a basis for effectively screening rice cultivars and breeding lines to important races of the rice blast pathogen in Arkansas (Levy et al., 1991; Xia et al., 1993; Zeigler et al., 1995). The overall objective of this research is to provide a better understanding of race diversity and population structure of the rice blast pathogen. These data should provide a basis for developing strategies to breed improved, blast-resistant cultivars for Arkansas rice producers.

MATERIALS AND METHODS

Blast samples were collected from nine rice cultivars from 30 locations in a total of 10 counties in Arkansas in 1994 (Tables 1, 2 and 3). Isolates were examined for their DNA fingerprints using previously described procedures (Levy et al., 1991; Xia et al., 1993). Selected isolates from several cultivars and geographical locations from throughout the state were examined for race diversity in greenhouse inoculations on a set of Arkansas differential rice cultivars. These isolates represent a diverse group of individuals within each of the four DNA fingerprint groups identified in the contemporary rice blast pathogen population. An additional group of isolates, initially identified by Drs. Fleet Lee and M.A. Marchetti and suspected of being a unique race pathogenic on Katy, also were characterized for race and DNA fingerprint group diversity.

Field plots were established at Kibler, Arkansas, in 1994 to examine disease development on nine rice cultivars and three breeding lines to specific races of the rice blast pathogen. Rice blast epidemics were induced by spray-inoculating rice seedlings and monitoring disease development during the course of the growing season.

RESULTS AND DISCUSSION

Although the frequencies of the DNA fingerprint groups vary among locations, four DNA fingerprint groups (A, B, C and D) appear to be common in contemporary populations of the rice blast fungus. These four DNA fingerprint groups were distributed throughout the counties sampled and were recovered from most, but not all, of the cultivars sampled.

Two races, IC-17 and IB-49, were identified among the diverse collection of isolates examined (Table 4). Among the recently collected isolates, a distinct correlation was observed between DNA fingerprint group and race: isolates in DNA fingerprint groups A and C had an IB49 race phenotype, and isolates in DNA fingerprint groups B and D had an IC17 race phenotype (Table 4).

Isolates that were pathogenic on Katy and Kaybonnet have been confirmed in greenhouse inoculation tests. The isolates tested belong to DNA fingerprint group "B," one of the four commonly found DNA fingerprint groups in Arkansas (Table 5). Interestingly, virulence diversity has been identified previously within DNA fingerprint group "B." A working hypothesis is that this particular DNA fingerprint group may be more "unstable" with regard to race than the others identified.

SIGNIFICANCE OF FINDINGS

The data indicate that the rice blast pathogen population in Arkansas is currently composed of four genetically distinct families or DNA fingerprint groups (A, B, C and D). These four groups are widely distributed and occur on most, but not all, cultivars. Since a correlation between DNA fingerprint groups and races of the blast fungus in the contemporary pathogen population in Arkansas has been demonstrated, it is hoped that the techniques employed may help expedite race identification from commercial rice fields. This information should lead to a greatly improved understanding of race diversity and population structure of the blast pathogen in the state and, consequently, should provide a basis for implementing strategies to develop improved blast-resistant cultivars for Arkansas rice producers. Also, a new race has been confirmed that is pathogenic on Katy and Kaybonnet, and preliminary data indicate that the origin of this new race is from one of the commonly occurring DNA fingerprint groups. Work in 1995 will continue to focus on this new, potential threat. In the future, a strategy to combine resistance genes to all of the DNA fingerprint groups may provide superior resistance stability to rice blast disease.

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Table 1. Rice blast samples examined in 1994.

Sample	Cultivar	County	Blast[z]
1	Katy	Monroe	-
2	Alan	Prairie	+
3	LaGrue	Lonoke	+
4	Lacassine	Lonoke	+
5	Bengal	Lonoke	-
6	Alan	Lonoke	+
7	Katy	Prarie	-
8	Mars	Lonoke	-
9	LaGrue	Poinsett	+
10	Cypress	Cross	+
11	LaGrue	Lawrence	+
12	M401	Lonoke	+
13	Lemont	Chicot	+
14	Lemont	Lawrence	+
15	Bengal	Cross	-
16	Bengal	Lawrence	+
17	M204	White	+
18	LaGrue	Lawrence	+
19	Lacassine	Lawrence	+
20	Kaybonnet	Lonoke	+
21	M204	Lonoke	+
22	M204	Clark	+
23	M204	Cross	+
24	M204	Lawrence	+
25	M204	St. Francis	+
26	M204	Chicot	+
27	Katy	MI (state)	+
28	LaGrue	Mississippi	+
29	Alan	MO (state)	+
30	20 cultivars	White Co.	+

[z] (+) = *Pyricularia grisea* recovered from sample.
(-) = *Pyricularia grisea* not recovered from sample.

Table 2. Rice blast samples recovered from 'M204' in 1994.[z]

County	Replicate plot	No. of isolates recovered
Lonoke	1	17
	2	19
	3	20
Clark	1	21
	2	19
	3	18
Cross	1	13
	2	14
	3	15
Lawrence	1	21
	2	5
	3	16
St. Francis	1	25
	2	17
	3	16
Chicot	1	11
	2	8
	3	32
White	1	20
	2	21
	3	22

[z]Samples were recovered from field plots established by Dr. Rick Cartwright.

Table 3. Rice blast samples recovered from 20 cultivars from a single location in White County, Arkansas, in 1994[z].

Plot No.	Cultivar	Number of samples incubated	Number of samples with blast	Number of isolates recovered
101	Newbonnet	25	25	23
102	Jackson	25	23	20
103	Adair	25	20	20
104	M204	25	22	20
105	L203	25	22	20
106	Cypress	25	24	24
107	Lacassine	25	24	24
108	Bengal	25	14	14
109	Millie	25	22	22
110	Lemont	25	23	22
111	Koshihikari	21	0	0
112	Alan	25	20	20
113	LaGrue	25	25	24
114	Kaybonnet	14	0	0
115	Maybelle	25	23	23
116	Jodon	25	23	23
117	Mars	25	24	24
118	RT7015	25	24	23
119	Katy	7	4	4
120	Jasmine 85	10	3	3

[z]Samples collected from plots established by Dr. Rick Cartwright. Only data from the first replication are included.

Table 4. The relationship between DNA fingerprint group and race among isolates of *Pyricularia grisea* in Arkansas.

Isolate	DNA fingerprint group[z]	County	Host	Race[y]
A598	A1	Cross	Alan	IB49
A603	A1	Cross	Alan	IB49
A491	A1	Arkansas	Newbonnet	IB49
A343	A1	Pulaski	Newbonnet	IB49
A359	A1	Pulaski	Newbonnet	IB49
A233	A1	Lonoke	Newbonnet	IB49
A177	A2	Lonoke	Mars	IB49
A274	A2	Lonoke	Newbonnet	IB49
A187	A3	Lonoke	Mars	IB49
A193	A5	Lonoke	Mars	IB49
A213	A4	Lonoke	Mars	IB49
A290	A5	Lonoke	Mars	IB49
A400	A5	Monroe	Newbonnet	IB49
A516	A7	Arkansas	Newbonnet	IB49
A201	A9	Lonoke	Mars	IB49
A264	B1	Lonoke	Newbonnet	IC17
A358	B1	Pulaski	Newbonnet	IC17
A624	B2	Lonoke	Newbonnet	IC17
A631	B3	Lonoke	Newbonnet	IC17
A139	B5	Lonoke	Newbonnet	IC17
A405	B7	Monroe	Newbonnet	IC17
A355	B8	Pulaski	Newbonnet	IC17
A361	B9	Pulaski	Lemont	IC17
A431	B10	St. Francis	L201	IG1
A460	B12	St. Francis	Lemont	IC17
A552	B13	Lawrence	Millie	IC17
A560	B15	Poinsett	Jackson	IC17
A496	B17	Arkansas	Newbonnet	IC17
A511	B18	Arkansas	Newbonnet	IC17
A601	B19	Cross	Alan	IC17
A119	C1	Lonoke	Newbonnet	IB49
A345	C1	Pulaski	Newbonnet	IB49
A434	C1	St. Francis	L201	IB49
A475	C1	Arkansas	L202	IB49
A136	C2	Lonoke	Newbonnet	IB49
A395	C3	Monroe	Newbonnet	IB49
A406	C6	Monroe	Newbonnet	IB49
A281	C7	Lonoke	Newbonnet	IB49
A362	C9	Pulaski	Lemont	IB49
A461	C11	Arkansas	L202	IB49
A549	C12	Lawrence	Lemont	IB49
A559	C13	Poinsett	Jackson	IB49
A575	C17	Poinsett	Alan	IB49
A536	C17	Jefferson	Newbonnet	?
A482	C?	Arkansas	Newbonnet	IB49
A142	D1	Lonoke	Newbonnet	IC17

continued

Table 4. continued.

Isolate	DNA fingerprint group[z]	County	Host	Race[y]
A143	D1	Lonoke	Newbonnet	IC17
A347	D1	Pulaski	Newbonnet	IC17
A542	D3	Lawrence	Lemont	IC17
A242	D5	Lonoke	Newbonnet	IC17
A513	D12	Arkansas	Newbonnet	IC17
A267	D6	Lonoke	Newbonnet	IC17
A366	D8	Pulaski	Lemont	IC17
A381	D9	Monroe	Newbonnet	IC17
A454	D10	St. Francis	Lemont	IC17
A493	D11	Arkansas	Newbonnet	IC17
A531	D13	Jefferson	Newbonnet	IC17
A561	D14	Poinsett	Jackson	IC17
A592	D14	Cross	Alan	IC17
A385	D15	Monroe	Newbonnet	IC17

[z]DNA fingerprint group was determined with the MGR586 probe.

[y]Races were determined by repeated inoculations on an Arkansas set of rice differentials (Xia et al., 1993). Note that races IC17 and IE1 cannot be distinguished on this set of differentials.

Table 5. Race diversity within a DNA fingerprint group in Arkansas.

Isolate	DNA fingerprint group[z]	Race[y]	Collection site and year
75A49	B	IG1	Arkansas 1975
A264 (3-2-17)	B	IC17	Arkansas 1992
M94020 (ss1)	B	IE1k	Arkansas 1994

[z]DNA fingerprint group was determined with the MGR586 probe.

[y]Race determination based on inoculations on Arkansas and International differentials (Xia et al., 1993). Race IE-1k is pathogenic on the differential cultivar Katy in greenhouse inoculations.

DISTRIBUTION OF RICE BLAST WITHIN COMMERCIAL RICE FIELDS WITHIN ARKANSAS

D.O. TeBeest, D.H. Long, F.N. Lee and J.C. Rupe

ABSTRACT

Field experiments were conducted in 1994 in two commercial rice fields seeded in 'Newbonnet' and 'LaGrue' cultivars to determine how rice blast develops and disperses within susceptible cultivars under commercial conditions. Fields were selected on the basis of susceptibility of the cultivars to rice blast and on the early occurrence of disease in fields. As in small plot tests, rice blast did not appear to develop continuously during the year, even under stressed conditions. In the Newbonnet field, an area identified as a disease center for leaf blast early in the growing season also appeared to be a disease center for neck blast near harvest, suggesting a relationship between these two phenomena. This relationship was not found in the LaGrue field where significant disease centers for leaf blast did not develop.

INTRODUCTION

Rice blast is an important disease of rice (*Oryza sativa* L.) worldwide and is favored wherever blast-susceptible cultivars are grown in the absence of effective management strategies. The pathogen *Magnaporthe grisea* infects the rice plant at any growth stage, causing leaf blast, collar rot, neck blast and panicle blast (Kingsolver et al., 1984). Rice blast has become more important in Arkansas since the mid 1980s. Widespread planting of a susceptible cultivar on more than 55% of the total acreage contributed to statewide reductions in rice yields (Lee, 1992).

The epidemiology of the disease has been investigated in other countries, but very little is known about its development in Arkansas. Information on key factors contributing to the initiation of epidemics, disease development and distribution in production fields is lacking. Primary inoculum that initiates epidemics in Arkansas may come from infested rice seed and stubble but not from weed or bamboo hosts (Lee, 1994). Infected leaves, collars, necks and panicles provide secondary inoculum (Kingsolver et al., 1984), but each phase contributes different amounts at different times (Koizuma and Kato, 1990).

Water and fertilization management strategies have a profound effect on rice blast severity and incidence in Arkansas. Rice blast progresses more rapidly under upland conditions (dry) than under flooded conditions (Kim and Kim, 1990). These results were later confirmed in water gradient studies using Arkansas cultivars (Lee, unpublished). Nitrogen fertiliztion rates and application time also influence the incidence and severity of rice blast (Kurschner et al., 1992). These management strategies play a major role in the initiation and development of rice blast epidemics in production fields in Arkansas (data not published).

Dispersal of spores within the rice canopy was significantly higher than above the canopy, but long-distance dispersal was enhanced under windy conditions. (Suzuki, 1975; Koizumi and Kato, 1990). The occurrence of rice blast within fields was more affected by development of infection centers within fields than by dispersal from a single source. Lesions on the uppermost two leaves are inoculum sources for neck infections (Parks et al., 1983), and the incidence of leaf blast has been correlated to neck blast incidence (Kingsolver et al., 1994). Neck blast has been strongly correlated with yield loss (Torres and Teng, 1993). However, these correlations are affected by host resistance and environmental conditions (Rangaswami and Subramanian, 1958; Bonman et al., 1983; Roumen et al., 1992).

The objectives of our research were to determine how rice blast develops and spreads in production fields in Arkansas and to define the relationship between leaf blast and neck blast incidence in commercial fields.

MATERIALS AND METHODS

Two commercial fields seeded to 'Newbonnet' and 'LaGrue' located near Hazen, Arkansas (Prairie County), were selected for study in 1994 because 1) the cultivars were susceptible to endemic races, 2) samples could be collected before panicle primordia and 3) there was localized disease pressure within each field. Environmental data (temperature, relative humidity and rainfall) were collected from a weather station located at Stuttgart, Arkansas, about 30 miles distant.

The spatial distribution of rice blast in each field was determined by establishing transect grids with lines running parallel to rows at 30-m intervals and perpendicular to rows at 15-m intervals. Disease incidence data were collected from 4-m^2 plots at intersections of transect lines (each 15x30 m). The sampled areas within fields were established based on natural boundaries and disease incidence. Leaf blast incidence was recorded at early stages of panicle primordia and during the late boot stage; neck blast incidence was taken during the kernel milk phase within each plot. Levee orientation, water management, fungicide applications and plant maturation were also recorded.

The distribution of rice blast was analyzed two ways. Contour and three-dimensional maps were constructed to provide a detailed outline of blast development in each field. Spatial autocorrelations were made to reveal the nature and orientation of disease patterns and the spatial dependencies of disease incidence between sampling points in all directions within the field (Modjeska and Rawlings, 1983; Gottwald, 1992). The relationships between leaf blast and neck blast incidence were determined in each field using the Pearson product moment correlation and linear regression.

RESULTS AND DISCUSSION

Disease Distribution and Development in the Newbonnet Field

In this field rows were oriented in a north/south direction along the gradient of the field with seven to nine levees perpendicular to the rows in the experimental area. Water management problems persisted in the northwestern corner of this field through most of the growing season. Rice blast was most severe in this stressed area.

On 3 July 1994, a high incidence of leaf blast clearly localized as a disease focus within 100 m of the northwestern corner, while disease incidence was low outside this area (Fig. 1A). Most of the samples taken outside the northwestern corner, particularly in the southeastern quadrant, were free of disease. On 14 July 1994, the disease was still highly localized to the northwestern corner (Fig. 1B) and had not spread significantly from the infection center to the remainder of the field, although several smaller infection centers were found 150 to 300 m from the original center. The mean disease incidence within the focus was less than that recorded earlier. By 9 August 1994, the incidence of neck blast in the northwestern corner was greater than 65%, much higher than in other quadrants (Fig. 1C). Neck blast was distributed randomly across the remainder of the field at moderate levels (<20%).

The incidence of disease throughout this field appeared to be greatly influenced by the very localized early occurrence of disease development within the northwestern corner (Fig. 1). Typically disease disperses from a distinct focus and has a well-defined gradient spreading outward (Minogue, 1989). The incidence of disease along transects extending from the northwestern corner followed this type of gradient. Dispersal from the initial focus appeared to be limited. Occasional "jumps" in disease levels were recorded as far as 300 m away from the initial disease center. The incidence of neck blast within the Newbonnet field was correlated to leaf blast infections (Fig. 2), although neck blast occurred on rice plants previously free of leaf blast (Fig. 1). The relationship between these two phases of rice blast needs further investigation because they have important implications in predicting the need for fungicide applications, occurrence of neck rot and subsequent yield losses.

Spatial autocorrelations for disease between sampling points within the Newbonnet field were not constant over the three sampling dates. The correlations among sampling points in the first sampling date had a stronger spatial dependency parallel to the rows (330 m) than perpendicular to the rows (210 m). However, the spatial dependencies of sampling points adjacent to one another, both along and across rows, were significantly less in the second sampling than that observed in the first sampling date and may be due to differences in the incidence of leaf blast observed in the samples outward from the disease focus. Leaf blast was not recorded in many samples taken on the first sampling date. The spatial correlation of sampling points in the neck blast data had a stronger spatial dependency running along rows than across rows. The dependency of adjacent sampling points for leaf blast (second sampling date) and neck blast were very similar and suggest a relationship between leaf blast and neck blast incidence.

Disease Dispersal and Development within a LaGrue Field

In this field, rows were oriented from north to south, and nine to 12 levees (east to west) dissected the rows. Although two water sources irrigated this field, obvious water management problems were prevalent in the southern portion of the field (high end) between levees 150 and 450 m north of the most southern levee (area indicated by the arrows)(Fig. 3). Water stress conditions persisted in this area throughout most of the season. Significant levels of disease were first found in the southern part of the area mapped (Fig 3A). Benomyl was applied once to this field before panicle emergence.

The incidence and distribution of leaf blast within this field was different from the Newbonnet field; it lacked a well-defined disease center of high incidence of leaf blast (Fig. 3A, 3B). Observations made on 4 July 1994 indicated a randomly dispersed, low incidence (less than 5%) of leaf blast disease across the field with one small infection center located 210 m north of the southwestern corner (Fig. 3A). Several disease centers were identified 15 July 1994 within the stressed area, and disease levels were slightly greater (up to 14%) than those recorded for the center found on 4 July 1994. The overall disease incidence across the field was slightly greater (Fig. 3B). Disease levels were greater within the water-stressed area. A general conclusion from these two samples was that the disease was moving in the direction of prevailing winds, from the southwest to the northeast.

The incidence of neck blast was very low on 14 August 1994 (<3%) across the entire field (Fig. 3C). Clustering of neck blast was more prevalent to the northern and northeastern corner. Neckblast centers did not overlap well with leaf blast centers. Tests for relationships between neck blast incidence and leaf blast were inconclusive in this field, perhaps due to variability between adjacent points, widespread distribution and low blast incidence for leaf and neck blast. The application of benomyl prior to panicle emergence also may have significantly reduced the development of blast in this field.

Spatial autocorrelations between sampling points for all sampling dates differed slightly in the number and pattern for disease centers for both leaf blast dates and neck rot. Spatial patterns for all data were slightly skewed toward the edges of the field as a result of the widespread distribution of low levels of disease across the field with disease centers near edges.

SIGNIFICANCE OF FINDINGS

It is significant that in both fields, infection centers for rice blast developed within water-stressed areas. The intensity of disease within centers depended upon susceptibility, the degree and length of stress and possibly the amount of inoculum early in the season. A surprising result of this study was that disease did not spread very far with great intensity from a heavily infected center in a susceptible cultivar. This is perhaps consistent with previous data that show that the incidence of leaf blast on upper leaves declines during mid-season. Of greater significance is that the incidence of leaf blast was correlated with the incidence of neck blast later in the year. Since neck blast is correlated with yield losses, early and high incidence of leaf blast may be an indication of the potential for significant yield reductions despite mid-year reduction in the incidence of leaf blast.

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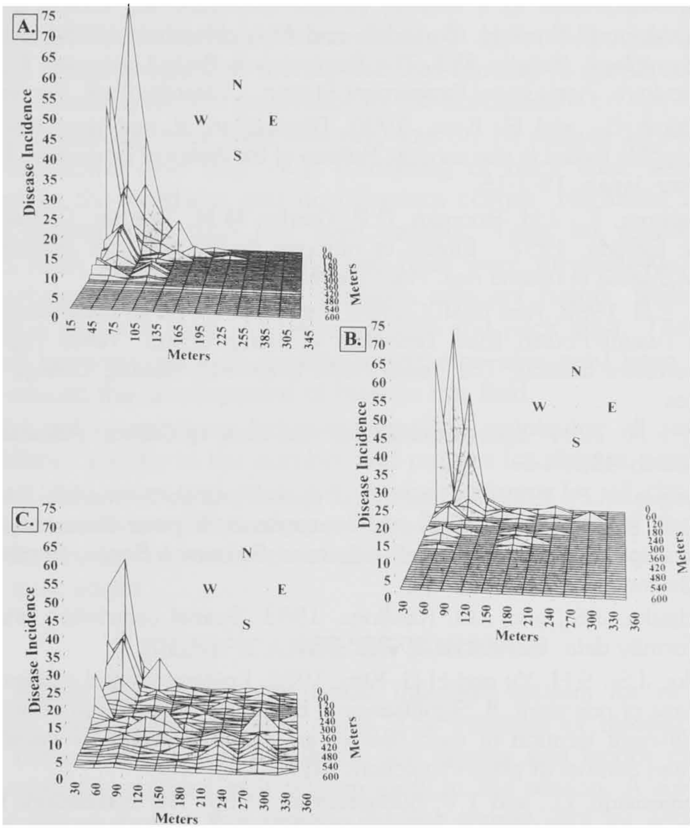

Figure 1. A three-dimensional diagram of the distribution and incidence of rice blast disease in a commercial field of Newbonnet in 1994. Each graph represents the experimental area and disease incidence within the Newbonnet field. A. The distribution and incidence of leaf blast on 3 July 1994. B. The distribution and incidence of leaf blast on 14 July 1994. C. The distribution and incidence of neck rot on 9 August 1994.

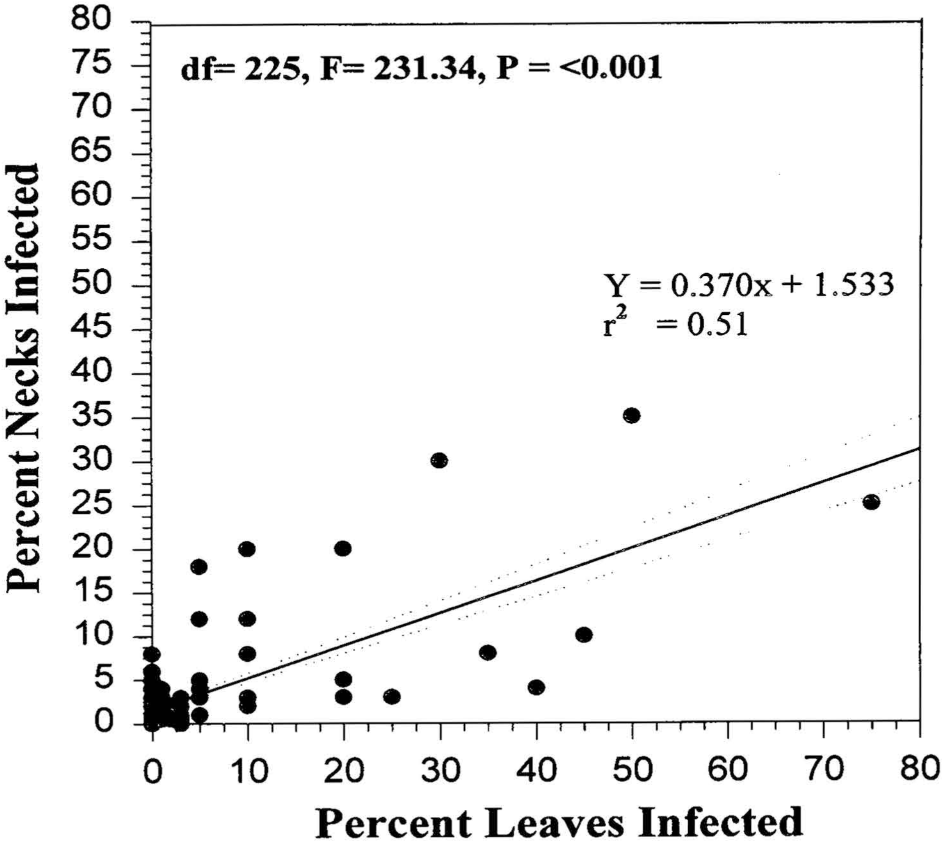

Figure 2. The relationship of the incidence of leaf blast (percent leaves infected) to the incidence of neck rot (percent necks infected) in a commercial Newbonnet field in 1994 as shown by linear regression analysis.

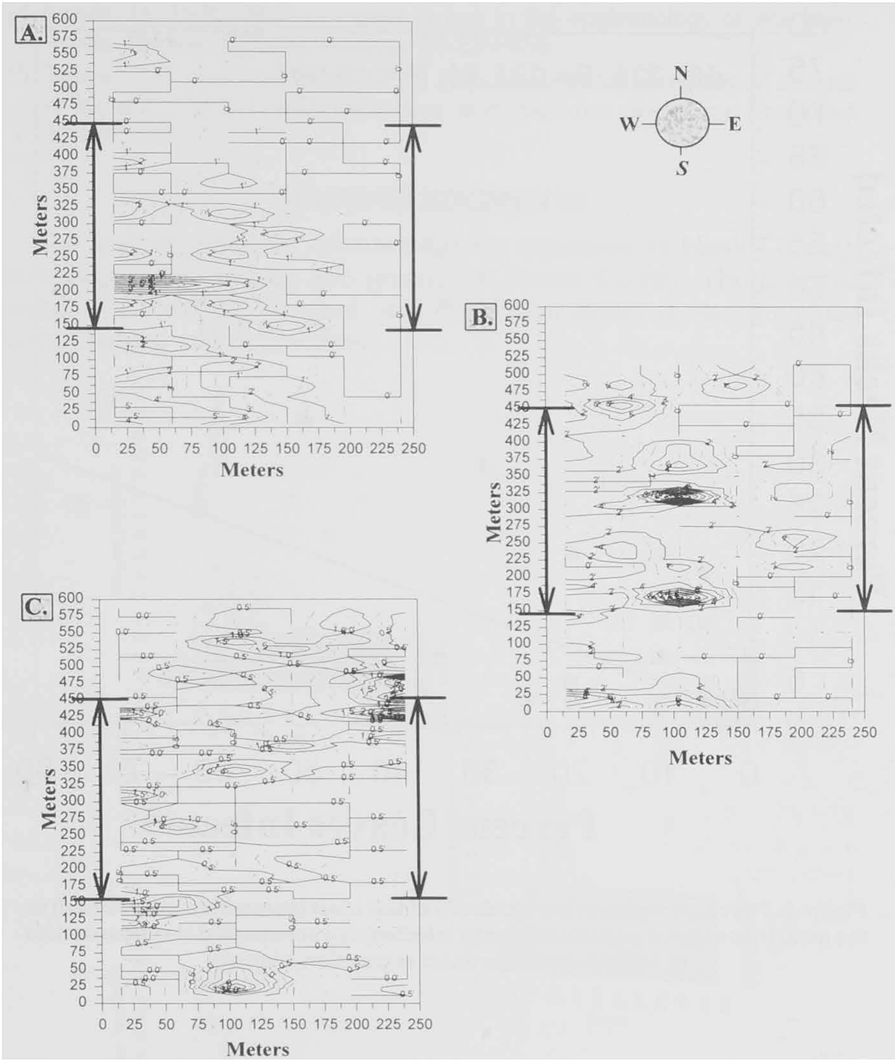

Figure 3.A two-dimensional diagram of distribution and incidence of rice blast in a commercial field of LaGrue in 1994. The values indicate the incidence of disease. A. The distribution and incidence of leaf blast on 3 July 1994. B. The distribution and incidence of leaf blast on 14 July 1994. C. The distribution and incidence of neck rot on 9 August 1994.

EFFECT OF CULTIVAR AND CULTURAL PRACTICES ON THE EPIDEMIOLOGY AND SEVERITY OF RICE BLAST DISEASE

D.O. TeBeest, D.H. Long and F.N. Lee

ABSTRACT

Field experiments were conducted to determine how rice blast develops and how fertilization affects the rate of development of rice blast on eight selected cultivars in replicated small plots at the Pine Tree Experiment Station, Colt, Arkansas. Results of these tests indicate that rice blast does not appear to develop continuously throughout the year and that application of nitrogen above recommended rates at preflood significantly increased the severity and incidence of rice blast on some cultivars. The incidence of collar rot was significantly correlated to the incidence of neck rot in small plots for all cultivars. In commercial fields, a high incidence of rice blast early in the year was associated with high incidence of neck rot at harvest. The incidence of leaf blast early in the season and the incidence of collar rot on flag leaves may present early indications of the potential for yield losses.

INTRODUCTION

Rice blast is an important disease of rice and can cause significant crop losses in the absence of effective management strategies. The pathogen *Magnaporthe grisea* infects leaves, collars, necks and panicles of rice. It has become an important disease in Arkansas on many of the new, high-yielding, blast-susceptible cultivars, such as 'Newbonnet'.

Management strategies include disease resistance, fungicides and cultural techniques such as water and fertilization management to reduce disease severity. These techniques should be additive in reducing the disease development and severity. Implementing these management strategies requires accurate information on probable disease development based on historical records or on effective models.

Although much is known about the development of rice blast in tropical regions, very little quantitative information describes how rice blast develops in Arkansas or how the various environmental and cultural factors affect disease development on Arkansas cultivars. Also, the inter-relationships of the neck blast, leaf spot and collar rot phases of the disease and their cumulative effects on yield are unknown. Recent reports have suggested that infections on leaves and collars provide inoculum for later epidemics on leaves, collars, necks and panicles. Torres and Teng (1993) have found that the incidence of neck rot is directly related to yield losses. Rangaswami and Subramanian (1958) showed a positive correlation between the incidence of leaf infection and neck infections on susceptible cultivars.

Several factors contribute to rice blast epidemics in Arkansas. Most cultivars are susceptible to rice blast, although the effects of disease resistance in terms of disease development during the growing season are unquantified. Marchetti (1983) showed that even moderately resistant cultivars slowed the rate at which disease developed. Bonman et al. (1989) showed that resistance to leaf infection is not necessarily related to resistance to neck infection in some cultivars and that environment also affects epidemic development.

Cultural management decisions such as rates and timing of nitrogen fertilization may also increase the severity of rice blast in Arkansas (Kurschner et al., 1992; Templeton et al., 1970). Kurschner et al. (1992) noted in the Philippines that although nitrogen is essential for productivity, the severity of blast also increases with the amount of nitrogen applied. Leaf blast was suppressed when N was supplied late in the season, even at levels that had no significant effects on yields. Amin (1983) and Templeton et al. (1970) reported that split applications of nitrogen reduce the severity of rice blast. The effect of nitrogen treatments on rice blast on cultivars now grown in Arkansas is unknown.

The specific objectives of these experiments were 1) to determine how fast rice blast develops on selected cultivars with different levels of resistance; 2) to determine if rice blast epidemics develop continuously or if they "slow-down" in mid-season or at host maturity and 3) to determine the influence of nitrogen fertilization on rice blast development on selected cultivars.

PROCEDURES

Field experiments were conducted at the Pine Tree Experiment Station at Colt, Arkansas, during 1994. The experimental site was bordered by trees on the northern and eastern sides, and the site was precision leveled for optimum water management. Temperature, relative humidity, water/soil temperature, leaf wetness, solar radiation, wind speed and wind direction were measured using a Campbell data logger.

Eight rice cultivars of diverse genotypes, maturities and susceptibilities to *M. grisea* were seeded in two replicated field trials at one-month intervals (Table 1). Four replications per cultivar were drilled-seeded at 110 lb/acre in 10 x 16-ft plots of 18 rows spaced 7 in. apart. Treatments were made in a split-plot design. Half of the plots received the recommended nitrogen (N) fertilization rate applied in a three-way split with the majority of the nitrogen applied at preflood and the remaining 60 units of N applied after internode elongation with two applications 10 days apart. The other half received 50% more than the recommended nitrogen requirement, all applied at preflood. Urea was used as the N source.

Blast was initiated by inoculation of susceptible cultivars (M201, 'M202' and 'L203') within spreader plots surrounding the cultivar plantings with four virulent races of *P. grisea* (IB49, IC17, IG1 and IB1). Spreader plots were planted at a seeding rate of 110 lb/acre in 5 x 16-ft plots of 9 rows at 7-in. row spacing. Conidia of *M. grisea* were harvested separately for each race from cultures grown on PDA from 7 to 10 days under continuous illumination. Spores were adjusted to 500,000 conidia/ml and combined prior to spraying. Xanthan gum (0.4 g/L) and Silwet L77 (0.2 ml/L) were added to the spore suspensions prior to inoculations. Inoculations were made between 10:00 p.m. and midnight using a compressed air applicator. The next morning plots were covered with a shade cloth to maintain moisture and to reduce the daytime temperatures. The cloth was removed the following morning. Disease ratings were made one week after inoculations to determine disease incidence in all the test cultivars and uniformity within spreaders. Water levels in the plots were drained for 10 to 14 days after inoculation but maintained at a 2- to 4-in. flood thereafter.

Leaf blast, collar rot and neck blast were measured biweekly during the growing season. Each leaf on 12 randomly selected plants in each subplot was examined to determine the number of lesions, lesion size, age of lesion and lesion location. Flag leaf, collar rot and rotten neck infections were recorded. In this report, total lesion area is the total area of each plant infected by *M. grisea*, disease incidence is the number of plants infected in each sample (expressed as percentage infected), and severity is the estimated proportion of each plant infected by *M. grisea*. Disease progress was determined from severity and incidence data for the entire plant and for the upper three leaves plotted against time. Panicle weights were used to determine percent yield reduction caused by *M. grisea*. Fifty panicles from each subplot were collected and compared to 50 panicles collected from fungicide-treated control plots. Values for the areas under the disease progress curves (AUDPC) and the differences between means of the AUDPCs for nitrogen treatments were analyzed with T-test and GLM procedures in SAS.

RESULTS AND DISCUSSION

Rice Blast Development on Different Cultivars

Leaf blast followed a basic pattern on all cultivars for both N levels in both plantings. Leaf blast increased from initial low levels to the highest levels recorded (at the early stages of panicle primordia, late June) then steadily declined after early July (Figs. 1-4). It should be noted that the highest disease incidence levels among all cultivars in the second plantings were reached as disease incidence was declining in the earlier planting. This suggests that plant effects rather than environmental conditions slow the rate of disease increase after early July.

Different levels of susceptibility were observed among the cultivars in this test. Newbonnet, RT7015 and 'Alan' were the most susceptible under 1994 conditions, followed by 'Adair' and 'Lacassine'. Cypress and 'Mars' appeared to be more resistant to leaf blast than all other cultivars except 'Katy'. Rice blast did not develop on Katy as it was resistant to races used in this test. Rice blast did not develop on the Mars cultivar in the first planting, although it reached significant amounts in the second planting. This may have resulted from an insufficient amount of inoculum of the race(s) pathogenic to Mars in the first planting that were present in the second planting.

Disease Development on Upper Leaves

Rice plants produce 14 to 17 leaves throughout the growing season, and new leaves emerge every 4 to 5 days during the vegetative stage and every 7 to 8 days during the reproductive stage, although only four to six leaves are present at any given time (Yoshida, 1981). The upper leaves of cultivars in the first planting were examined separately to determine if new lesions developed continuously on new leaves during the season.

There was less leaf blast on the upper leaves; however, the pattern of infection of the upper three leaves was similar to disease development on whole plants (Figs. 5 and 6). There was an increase in the incidence of leaf blast on the upper three leaves from early June through late June or early July. This was followed by a general decline in the incidence of upper leaf infection beginning after late June to early July, depending upon cultivar. Although both plant and environmental effects mentioned can reduce disease incidence, leaves that emerge after initiation of panicle primordia are significantly more resistant than leaves emerging during the vegetative growth stages.

The Effects of Nitrogen Fertilization

The effect of applying extra N at the pre-flood stage on the development of rice leaf blast symptoms was similar in both plantings (Figs. 1-4). The application of extra N generally increased disease incidence and severity on all cultivars except Katy. The effect on disease incidence was especially significant for Alan and Adair in the first planting where wide differences in disease were noted in early July (Fig. 1). The increases in disease incidence, disease severity, total lesion area and the number of lesions per plant were significantly greater in the extra N treatment than in the recommended N treatment for RT7015, Newbonnet, Alan and Adair (Table 2). The number of lesions per plant and the total lesion area were also greater in the extra N treatment than in the recommended N treatment for Lacassine. Two exceptions to the basic pattern were observed in the second planting of Newbonnet and Alan (Fig. 3). In these cultivars, disease incidence increased in the extra N treatment and maintained high disease levels throughout the season.

The effect of applying extra nitrogen at preflood on disease incidence for the upper three leaves was similar except the differences between the N treatments on Adair were not significant and incidence on Lacassine was significant, but not total lesion area or mean lesions per plant (Figs. 5 and 6, Table 3).

Analysis of disease progress curves for both plantings indicated some significant differences between cultivars for incidence, severity, total lesion area and lesions per plant (Table 4). Analysis of disease progress curves for cultivar x nitrogen interactions on rice blast disease for whole plants indicated that differences were significant for disease severity, disease incidence, lesion area and the number of lesions per plant (Table 5). However, analysis of disease progress on the upper three leaves of infected plants indicated that cultivar x nitrogen interactions for disease severity on the upper three leaves were not significant (Table 5). This may indicate that the effect of applying extra N at preflood may have been lost by the end of the vegetative phase.

Collar rot. Collar rot infection appeared to be more prevalent on the more susceptible cultivars RT7015, Newbonnet and Lacassine. The incidence of rotten neck was strongly correlated to the incidence of collar rot of the flag leaf (Fig. 7). Although neck rot can occur without collar rot, occurrence of rotten neck appeared to be certain when collar rot infections were present. This relationship may have important implications in predicting the occurrence of neck rot and yield losses because neck rot has been closely correlated to yield losses (Torres and Teng, 1993). Analysis of data concerning the effect of extra nitrogen on the incidence of collar rot was statistically inconclusive but suggested that collar rot was more prevalent on plants treated with extra nitrogen.

Neck rot infection. Differences between nitrogen treatments within cultivars for neck rot were generally small and not significant. The incidence of neck blast was generally greater in the high-nitrogen treatment than in the recommended-N treatment in all cultivars. Neck rot was significantly higher in the high N treatment for Newbonnet and RT7015 in the first planting and for Adair, Lacassine and Mars in the second planting. In contrast, neck blast incidence in Cypress was significantly higher in plots with recommended N levels than in the preflood N treatment in both tests. Plants in the high-nitrogen sub-plots were consistently 7 to 10 days later in maturing compared to the recommended-N sub-plots. Since reports suggest a small infection window for the neck blast phase of the disease (Amin, 1983; Willis et al., 1968), delaying maturity may have played a role in increasing rotten neck incidence.

Adjusted yields from infected plots. Analysis of panicle weights suggested that application of extra nitrogen at preflood reduced grain yields compared to recommended nitrogen treatments. However, due to variability between plots, blast development in our control plots, differences in maturity of cultivars relative to blast development (Takasaki, 1988) and the small sample size, significant differences were not detected between treatments.

SIGNIFICANCE OF RESULTS

Methods developed in 1994 permitted establishment of rice blast in epidemic proportions in small plots.

The incidence of leaf blast was greater when susceptible cultivars received N above the recommended rates at the preflood stage. However, the incidence of leaf blast appeared to decline on the upper leaves after mid-July, despite the presence of sporulating lesions on lower leaves.

There was a strong correlation between the incidence of collar rot and the incidence of neck rot. Since neck rot is highly correlated with yield losses, this relationship may provide a useful indicator of the potential severity of rice blast on yield and may also be a decision point for application of fungicides. The relationship of peak incidence of leaf blast to collar rot and neck rot must still be resolved.

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Table 1. Cultivar characteristics and susceptibility of the eight cultivars to *Magnaporthe grisea* races used in the 1994 experiments.

Cultivars	Cultivar characteristics[z]	Blast Ratings[z,y]				
		IB49	IC17	IG1	IB1	Field
Adair	* long grain rice * very short season * 43 in. ht. * very high yielding	5	6	7	4	S
Alan	* long grain rice * very short season * 35 in. ht. * high yielding	8	7	4	1	S
Cypress	* long grain rice * short season * 35 in. ht. * high yielding	6	6	1	1	MR
Katy	* long grain rice * midseason * 44 in. ht. * sensitive to flood depth	2	1	1	1	R
Lacassine	* medium grain rice * midseason * 37 in. ht. * high yielding	6	6	1	2	MR
Mars	* medium grain rice * short season * 46 in. ht. * high yielding	8	3	2	7	MR
Newbonnet	* long grain rice * midseason * 43 in. ht. * high yielding	8	8	1	1	VS
RT7015	* long grain rice * very short season * 35 in. ht. * high yielding	8	8	8	1	VS

[z]Source: Rice Production Handbook, Cooperative Extension Service, University of Arkansas.
[y]Summary by degree of susceptibility: 1 = least susceptible to 9 = most susceptible; R = resistant, S = susceptible (M = moderately and V = very).

Table 2. Statistical differences in the area under the disease progress curves for the incidence, severity, total lesion area and mean number of lesions per plant caused by *M. grisea* for the eight cultivars and two nitrogen (N) fertilization treatments used in tests planted 21 April 1994 at Colt, Arkansas.

	Incidence		Severity		Total lesion area		Mean No. lesions/plant	
Cultivars	Normal N	High N	Normal N	High N	Normal N	High N	Normal N	High N
Adair	1126	2608*	18.96	41.92*	203.7	609.7*	22.63	74.17*
Alan	1390	3250*	14.52	42.66*	163.9	605.2*	20.29	88.05*
Cypress	368	778	3.97	6.29	34.4	78.9	4.12	13.09
Katy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lacassine	1877	2363	24.52	34.72	219.4	469.5*	27.33	61.88*
Mars	78.7	80.0	0.00	0.32	0.00	4.6	0.00	1.30
Newbonnet	1730	3175*	25.65	53.86*	203.5	670.7*	36.33	88.37*
RT7015	2335	3705*	41.36	68.06*	365.8	963.6*	44.28	129.9*
LSD	644.63		16.292		182.87		23.244	

*Asterick indicates significant differences between treatments within cultivars at $P = 0.05$.

Table 3. Statistical differences in the area under the disease progress curves for the incidence, severity, total lesion area and mean number of lesions on the upper three leaves caused by *M. grisea* for eight cultivars and two nitrogen (N) fertilization treatments used in tests planted 21 April 1994 at Colt, Arkansas.

	Incidence		Severity		Total lesion area		Mean No. lesions/plant	
Cultivars	Normal N	High N	Normal N	High N	Normal N	High N	Normal N	High N
Adair	767.3	1228	13.36	17.96	103.6	187.6	14.70	30.68*
Alan	387.8	2138*	5.42	25.08*	59.73	267.7*	8.40	45.12*
Cypress	439.0	508.0	1.73	6.51	11.50	56.9	6.04	8.33
Katy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lacassine	844.5	1433*	9.45	23.24	64.29	175.3	12.48	28.08
Mars	78.7	40.0	0.00	0.14	1.07	1.34	0.00	0.40
Newbonnet	1277	2232*	17.34	35.03*	116.35	310.9*	22.51	44.42*
RT7015	1283	2795*	31.89	54.14*	202.6	561.9*	22.65	77.08*
LSD	560.75		17.11		142.79		18.23	

*Asterisk indicates significant differences between treatements within cultivars at $P = 0.05$

Table 4. Differences between means of the areas under the disease progress curves of the nitrogen treatments for disease incidence, severity, total lesion area and total number of lesions per plant for eight cultivars grown in tests planted 21 April and 23 May 1994 at Colt, Arkansas.

	Incidence		Severity		Total lesion area		Mean No. lesions/plant	
Cultivars	1st planting	2nd planting	1st planting	2nd planting	1st planting	2nd planting	1st planting	2nd planting
Adair	1482.0a[z]	460.8bc	22.96an	4.59bc	405.93bc	87.05bc	51.54bc	19.0bcd
Alan	1860.0a	1450.7a	28.12a	19.60ab	441.27ab	207.97b	67.77ab	36.7ab
Cypress	409.7c	69.0c	2.31c	4.78bc	44.25d	45.48c	8.97de	2.29d
Katy	0.00c	0.00c	0.00c	0.00c	0.00d	0.00c	0.00e	0.00d
Lacassine	485.7bc	588.7bc	10.20bc	17.8abc	250.08c	111.1bc	34.54cd	15.60d
Mars	1.3c	0.00c	0.32c	0.00c	4.60d	0.00c	1.30e	0.00d
Newbonnet	1444.8a	1004ab	28.21a	17.68ab	467.15ab	194.6b	52.04bc	54.43a
RT7015	1369.7ab	1512.5a	26.71a	22.26a	597.83a	359.21a	85.70a	54.43a
LSD	944.06	702.87	15.18	17.15	181.31	144.28	27.86	19.40

[z]Means within a column with the same letters are not significantly different.

Table 5. Analysis of variance for the areas under the disease progress curves of the nitrogen treatments for disease incidence, severity, total lesion area and total number of lesions per plant for eight cultivars and two nitrogen treatments in two tests planted 21 April and 23 May 1994 at Colt, Arkansas.

		Severity		Incidence		Total lesion area		Mean no. lesions/plant	
	Source of Variation	F-value	Tabular F	F-value	Tabular F	F-value	Tabular F	F-value	Tabular F
Whole plant	Cultivar	24.86	.0001**	54.29	.0001**	29	.0001**	31.26	.0001*
	Nitrogen	27.57	.0001**	62.09	.0001**	76	.0001**	87.46	.0001**
	Cult*Nitro	2.61	.0298*	5.43	.0004**	7	.0001	**7.88	.0001**
		C.V. = 14.66		C.V. = 32.01		C.V. = 21.79		C.V. = 32.01	
Upper three leaves	Cultivar	11.95	.0001**	29.88	.0001**	13.34	.0001**	14.71	.0001**
	Nitrogen	12.11	.0015*	42.02	.0001**	25.57	.0001**	34.86	.0001**
	Cult*Nitro	1.16	0.3544	5.24	.0005**	3.08	.0135*	4.64	.0001**
		C.V. = 68.15		C.V. = 34.35		C.V. = 64.76		C.V. = 55.01	

*A single or double asterick indicates significance at $P = 0.05$ or $P = 0.01$, respectively.

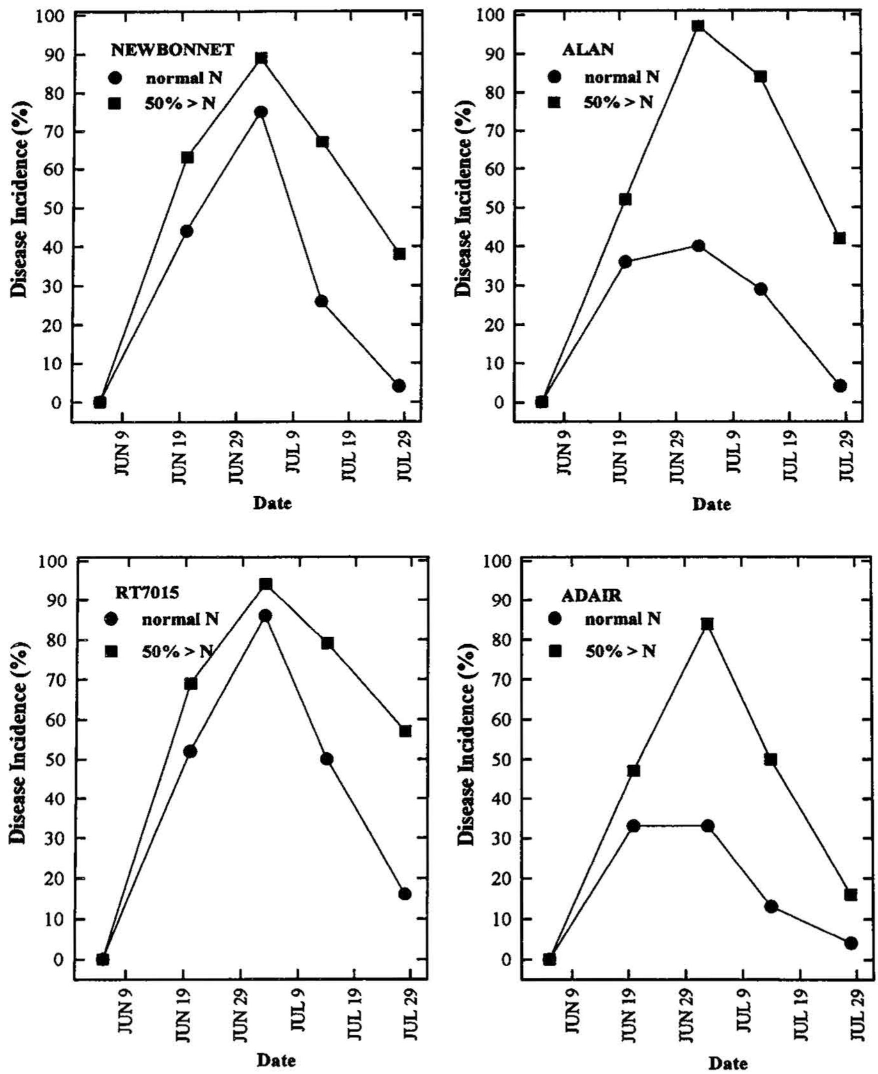

Figure 1. Disease progress curves for leaf blast on 'Newbonnet', 'RT7015', 'Alan' and 'Adair' fertilized with nitrogen (N) applied at either recommended rates and timings or at preflood at rates 50% above recommended rates in small plots. The test was planted 21 April 1994.

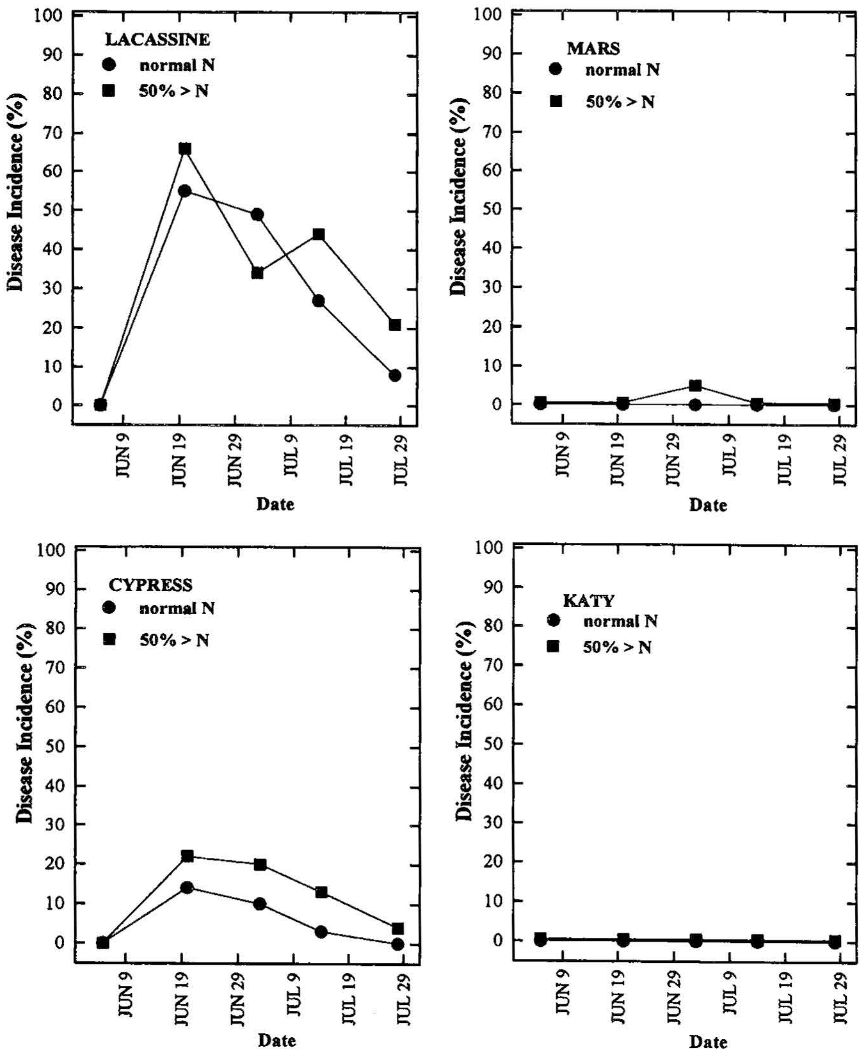

Figure 2. Disease progress curves for leaf blast on 'Lacassine', 'Cypress', 'Mars' and 'Katy' fertilized with urea nitrogen (N) applied at either recommended rates and timings or at preflood at rates 50% greater than recommendations in small plots. The test was planted 21 April 1994.

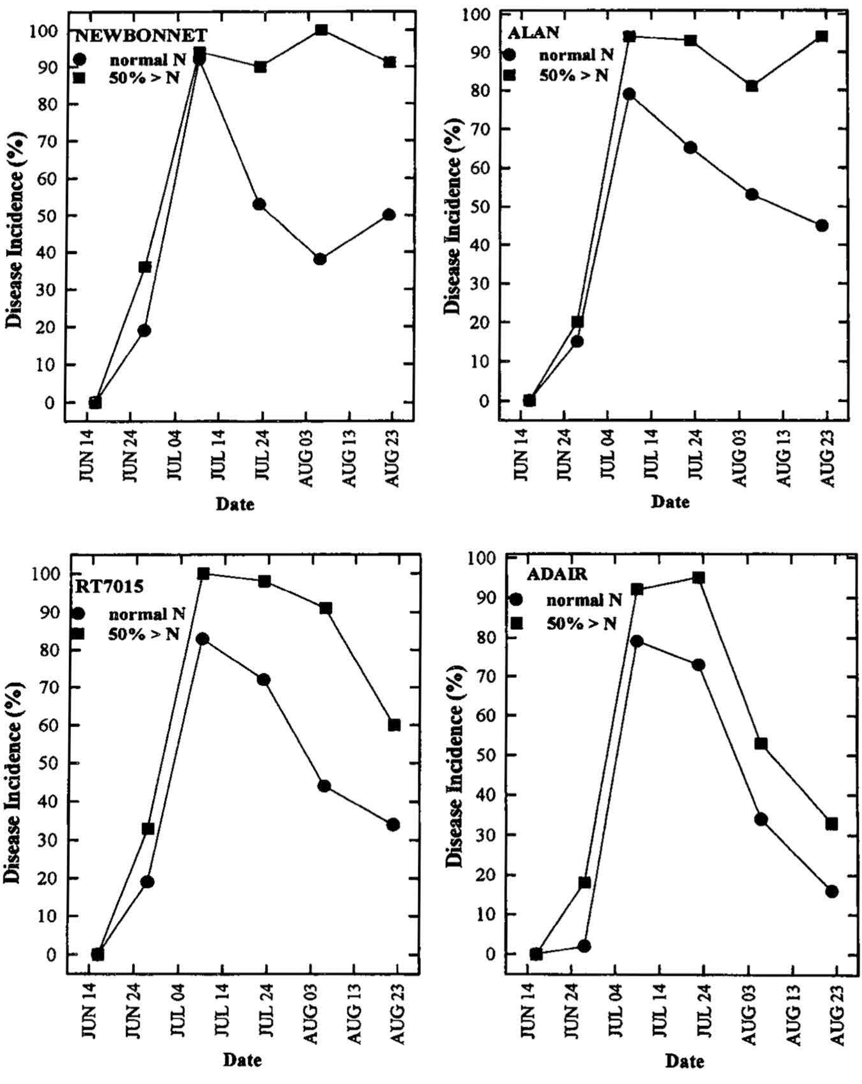

Figure 3. Disease progress curves for leaf blast on 'Newbonnet', 'RT7015', 'Alan' and 'Adair' fertilized with urea nitrogen (N) applied at either recommended rates and timings or at preflood at rates 50% above recommendations in small plots. The test was planted 23 May 1994.

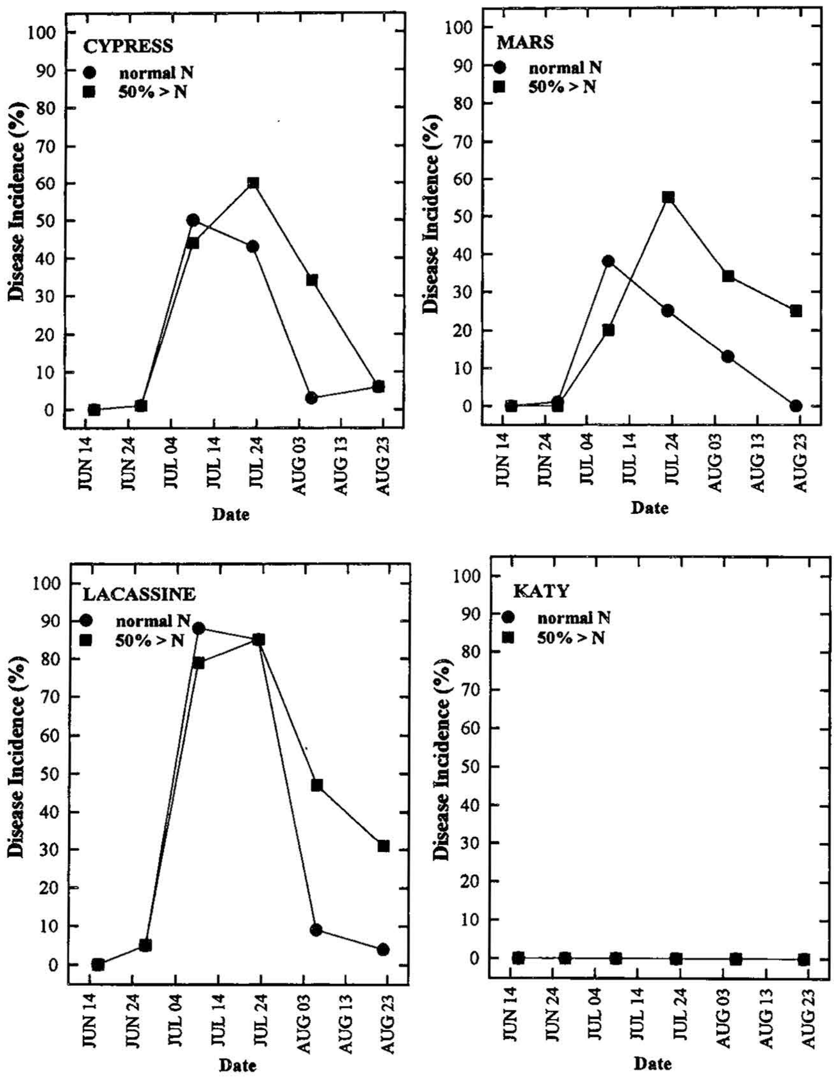

Figure 4. Disease progress curves for leaf blast on 'Lacassine', 'Cypress', 'Mars' and 'Katy' fertilized with urea nitrogen (N) applied at either recommended rates and timings or at preflood at rates 50% greater than recommendations in small plots. The test was planted 23 May 1994.

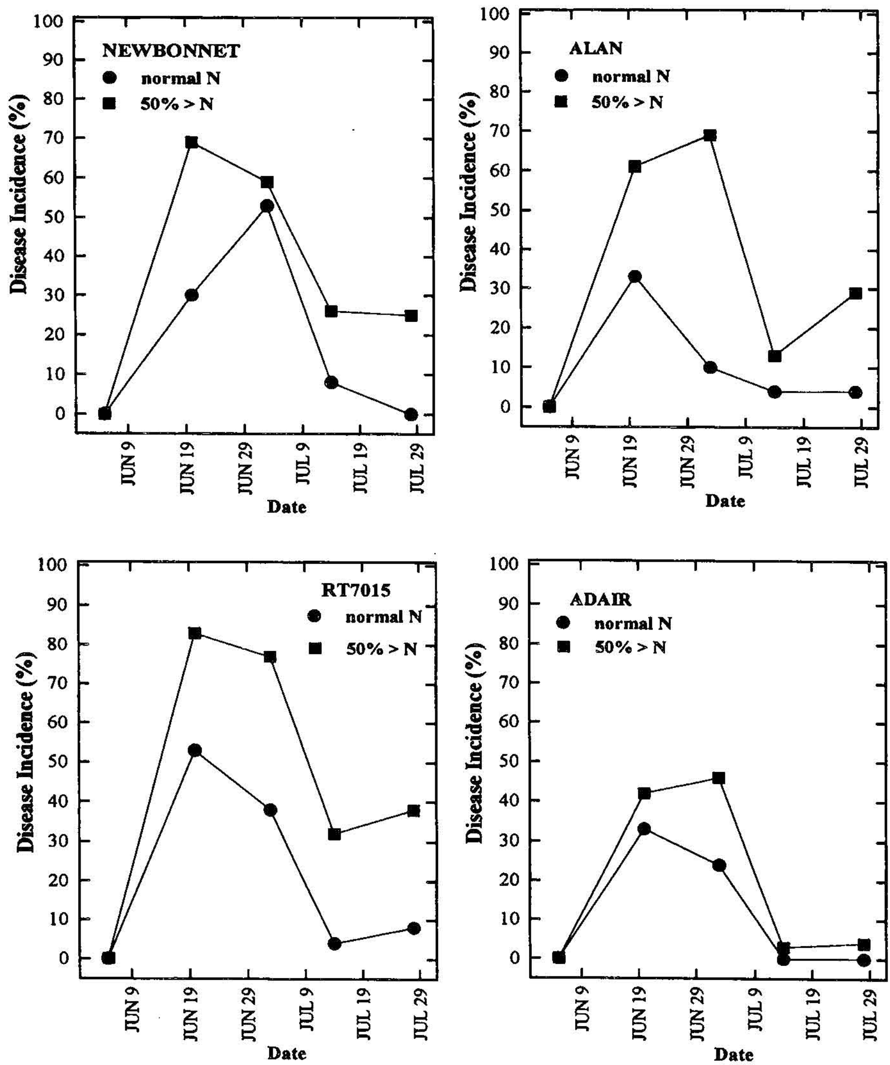

Figure 5. Disease progress curves for leaf blast on the upper three leaves of 'Newbonnet', 'RT7015', 'Alan' and 'Adair' fertilized with urea nitrogen (N) applied at either recommended rates and timings or at preflood at rates 50% above recommendations in small plots. The test was planted 23 May 1994.

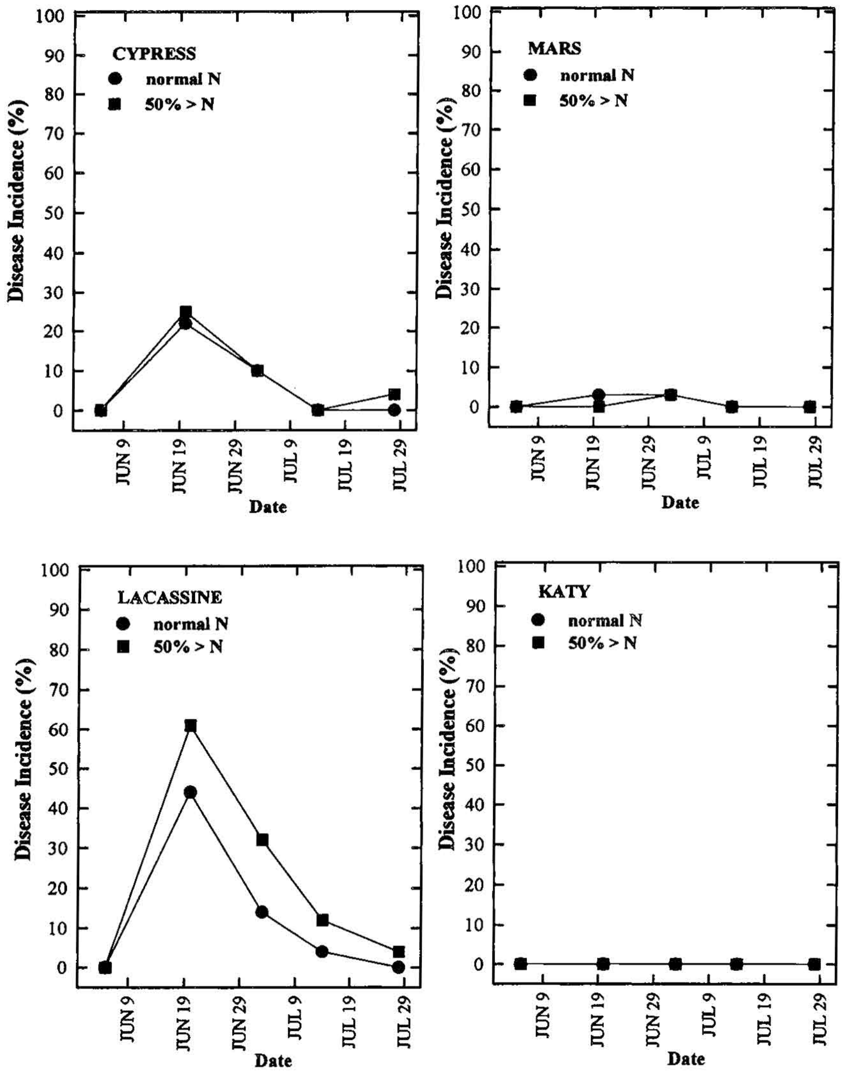

Figure 6. Disease progress curves for leaf blast on the upper three leaves of 'Lacassine', 'Cypress', 'Mars' and 'Katy' fertilized with urea nitrogen (N) applied at either recommended rates and timings or at preflood at rates 50% greater than recommendations in small plots. The test was planted 23 May 1994.

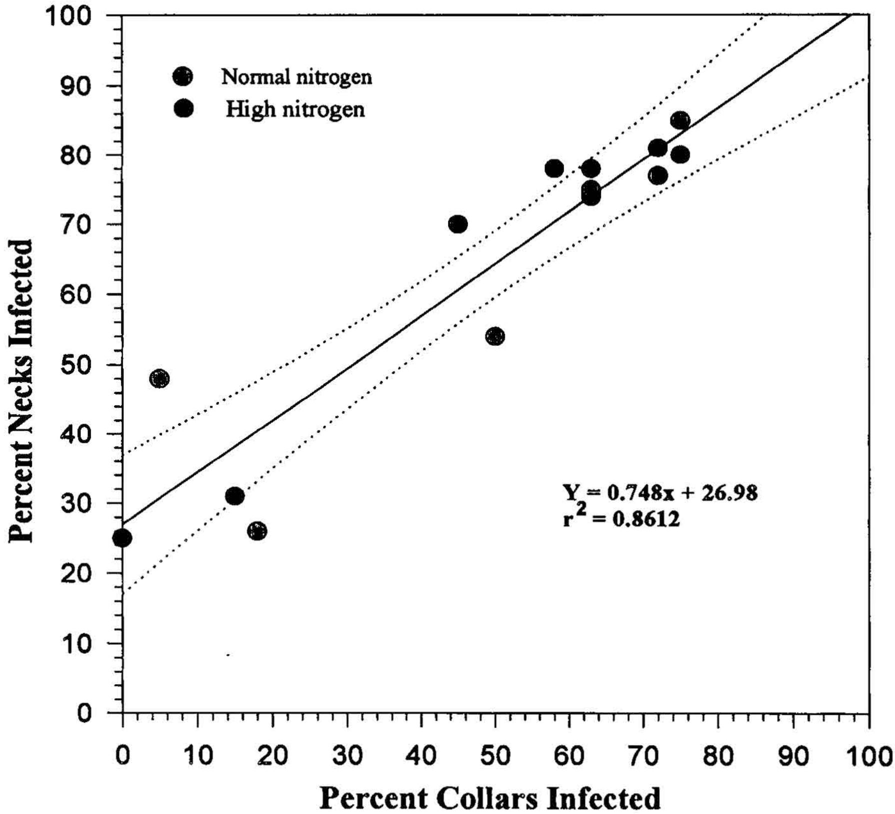

Figure 7. Linear regression analysis of the relationship between the incidence of neck infection and collar rot on seven cultivars and two different rates of urea nitrogen (N) fertilization. The results are from tests planted 21 April 1994.

RICE BLAST *(PYRICULARIA GRISEA)* ADAPTATION TO 'KATY' AND 'KAYBONNET'

Fleet N. Lee and James C. Correll

ABSTRACT

Pyricularia grisea isolates were obtained from rice blast samples collected throughout Arkansas production areas during 1993 and 1994. In greenhouse tests, the isolates were assayed to three- or four-leaf differential cultivars. Leaf blast symptoms compared with those caused by known reference isolates. Previously described blast races IB-1, IB-49, IC-17, IE-1, IG-1 and IH-1 were identified. *Pyricularia grisea* isolates capable of causing leaf lesions on the blast-resistant cultivar 'Katy' were also detected. Reactions on the differential cultivars defined these isolates as being race IE-1k. Race IE-1k was found in 15 cultivars from 12 Arkansas rice producing counties.

INTRODUCTION

Cultivar resistance, the most efficient, reliable and inexpensive disease control method, serves as the mainstay of rice disease control in Arkansas. Conservation and improvement of existing resistance sources as well as location and incorporation of new resistance gene sources are continuous research endeavors in the Rice Research and Promotion Board-funded project *Identification and Utilization of Varietal Resistance for Control of Rice Diseases in Arkansas*. 'Kaybonnet', the newly released, blast-resistant cultivar, is an example of results from the research efforts to develop modern, disease-resistant varieties for Arkansas rice production areas. When released, Kaybonnet and the resistance donor parent, 'Katy', were resistant to all rice blast races previously occurring in the U.S. but susceptible to laboratory culture variant race IB-33, currently not found in rice production fields.

The utilization of resistant cultivars as a means of disease control places the pathogen under substantial selection pressure to adapt to that resistance. An apparent recent adaptation of the blast pathogen, *Pyricularia grisea*, to overcome the blast resistance genes found in Katy is documented in this research.

MATERIALS AND METHODS

Blasted rice samples were collected from experimental test plots during visits to rice production fields and as grower samples submitted for blast race identification via the UA Cooperative Extension Service. Specimens were stored at room temperature until being placed on a moistened filter paper in a petri dish for approximately 24 hours to induce fungal growth. Conidia were carefully picked from blast lesions with the aid of a microscope and placed on Potato Dextrose Agar for additional growth. Cultures free of contaminating fungi were increased for inoculation and storage as field isolates of *Pyricularia grisea*. One to three field isolates per sample were tested for pathogenicity and race determination. Single spore isolates were obtained by spreading conidia in a drop of sterile water over the surface of an agar plate. After 24 hours, individual conidia observed to be growing were removed and increased for inoculation and storage.

Race determinations were made with a minimum of two replications of differential cultivars inoculated at the three- to four-leaf growth stage. Known reference isolates were included in the race determination assays. Conidia were washed from the surface of 6- to 8-day-old cultures in SDW, diluted to 5×10^4 to 5×10^5 spores/ml and atomized onto the surface of differential plants until runoff. Plants were then placed into a dew chamber at approximately 22 C for 24 hours, returned to the greenhouse until lesions developed (usually about 7 days) and visually rated on the following numerical scale:

0 - No symptoms evident to indicate the plant was challenged.
1 - Small pin point flecks.
2 - Larger infection sites indicating infection had began but development was quickly limited by plant response.
3 - Lesions larger than type 2 but with the lesion center still closed. Often starting to elongate, sometimes as much as 3-4 mm.
4 - Elongated or roundish infections where the lesion center is beginning to open or has opened slightly. The intermediate between resistant and susceptible. Phytoalexin response very evident.

5 - Typical susceptible lesion, usually elongated, spindle shaped with a well-opened center. Development between veins is inhibited, and there is definite discoloration, indicating phytoalexin response. These plants are susceptible but *generally* have good field tolerance.
6 - Still tends to be spindle shaped but with less indication of lateral inhibition and with much less indication of discoloration at the border.
7 - A definite susceptible reaction with very little if any indication of discoloration near the lesion border. Indicates a susceptible plant with little field resistance and substantial yield loss under conditions especially conducive for rice blast.
8 - between 7 and 9.
9 - A very rapidly developing (usually in 4-5 days) lesion indicating complete susceptibility--that is the 'toxic' lesion. Leaves are usually dead by the time the other plots are ready for evaluation (7-9) days. Plants usually possess little if any field resistance and sustain major losses under field conditions not necessarily favorable for blast.

A type 3 rating is considered to be a resistant reaction, a type 4 rating is considered to be susceptible but tolerant, and a type 5 rating is considered susceptible. However, Katy usually exhibits a zero rating in greenhouse tests when inoculated with common field isolates. Thus three ratings on Katy were recorded and considered to be an indication that race IE-1k or a very close variant was present in the blast sample.

RESULTS AND DISCUSSION

Several *Pyricularia grisea* isolates were isolated from various samples and tested for race identity. Races IB-49, IB-1 and IC-17 were commonly identified while other races such as IE-1, IG-1 and IH-1 were recovered occasionally. Katy and Kaybonnet are resistant to all these races. Blast samples from fields reported to be Katy have been collected since the release, but *P. grisea* isolates from these samples have always tested as nonpathogenic on Katy (a type 0 rating) and are assumed to be the result of seed contamination. During 1993, however, isolates capable of causing leaf lesions on Katy plants in greenhouse race assays were recovered from several blast samples collected from Arkansas rice production fields and from outlying research plots planted in grower fields (Table 1). None of the 1993 samples were from Katy or Kaybonnet fields. During 1994 isolates virulent on Katy were recovered from one Katy and seven Kaybonnet samples collected in Arkansas rice fields (Table 2). Isolates obtained in 1993 and 1994 have been compared with and are tentatively identified as being the race IE-1k as first reported in 1993 from a single blast sample from Mississippi by Dr. Marchetti (Table 3). To date, IE-1k has been found in rice samples from 15 cultivars in 12 rice producing counties in Arkansas.

The search for resistance sources to race IE-1k is underway. Preliminary tests on the Uniform Regional Nursery and on advanced Arkansas breeding lines indicate that all commercial cultivars are susceptible to IE-1k. Fortunately, some experimental entries appear to be resistant or highly tolerant. Tests are being conducted to confirm these results and/or locate resistance before the 1995 crossing season.

SIGNIFICANCE OF RESULTS

As anticipated, *P. grisea* races to counter the resistance genes in Katy have developed. The relative susceptibility of Katy and Kaybonnet to this new race has not been determined at this point. Kaybonnet does appear to be more susceptible than Katy, but potential yield reductions cannot be estimated without additional data. However, this information comes in time to alert growers to scout fields and implement alternative control measures if needed.

Katy resistance genes have been utilized in many of the advanced breeding lines now being evaluated for release by Arkansas and other rice breeders. This report provides information to be used in those release determinations and a warning that the resistance may be short lived.

The frequency of occurrence of race IE-1k in Arkansas rice production areas increased dramatically during 1993-1994. Only one possible sample, which was quickly lost in the laboratory, was detected in 1992. Fourteen samples in nine rice producing counties contained IE-1k in 1993. One can speculate that these 14 samples arose from one genetic variation in *P. grisea* that had occurred at some time prior to 1993 and was increased and spread over the rice production area. If this speculation is correct, another can be made for the point that an efficacious eradication program in seed rice could have prevented this new race from spreading so quickly.

Table 1. Rice blast samples collected in 1993 with *Pyricularia grisea* isolates identified as being pathogenic on the cultivar 'Katy" in greenhouse tests.

Variety	Source	County	Katy rating[z]
Alan	RRVT	White	6
Alan	Grower	Lee	4
Alan	Grower	Monroe	4,7
Delmont	Grower	Arkansas	5,6
Gulfmont	Grower	Monroe	3,3
Jackson	Grower	Clay	3
L202	Grower	Clay	6,6
Mars	Grower	Poinsett	5,6,3
Maybelle	Grower	Green	5
Millie	Grower	Clay	3
Newbonnet	Grower	Green	5
Newbonnet	Grower	Mississippi	4
RT7015	Grower	Mississippi	3
Unknown	Grower	Monroe	3,6,7
Mixed	Research	Cross	3
Mixed	Research	Cross	6,8
Mixed	Research	Cross	3-6 (8 isolates)
Mixed	Research	Lonoke	6,5,7,8,5
LaGrue	Research	Lonoke	4,5
Mixed	Research	Lonoke	6,7,6,7,5

[z]Susceptibility rating of Katy assay plants on a numerical scale of 0 = immune to 9 = very susceptible when inoculated with isolates obtained from multiple spores produced on diseased tissue.

Table 2. Rice blast samples collected in 1994 with *Pyricularia grisea* isolates that were identified as being pathogenic on the cultivar 'Katy' in greenhouse tests.

			Katy Rating		
			Field	Single Spore Isolates	
Variety	Source	County	Isolates[z]	Susceptible[y]	Resistant[y]
LaGrue	Grower	Phillips	3,0	-	-
LaGrue	RRVP	Mississippi	6,6	-	-
Cypress	RRVP	Jefferson	5,0	-	-
Lacassine	Grower	Lawrence	4,0	-	-
Kaybonnet[x]	Grower	Clay	-	6,6,7,8	-
Kaybonnet[x]	Grower	Clay	4	5,8,6	-
Kaybonnet[w]	Grower	Lonoke	6,2	-	-
Kaybonnet[w]	Grower	Lonoke	5	6	2
Kaybonnet	Grower	Lawrence	4,0	6,6,6	0
Kaybonnet	Research	Lonoke	-	5	3,1,1,1
Kaybonnet	Research	Cross	-	7,7,6,5,7,5,5	2
Katy	Grower	Craighead	8,0	5,7,6,6,7	-

[z]Susceptibility rating of Katy assay plants on a numerical scale of 0 = immune to 9 = very susceptible when inoculated with isolates obtained from multiple spores produced on diseased tissue.

[y]Susceptibility rating of Katy assay plants on a numerical scale of 0 = immune to 9 = very susceptible when inoculated with isolates obtained from single spores.

[x]Samples obtained from the same field on different dates.

[w]Samples obtained from the same field on different dates.

Table 3. Mean susceptibility rating of selected cultivars and international differentials from a two-replication assay of single spore isolates.

Isolate	RU 9201191	Katy	Kbnt[z]	Lmnt	M201	Mars	Mble	Nwbt	Stbn	Znth
94020SS1	6.0[y]	5.5	7.0	7.0	8.0	0.0	7.5	8.0	7.0	0.0
94020SS3	5.5	5.0	5.5	6.0	7.5	2.5	6.0	7.5	6.0	1.0
94079SS3	7.0	7.0	8.0	6.5	8.0	3.5	5.5	8.0	7.5	0.0
IE-1k	8.0	7.0	8.0	8.0	8.0	3.5	7.5	8.0	8.0	1.5

Isolate	Caloro	Dular	Kanto51	Katy	Mars	NP125	RS3	Usen	Znth
94020SS1	8.0	7.0	8.0	6.5	1.0	4.5	0.0	4.5	0.5
94020SS3	8.0	7.5	8.0	5.0	3.5	5.0	0.0	4.5	0.5
94079SS3	8.0	7.0	7.5	7.0	3.5	7.0	0.0	4.5	0.0
IE-1k	8.0	7.5	7.5	7.0	2.0	5.5	1.5	5.0	0.0

[z]Kbnt = Kaybonnet; Lmnt = Lemont; Mble = Maybelle; Nwbt = Newbonnet; Stbn = Starbonnet; Znth = Zenith; RS3 = Raminad Strain 3.

[y]Susceptibility rating of assay plants on a numerical scale of 0 = immune to 9 = very susceptible.

EFFECT OF REDUCED TILLAGE PRACTICES ON STEM AND SHEATH DISEASES OF RICE IN ARKANSAS

R.D. Cartwright, F.N. Lee, R. Eason, D.L. Crippen and G.E. Templeton

ABSTRACT

A long-term field experiment was continued in 1994 at the Pine Tree Experiment Station, Colt, Arkansas, to determine the effect of reduced tillage on diseases of rice. Cultivars 'Katy' and 'Lacassine' were seeded on conventional, stale- and no-till seedbeds in large, permanent plots with separate water systems on Site 2, and 'Hutcheson' soybeans were drill planted on Site 1. Levels of *Rhizoctonia solani* (sheath blight) sclerotia in plot seedbeds were determined prior to seeding, and they tended to be at low and fairly uniform levels. Sheath blight incidence for Site 2 (percent infected tillers) was 3, 7.5 and 1.5% for Lacassine and 1, 0.5 and 0.5% for Katy on conventional, stale-seedbed and no-till treatments, respectively. Where present, vertical development of sheath blight in the Lacassine plots reached the flag leaf. Rice yields for Katy did not differ significantly and were 165, 156 and 161 bu/acre for Katy on conventional, stale-seedbed and no-till plots. Corresponding yields for Lacassine were 201, 188 and 177 bu/acre. The conventional treatment for Lacassine gave significantly higher yield. Foliar diseases were more common on both cultivars than in 1993 but appeared to have only a minor effect, if any, on rice yields. All soybean plots on Site 1 yielded well (61-68 bu/acre) and appeared to be relatively unaffected by diseases. Soybean yields, while not significantly different, tended to be higher in no-till plots.

INTRODUCTION

The type and intensity of rice diseases change over time in response to changes in rice production practices by growers. Sheath blight (caused by *Rhizoctonia solani*) was once considered a minor curiosity until farmers adopted shorter-statured cultivars, denser stands, shorter crop rotations and increased nitrogen rates. These practices increase the severity of many rice diseases, including blast, sheath blight, stem rot and kernel smut--all of which may cause widespread damage in Arkansas in any given year.

Over the past few years, Arkansas rice growers have continued to adopt even shorter rotations and reduced tillage practices, primarily for economic reasons (USDA, 1992). In many areas, the most common crop rotation is now rice-soybean-rice with the only tillage done in the fall. This "stale seedbed" is left undisturbed until the following spring when the weed cover is killed with an application of glyphosate. Rice (or soybeans) is seeded into the undisturbed seedbed with minimum-tillage planting equipment. In some instances, growers are experimenting with "no-till" rice in which the crop is seeded directly into the previous crop residue with no tillage at all. Previous studies have been conducted in Arkansas and Louisiana (Bollich et al., 1992; Smith, 1992) on the effect of reduced tillage on fertilizer, weed control and other agronomic practices in rice with little or no consideration of rice diseases. Since survival between crops of many stem and sheath pathogens of rice is linked to the rice residue they colonize during the growing season, most plant pathologists expect increased rice disease problems if rice residue is not effectively destroyed. This belief has been supported by research in other crops. For example, increased severity of tan spot of wheat in the midwestern U.S. is a direct consequence of adoption of reduced-tillage practices in wheat production (Hosford, 1976; Watkins et al., 1978). However, diseases such as take-all of wheat have actually declined in certain areas in which reduced tillage has been adopted (Brooks and Dawson, 1968). In California, recent evidence on stem rot of rice suggests that reduced-tillage practices in continuous rice culture may not result in increased disease severity, depending on in-season rice management and the buildup of beneficial fungi (Cartwright, 1992). Since so little information is available, this research project was undertaken to determine the effect of reduced tillage practices on stem and sheath diseases of rice in a rice-soybean-rice rotation so that reliable information would be available to growers before these practices become widely adopted.

PROCEDURES

A long-term field experiment was established at the Pine Tree Experiment Station, Colt, Arkansas, on a site with a history of rice and soybean cropping. Large, permanent plots (20 x 50 ft) with separate water systems to prevent exchange of soil, water and inoculum were installed on two adjacent sites (Fig. 1).

The experimental design was a 2 x 3 factorial in a randomized complete block design with four replications (Fig. 1). Factors were cultivar ('Katy' and 'Lacassine') and tillage practices (conventional, stale seedbed and no-till). Agronomic practices were according to current University of Arkansas Cooperative Extension guidelines, and the rotation was rice and soybeans in alternate years. Site 1 has rice in 1993, 1995 and 1997 and site 2 in 1994, 1996 and 1998. 'Hutcheson' soybeans will be drill planted on the plots in non-rice years.

Prior to seeding, 20 soil cores, 3 in. diameter x 2 in. thick, were randomly collected from each plot, bulked and dried in the greenhouse for two weeks. Bulk samples were wet sieved according to the method of Lee (1980) to estimate the number of sclerotia of *Rhizoctonia solani* AG1-IA (the sheath blight fungus). A smaller sieve (150-µm openings) was used to collect sclerotia of other rice field fungi, including the stem rot fungus. Prior to sieving, small soil samples and bits of residue were plated on semi-selective media plates to estimate the population of *Gaeumannomyces graminis* var *graminis*, the black sheath rot fungus.

Conventional seedbeds were prepared by fall and spring tillage as needed, while stale seedbed preparation involved only fall tillage. Glyphosate was applied approximately 7 days prior to planting in April 1994 to kill existing vegetation on stale-seedbed and no-till plots.

Seeding of rice on Site 2 was done 29 April-31 May 1993 using a minimum tillage drill with 7-in. row spacings. As before, all plots were watered and managed separately after seeding to prevent exchange of soil- or water-borne inoculum between plots. Hutcheson soybeans were planted on Site 1 on 31 May 1994 using the drill and row spacings above.

Plots were monitored periodically for disease development throughout the growing season. Final disease incidence and severity data for the rice plots were estimated at grain maturity by randomly collecting 200 tillers from each plot and analyzing. Grain was combine harvested and weighed, and values were adjusted to 12% moisture for analysis. Precautions were taken during harvest to retain rice and soybean residue within respective plots in order to prevent cross contamination.

RESULTS AND DISCUSSION

Sclerotial levels of *R. solani* for Site 2 were rather low but equivalent in all plots (Table 1). Levels on Site 2 were consistently higher than levels for Site 1 in the first year (Table 1). Site 1 levels in 1994 were higher as well, indicating an increase over the previous rice crop (Table 1). Variation in these data remains high, and additional soil samples and/or modification in extraction methods will be considered in future years.

Final incidence for several diseases are listed in Table 2. Sheath blight and other stem diseases were less widespread in the Site 2 plots than in the Site 1 plots of 1993. Neck blast and other foliar diseases were more prevalent than in 1993 due to the wet weather during early to mid summer in 1994 (Table 2). Sheath blight incidence tended to be highest in the Lacassine stale-seedbed plots, but the difference was not statistically significant (Table 2). Nevertheless, since the yield of these plots (188 bu/acre) was significantly lower than that of the Lacassine conventional plots (201 bu/acre), the disease may have had an impact (Table 3). Again, the lower yield for the Lacassine no-till plots (177 bu/acre) was apparently due to more than disease since there were some early problems in stand establishment. Yield for the Katy conventional plots (165 bu/acre) was numerically higher than for either the stale-seedbed (156 bu/acre) or no-till (161 bu/acre) treatments, but not significantly so (Table 3).

Soybean yields for Site 1 averaged 61-68 bu/acre, with a trend for higher yields on the no-till plots (Table 3). Diseases were of minor importance on the soybeans, although most younger plants had basal stem lesions thought to be caused by *R. solani*. These symptoms disappeared as the plants grew. In addition, soybean plants on the no-till plots had noticeably less brown spot (Septoria leaf spot) than those on the other tillage treatments.

SIGNIFICANCE OF FINDINGS

The tendency toward higher sheath blight incidence and lower yields for Lacassine on stale seedbed and no-till plots was again observed in 1994. While differences are relatively small at this time, these observations are a cause for future concern. Rice seeded on Site 1 in 1995 should yield additional significant information in this regard, as it will be the second time in rice for this location. On the other hand, results thus far illustrate the possibilities for labor and cost reduction using these reduced-tillage methods while still producing adequate yields. Even if diseases increase under these practices, management of the diseases during the season by careful consideration of stand density and fertilization offers some hope for control. Again, it should be noted that this is a long-term experiment, and these initial results should be viewed with caution until additional crop cycles are completed.

ACKNOWLEDGMENTS

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Table 1. Sclerotial levels of *Rhizoctonia solani* (sheath blight fungus) detected in soil samples from reduced-tillage experiment field plots at the Pine Tree Station, Colt, Arkansas.

Previous/Current Rice Cultivar	Tillage Trt.	Viable sclerotia per Kg dry soil (mean) Site 1 1993	Viable sclerotia per Kg dry soil (mean) Site 1 1994	Viable sclerotia per Kg dry soil (mean) Site 2 1994
Katy	Conventional	1	2 a[z]	7 a
Katy	Stale-seedbed	ND	8 a	9 a
Katy	No-till	1	9 a	11 a
Lacassine	Conventional	ND	8 x	9 x
Lacassine	Stale-seedbed	2	8 x	11 x
Lacassine	No-till	1	9 x	7 x

[z]Means followed by the same letter within cultivar are not significantly different according to Tukey's HSD test at $P = 0.05$. ND = not detected.

Table 2. Final disease incidence data for various rice diseases detected in reduced-tillage experiment field plots at Pine Tree Station, Colt, Arkansas - 1994 (Site 2).

Cultivar	Tillage trt.	Final disease incidence % infected tillers SHB[z]	SR	BSHR	NB	NBLS	BS	LS
Katy	Conventional	1.0 a	0	0	0	100	100	100
Katy	Stale-seedbed	0.5 a	.5	0	0	100	100	100
Katy	No-till	0.5 a	.5	0	0	100	100	100
Lacassine	Conventional	3.0 x	.1	0	2.5	100	100	100
Lacassine	Stale-seedbed	7.5 x	0	0	1.5	100	100	100
Lacassine	No-till	1.5 x	.5	0	2.0	100	100	100

[z]SHB = sheath blight; SR = Stem rot; BSHR = Black sheath rot; NB = Neck blast; NBLS = Narrow brown leaf spot; BS = Brown spot; LS = Leaf smut. (SHB means followed by the same letter within cultivar are not significantly different according to Tukey's HSD test at $P = 0.05$).

Table 3. Yield data (bu/acre at 12%) for reduced-tillage experiments at Pine Tree Experiment Station, Colt, Arkansas - 1994 (Sites 1 and 2).

Tillage trt.	Site 1 Hutcheson Soybeans	Rice Cultivar	Site 2 Rice
Conventional	61 a[z]	Katy	165 a
Stale-seedbed	64 a	Katy	156 a
No-till	68 a	Katy	161 a
Conventional	61 x	Lacassine	201 x
Stale-seedbed	64 x	Lacassine	188 y
No-till	68 x	Lacassine	177 y

[z]Statistical analysis using Tukey's HSD means separation test conducted within cultivar. Means followed by the same letter within cultivar are not significantly different at $P = 0.05$.

NORTH

SITE 1
Rice in 1993, 1995, 1997. Hutcheson soybeans in 1994, 1996, 1998.

141 L1	142 K3	143 K2	144 L3	145 L2	146 K1
131 K1	132 K2	133 L1	134 K3	135 L3	136 L2
121 L3	122 K3	123 K1	124 L2	125 K2	126 L1
111 K3	112 L2	113 K1	114 L1	115 L3	116 K2

SITE 2
Rice in 1994, 1996, 1998. Hutcheson soybeans in 1995, 1997, 1999.

241 L3	242 K2	243 K1	244 K3	245 L2	246 L1
231 K1	232 K3	233 L1	234 L2	235 L3	236 K2
221 K3	222 L2	223 L3	224 K1	225 L1	226 K2
211 K2	212 L1	213 K3	214 L2	215 K1	216 L3

SOUTH

Notes: Plot numbers coded as follows: First number = site (1 or 2), second number = rep (1,2,3 or 4), third number = plot (1,2,3,4,5 or 6) -e.g. Plot 111 = site 1, rep1 and plot 1 or sw corner plot in site 1. Treatment codes are for rice years, i.e. K = cultivar Katy and L = cultivar Lacassine and numbers following these letters represent tillage treatments - 1= conventional seedbed; 2= stale seedbed (fall tillage only, spring burndown); 3= no till seedbed (spring burndown). In non-rice years, all plots are drill planted to Hutcheson soybeans, but tillage treatments remain the same. Plots measure 20' x 50' and feature permanent levees with separate water systems to prevent exchange of soil, crop residue, and soil-borne inoculum of rice pathogens.

Fig. 1. Layout of long-term experiment on effect of reduced tillage on rice diseases at Pine Tree Experiment Station, Colt, Arkansas.

RESEARCH IN ARKANSAS ON KERNEL SMUT OF RICE

R.D. Cartwright, F.N. Lee, R.L. Hunter, D.L. Crippen and G.E. Templeton

ABSTRACT

In 1994, kernel smut of rice was again a major disease problem in Arkansas, causing widespread but sporadic yield and quality losses on 'Cypress', 'Alan', 'Newbonnet', 'LaGrue' and 'RT7015' rice. Severity was again heavily influenced by excessive nitrogen fertilization. Continued research on development of an improved, "more natural" inoculation technique than the boot injection method for screening for smut-resistant rice germplasm resulted in the development of a mist inoculation technique--successfully used in the greenhouse to distinguish the resistance level of a susceptible cultivar ('M202') from that of a field-resistant cultivar ('Lemont'). This method will be modified and tested for field use in 1995. Evaluation of kernel smut resistance in 20 commercial rice cultivars and three advanced lines under field conditions was achieved at one disease monitoring location where natural kernel smut pressure was severe. Genetic studies of the smut organism were continued by combining monosporidial isolates from one teliospore with previously identified mating type tester strains and inoculating on rice. Of 30 isolates tested so far, 20% were of one mating type and 80% the other.

INTRODUCTION

Kernel smut of rice was sporadically severe on several rice cultivars in Arkansas in 1994, causing significant yield losses in some fields and resulting in low-quality grain delivered to the mills. Severity was heavily influenced by nitrogen fertilization, especially on the new rice cultivar

'Cypress'. Growers frequently overfertilized this naturally "light green" cultivar in attempts to "green it up," as done with older cultivars such as 'Lemont'.

Kernel smut is caused by the fungus *Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc. (= *Neovossia horrida* (Takah.) Padwick & A. Khan) (Whitney, 1989), which closely resembles the karnal bunt of wheat fungus, *Tilletia indica* Mitra (= *Neovossia indica* (Mitra) Mundkur) (Royer and Rytter, 1988). It was believed that *T. barclayana* infects the open rice flower only at anthesis, grows within the developing rice kernel as mycelium and eventually consumes the endosperm, converting it into numerous, spherical black teliospores (chlamydospores) that survive on seed, on residue and in the soil (Whitney and Frederiksen, 1975). Research has determined that the fungus is capable of infecting florets before anthesis and confirms that the process is enhanced by high moisture during the heading phase. Teliospores overwinter, float to the water surface during the next rice crop, germinate and produce airborne sporidia that infect the florets, thus completing the life cycle (Whitney and Frederiksen, 1975). Most smut fungi have sporidia of opposite mating types that must combine and establish a dikaryotic mycelium before successful infection and development can occur in the host (Fischer, 1953). This phenomenon is not clearly understood for the kernel smut fungus.

As previously stated, kernel smut is more severe on rice that has received heavy rates of nitrogen fertilizer (Templeton et al., 1960) and is thought to be favored by light rainy weather during heading (Whitney and Frederiksen, 1975). Certainly these conditions were satisfied in Arkansas during the 1994 growing season.

Rice cultivars vary greatly in susceptibility to kernel smut, and this is the basis for resistant cultivars, the only practical means of control. The mechanism of resistance is not understood but is believed to involve duration of flowering and, possibly, size of the floret opening (Whitney and Frederiksen, 1975). Current research suggests other factors as well. Kernel smut infection has historically been difficult to induce under controlled conditions; however, improvements in the boot injection technique (Lee et al., 1991)--used originally in karnal bunt of wheat research--have resulted in a useful method to study certain aspects of this disease (Whitney and Frederiksen, 1975). Unfortunately, the method results in severe kernel smut on all rice cultivars tested, even those observed to be resistant in the field. A more "natural" inoculation procedure to screen germplasm should improve discovery of "field"-resistant germplasm for inclusion in the breeding program.

Unfortunately, the actual infection process of the fungus has never been demonstrated clearly. Most studies have relied on sectioning of infected tissue at various times following inoculation, and the actual infection site was not determined (Singh and Pavgi, 1973 a,b). Indirect evidence clearly suggests that the floret alone is infected (Templeton, 1961), but whether this actually occurs in nature by a spore landing inside an open floret or by penetration of the young glumes or other tissue (as in karnal bunt--Dhaliwal and Singh, 1988) has not been observed. Evidence from this study suggests the latter (Table 1).

Regardless, after considerable work with the boot injection method, it was decided in 1993 to attempt development of a more natural inoculation procedure. To do this, a better understanding of the fungus--its genetics and infection process--is required. This basic work was undertaken with the understanding of the difficulties involved that have prevented many others from successfully understanding this disease, i.e., the short period of susceptibility and the single infection time on heading plants. To prevent any possibility of aerial contamination that would confuse results, most of the research is being conducted at Fayetteville, approximately 200 miles from the rice producing region of Arkansas.

PROCEDURES

Since the kernel smut fungus may change through repeated culturing or when isolates become accidentally mixed or contaminated, it was decided to start with fresh isolates. To study the genetics of any organism, it is most logical to start with the individual rather than a population of individuals. With this in mind, single teliospores of the kernel smut fungus from Arkansas rice were germinated on separate water agar plates. After germination, the primary sporidial cluster from the single teliospore was transferred to a fresh plate of Emerson agar. On this medium, the cluster produced abundant secondary sporidia, which were collected in cryopreservation fluid and stored in vials at -80 C until needed. Several single teliospore cultures from various smutted kernel collections in Arkansas were produced and stored in this fashion. In addition, attempts were made to singly isolate and store separately all of the primary sporidia from a single, germinated teliospore. This was technically very difficult because of the small size of the sporidia and their susceptibility to drying out and dying during transfer. After many attempts, a complete set of primary sporidia from a single teliospore was separated and each individual sporidium transferred to a separate Emerson agar plate for culture and storage as before. This "pedigree" set was composed of 51 individual primary sporidia, and purity was assured by inspection of each transferred sporidium with a compound microscope to verify that one and only one sporidium was transferred.

Using the boot injection technique, several rice cultivars were inoculated with a known pathogenic isolate of the kernel smut fungus under greenhouse conditions to determine the most amenable cultivar for experimental purposes. Based on ease of growth under greenhouse conditions, susceptibility to infection and ease of visualizing smutted kernels, the medium-grain rice cultivar 'M202' (California) was selected for further experimentation as a susceptible check. The cultivar 'Lemont' was selected as the resistant check for comparison. Repeated tests of the single teliospore isolates resulted in isolate 4T3 being selected as a routine pathogenic isolate for further experimental work.

For inoculum production, all isolates were suspended from the cryofreezer directly into 10 ml of Emerson broth, vortexed and poured onto the surface of antibiotic-amended water agar plates. The suspension in the plate was swirled gently and poured onto the surface of another plate, and so forth, until all the suspension had been adsorbed. This procedure was conducted in a laminar flow transfer hood to prevent contamination of these plates. Plates were incubated under fluorescent lights (12 hr light/dark period) at approximately 25 C for 2 to 3 weeks. Abundant production of secondary filamentous and allantoid sporidia occurred under these conditions. For inoculum, sterile distilled water was added to the sporulating plates and secondary sporidia dislodged into the water using a sterile rubber policeman. The resulting suspension was filtered through new cheesecloth (2 layers) to remove clumps and mycelium, and the filtered suspension was standardized to 1×10^6 sporidia/ml.

For development of a more natural inoculation method, only inoculum of isolate 4T3 was used. A sporidial suspension (10^6 sporidia/ml) was atomized onto panicles and boots of M202 and Lemont at various developmental stages (Table 1) using a compressed air canister and paint atomizer attachment. Tillers were individually labeled for later identification during data collection as to stage at inoculation. The boot injection method using isolate 4T3 was used as a pathogenic control for comparison. Inoculated plants were covered by a plastic tent at night and mist supplied until morning (15-16 hrs). The canopy was removed during the day. Nightly mist cycles included 0, 1, 3 and 7 nights after inoculation--depending on treatment--and were designed to determine optimum conditions for development of kernel smut.

For genetic studies of isolate combinations, inoculum of isolates was produced separately as before, and equal volumes of standardized sporidial suspensions were mixed prior to boot injection. Each isolate from the "pedigree" set of 51 monosporidial isolates from a single teliospores was mixed with tester strain 18 (A) and 43 (a), then injected into the swollen boot of M202 tillers. At least six boots were injected per combination, and care was taken to prevent cross contamination of isolates. A positive combination (mating of opposite mating types) was determined by development of kernel smut.

RESULTS AND DISCUSSION

Summary results of mist inoculation experiments for kernel smut are shown in Table 1. The boot injection method was also used for comparion. Mist inoculation at developmental stages 2 and 3 (exsertion - early anthesis) with three or seven nightly mist cycles resulted in the highest and most consistent number of smutted grains per panicle in both M202 and Lemont rice (Table 1). These results suggest that infection of the fungus is favored by young panicle tissue and by extended periods of high relative humidity (Table 1). A critical test of this method is its ability to differentiate highly susceptible germplasm from resistant germplasm. In multiple experiments with the method in the greenhouse, smutted grains per panicle have been consistently high for the susceptible check, M202, and low--but present--for the resistant check, Lemont. If these results are confirmed in a field test, the method would clearly represent a significant step forward in screening for kernel smut-resistant germplasm. Field validation will be attempted in 1995.

Results of a successful assessment of relative field resistance to kernel smut for 20 commercial cultivars and three advanced lines was achieved at the Lawrence County disease monitoring site (Table 2 and Fig. 1). Data (smutted grains per panicle) are presented from most resistant cultivars/lines to most susceptible in both Table 2 and Fig. 1. It is interesting--and disturbing--that all very-early-maturing cultivars, most recently released cultivars and the advanced breeding lines in this test were all quite susceptible to this disease. This again underscores the need of the above-mentioned screening method for use by the rice breeding program in the future.

It should be emphasized that these are single-year data. Although they correspond very well with damage from smut seen in grower fields this year, the role of climate in smut development is not thoroughly understood and may change the relative rankings of smut resistance in future seasons.

Results of pathogenicity tests on combinations of single primary sporidial isolates from the same teliospore with the two tester strains previously identified are shown in Table 3. Results continue to suggest only two mating types within these isolates,. The ratio of the two types within the 30 or so isolates tested thus far were 4:1 (A:a), an unexpected ratio. The hypothesized ratio for progeny from a single teliospore would be 1:1; however, firm conclusions will have to wait until the remainder of the isolates are tested. Once the mating type genetics of the individual are understood, the mating strains can be used to test the kernel smut population in the state. This type of information will have a direct bearing on the diversity of this fungus in nature and the likelihood that races may exist. This is of practical concern since diversity of pathogenicity in the fungal population could eventually lead to the break down of resistant cultivars.

SIGNIFICANCE OF RESULTS

Progress on development of a more "natural" inoculation method for kernel smut that can distinguish susceptible from resistant germplasm showed great promise in 1994. The method developed in the greenhouse appears reliable and amenable to this task. If the method works in the field this year, we will be well on the way to developing effective and reliable kernel smut-resistant germplasm for use by Arkansas and other U.S. rice breeders. Further progress on understanding the genetics of the kernel smut fungus should eventually assist our breeding program in developing durably resistant cultivars, especially in the event that races of the kernel smut fungus exist in the U.S. Assessment of kernel smut susceptibility/resistance in commercial cultivars/ lines under grower field conditions in the disease monitoring project remains a valuable support mechanism for Arkansas rice producers, providing additional information on risk in selecting current cultivars as growers struggle to manage the many disease problems in Arkansas rice.

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Table 1. Results of greenhouse experiments on boot injection and mist inoculation techniques for kernel smut of rice at Fayetteville, Arkansas (1994).

Development stage when inoculated[z]	No. of nightly mist cycles	Smutted grains/ panicle M202 (susceptible cv)	Smutted grains/ panicle Lemont (resistant cv)
1	0	0.0	0.0
1	1	0.3	0.0
1	3	3.6	0.0
1	7	2.0	0.4
2	0	0.6	0.0
2	1	5.0	0.0
2	3	24.0	0.8
2	7	5.3	1.4
3	0	0.7	0.0
3	1	4.8	0.3
3	3	8.6	1.1
3	7	2.7	0.7
4	0	0.0	0.0
4	1	0.3	0.0
4	3	0.0	0.0
4	7	0.1	0.5
Boot Injection Checks		83	68

[z]1= late boot, pre-exsertion; 2= panicle exserted, pre-anthesis; 3= top of panicle in anthesis, bottom pre-anthesis; 4= top of panicle post anthesis, bottom in anthesis. Panicles (and/or boots) sprayed to run-off with $1x10^6$ sporidia/ml of *T. barclayana* isolate 4T3.

Table 2. Relative resistance of commercial rice cultivars and advanced lines to kernel smut under field conditions (1994 - Lawrence County Disease Monitoring Plots).[z] See related Figure 1.

Cultivar	Grain type	Maturity	Mean (smutted grains/panicle)	S.E.
Jasmine 85	Long	Late	0.0	± 0.00
Katy	Long	Midseason	0.6	± 0.15
Lemont	Long	Midseason	0.7	± 0.14
Lacassine	Long	Early	0.9	± 0.18
Mars	Medium	Early	1.0	± 0.19
Bengal	Medium	Early	2.3	± 0.49
Koshi-Hikari	Short	Midseason	2.7	± 0.47
Kaybonnet	Long	Early	3.3	± 0.34
RU9201179	Long	Midseason	3.4	± 0.47
RU9201191	Long	Midseason	3.4	± 0.37
Jackson	Long	Very early	3.6	± 0.53
RU9201176	Long	Midseason	3.8	± 0.41
Newbonnet	Long	Midseason	4.4	± 0.41
Millie	Long	Very early	4.5	± 0.58
Jodon	Long	Very early	5.4	± 0.82
Cypress	Long	Midseason	5.5	± 0.61
LaGrue	Long	Early	5.6	± 0.75
M204	Long	Very early	7.4	± 0.85
Adair	Long	Very early	9.2	± 1.09
Maybelle	Long	Very early	9.7	± 1.31
Alan	Long	Very early	11.3	± 1.34
L203	Long	Very early	18.3	± 1.74
RT7015	Long	Very early	21.2	± 1.55

[z]Data collected on 10 random panicles per plot, three plots per cultivar/line. Data arranged with most resistant cultivar/line at top to most susceptible at bottom (low - high smutted grains per panicle). S.E. = standard error of mean.

Table 3. Summary of pathogenicity tests of combinations of monosporidial lines of *T. barclayana* from the same teliospore and known tester strains 18 (A) and 43 (a).

Isolate no.	Tester 18 A	Tester 43 a	Isolate No.	Tester 18 A	Tester 43 a
1	-	+	17	+	-
2	-	-	18	-	+
3	+	-	19	+	-
4	-	+	20	+	-
5	+	-	21	+	-
6	+	-	22	-	+
7	-	-	23	-	+
8	+	-	24	-	+
9	+	-	25	+	-
10	+	-	26	+	-
11	+	-	27	+	-
12	+	-	28	+	-
13	+	-	29	+	-
14	+	-	30	+	-
15	+	-	34	+	-
16	+	-	43	+	-

Note: Isolates 2 and 7 are being retested. Also, the balance of the 51 monosporidial isolates from this single teliospore are being evaluated (roughly nos. 31-51 with two exceptions). Combinations were considered positive (+) if any smut developed after inoculation. Mating type "A" (18) represent 6/30 isolates or 20% of this collection thus far. Mating type "a" (43) represent 24/30 isolates or 80%. Virulence of these combinations was low (1-10 smutted grains per panicle) compared to the check isolate 4T3, a highly virulent isolate (50-119 smutted grains per panicle) derived from all primary sporidia of one teliospore.

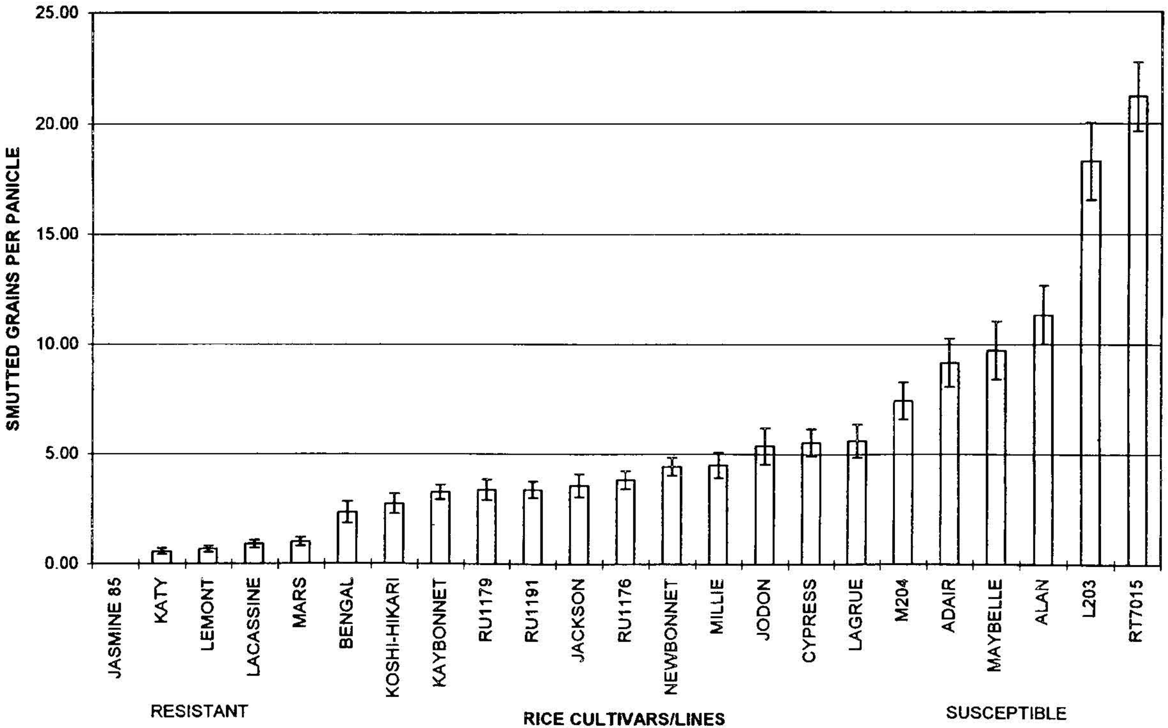

Fig 1. Relative resistance of commercial rice cultivars and advanced lines to kernel smut under field conditions (1994 - Lawrence County, Arkansas).

MONITORING OF RICE DISEASES UNDER DIFFERENT LOCATIONS AND CULTURAL PRACTICES IN ARKANSAS

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ABSTRACT

A comprehensive rice disease monitoring project was continued in 1994 to determine the identity, distribution and severity of rice diseases in Arkansas. Replicated (3) monitoring plots (eight locations, 23 cultivars/lines) and a systematic grower field survey (50 fields, four counties, 13 cultivars) were utilized in the study. Seventeen known diseases/disorders were recorded on rice in the state, and several diseases of unknown cause were again noted. Sheath blight, stem rot, blast and kernel smut were widespread in 1994, occurring at more than 20% positive stops in 50, 32, 16 and 32%, respectively, of surveyed fields. Most diseases were of concern early in the season when warm and wet conditions predominated in the state. Cooler, drier weather moved into Arkansas in mid- to late July and resulted in much less disease damage than feared early on. Regardless, severe damage from brown spot and stem rot on potassium-deficient 'Bengal' (and several other cultivars) rice in northeastern Arkansas was noted.

INTRODUCTION

The spectrum and intensity of rice diseases vary greatly due to geographic location and rice production practices in a particular area. In 1985, there were 74 major diseases of rice reported around the world caused by various agents including virus/mycoplasma-like organisms, fungi, bacteria, nematodes and physiological imbalances (Ou, 1985). Since that time, several new diseases have been reported as rice cultivars and cultural practices continue to evolve (Webster and Gunnell, 1992).

In the U.S., there are currently six major diseases (sheath blight, blast, stem rot, kernel smut, seed rot/seedling blight and, possibly, black sheath rot) all caused by fungi and one major physiological disorder (straighthead) (Webster and Gunnell, 1992). In addition, the fungal disease brown spot can be of major importance on potassium-deficient rice, as observed in Arkansas in 1994. There are also numerous minor diseases principally caused by fungi, although bacterial and nematode diseases have also been reported (Webster and Gunnell, 1992). In addition, there are a few diseases of causes yet unknown that have been recently noted.

In Arkansas, all major fungal diseases and straighthead are common, and many other minor fungal diseases are present. The composition of diseases in the state and their relative severity year to year are not precisely known.

Monitoring of plant diseases is a time-consuming but valuable service, performed to better understand the spectrum of disease problems on a particular crop and the potential for diseases to change in importance due to changes in the production practices of the crop over time. Monitoring must be annual, long-term and systematic to be of value. If done properly, the information generated can help establish or modify research priorities and develop or improve control strategies. Monitoring serves as a first-line defense in the ongoing battle with plant diseases, and one of the most valuable functions of this research is early identification of new plant diseases or increasing importance of currently minor diseases. Early warning allows researchers to develop information on the disease and devise control methods before it causes major losses to producers.

Monitoring of rice diseases in Arkansas on various cultivars under different management systems is a logical first step in discovering potential disease problems, guiding future research to address them and advising breeding and extension programs to minimize subsequent yield losses. For these reasons, this disease monitoring project was established in 1993 to identify the diseases present in Arkansas, their distribution and severity in relation to various management practices and the reaction of various cultivars to diseases in different areas of the state.

PROCEDURES

Disease Monitoring Plots

A set of rice cultivars with a range of resistance to various diseases was planted in eight grower fields in southwestern, southeastern, east-central and northeastern Arkansas and on the Pine Tree Experiment Station, Colt, Arkansas (Fig. 1). Grower fields were selected by the cooperating Cooperative Extension Service agent based on grower, disease history, cultural practices and previous observations. Cultivars were planted in 7 row x 16 ft plots and replicated three times in a randomized complete block design. Fertilization and other management practices were conducted by the grower with the rest of the field. No fungicides were applied to any of the test plots. Plots were examined periodically beginning at internode elongation for the earliest cultivars for diseases, and final disease incidence and severity data were taken at grain maturity for each cultivar based on a sample of 25 randomly collected tillers from each plot. Plots were harvested by plot combine or hand, and yield was determined at 12% moisture.

Systematic Grower Field Survey

A systematic survey of grower fields with various cultural practices was also conducted at late heading to grain maturity for each cultivar and location. Several fields (≈ 50) in Chicot, Cross, Lawrence and Lonoke counties (Fig. 1) were assessed for rice disease identity and incidence. Fields were sampled by walking in a zigzag fashion (across levees) in the central region of each field to avoid edge, high end and low end effects. Tillars in a 1-m-long section of row were inspected at each 40th step with 50 stops made per field (to maintain sampled area at approximately the same size regardless of field size). Diseases were identified and noted according to recognized symptoms. Tillers with unrecognized symptoms were collected for further study in the laboratory.

RESULTS AND DISCUSSION

Disease Monitoring Plots

Eleven common fungal diseases were observed in the monitoring plots, depending on location and cultivar (Table 1). In addition, white tip (nematode) was observed on 'Koshihikari' at several locations (data not shown). Another condition, designated brown sheath, was noted at most sites (Table 1). This disease is of unknown cause but may be related to the fungal disease sheath rot. Lodging, salt and bird damage were noted also and varied depending on cultivar and location (Table 1). Of the major diseases, sheath blight was most common, being observed at all locations (Table 1). Incidence and severity were highest on short cultivars (e.g., 'Maybelle', 'Cypress', etc) and lowest on the taller types (e.g., Adair) (Table 1). Vertical development of sheath blight on infected tillers is a measure of severity and, possibly, an estimate of cultivar resistance to the disease (Ahn et al., 1986). Maximum symptom height was 70% of tiller height on Maybelle and Jodon with all other short cultivars ranging between 50 and 70% (Table 1). On the taller cultivars, maximum symptom height was 30-50% of tiller height (Table 1). Early-planted locations had more severe sheath blight than late-planted ones (data not shown). Vertical development of the disease at the early Pine Tree location essentially ceased after the week of 17 July, apparently due to more consistent, cooler night temperatures.

Stem rot was noted at varying intensities at several locations with all cultivars showing some susceptibility (Table 1). 'Adair', Koshihikari, and Maybelle were the most consistently damaged with lodging often the result (Table 1).

Significant neck blast was noted primarily at the three late-planted sites, especially the location in White County that was planted 2 June (data not shown). 'M204' and 'L203', the susceptible checks from California, were most heavily damaged (Table 1). Other cultivars consistently damaged included 'Newbonnet', Maybelle and 'RT7015' (Table 1). The new cultivar Cypress, which was planted on such significant acreage in Arkansas in 1994, suffered only minor damage. Its sister line, Jodon, appeared somewhat more susceptible (Table 1). Blast was again not observed on 'Katy'. Neck blast was observed rarely at the White County site on the new cultivar 'Kaybonnet' (Katy x 'Newbonnet') but was of extremely low incidence (Table 1). Blast was also observed in at least one Kaybonnet seed field in Lonoke County (Q.R. Hornsby, personal communication) and Clay County (R. Gipson, personal communication). While resistance to blast in this new high-yielding cultivar appears excellent overall, these observations warrant concern for the future of this new release, especially considering confirmation of the new blast race IE-1k from field samples of Kaybonnet and other cultivars. This race is capable of attacking both Katy and Kaybonnet in experimental greenhouse tests.

Kernel smut was observed at all sites in 1994. It was again most severe at the Lawrence County site. RT7015, L203, M204, 'Alan', Adair, 'Jackson', Newbonnet, 'LaGrue' and Maybelle had significant levels of smutted panicles at this and other sites (Table 1). Cypress and Jodon had moderately high levels of smutted panicles at the Lawrence County site under high nitrogen fertilization (Table 1). Smut was again at low levels on 'Lacassine', 'Lemont', 'Bengal', 'Mars' and Katy (Table

1). The new cultivar Kaybonnet and related lines (RU9201176, 79, 91) appear moderately susceptible to this disease (Table 1).

Most other foliar diseases of rice were more common in 1994 than 1993. One disease of note, scab, was regularly observed in monitoring plots and grower fields in 1994. This disease, which also attacks wheat, appears to be increasing in importance in Arkansas. In these plots, scab was especially common on early-season and medium-grain cultivars, while mid-season long-grain cultivars such as Katy, Lemont and Lacassine, and the new cultivar, Kaybonnet, suffered less damage (Table 1).

Plot yields and variation in yield across locations (CV) are shown in Table 1. This information, combined with the disease data and knowledge of site and grower practices, gives a better picture of cultivar risk than previously available. An assessment of yield variability across sites was made by calculating the coefficient of variation for mean yield for each cultivar across all eight sites. This value (CV) can be used as an assessment of yield stability, as illustrated by the following two examples from Table 1. The California cultivar M204, which has high yield potential under disease-free conditions, yielded 200 bu/acre at one site but only 12 bu/acre at another site with heavy blast pressure, resulting in an overall yield of 131 bu/acre. Its CV value was a very high 46, meaning high variation in yield across sites, and obviously suggesting low yield stability and high risk under Arkansas conditions. On the other hand, the new cultivar Kaybonnet had a mean yield of 165 bu/acre with a low of 141 bu and a high of 203 (data not shown). This resulted in a CV of only 13, meaning low variation in yield across sites and suggesting high yield stability and lower risk under Arkansas conditions. Information from this monitoring work is currently being used to supplement rice performance data generated by the rice breeding program and will continue in this vein in the future. Further research should help more clearly define the overall yield and risk potential of a given cultivar under Arkansas conditions, hopefully reducing the chance of loss to Arkansas rice producers and resulting in higher and more reliable rice yields in the state.

Systematic Grower Field Survey

A total of 50 grower fields in four counties were surveyed for rice diseases (Table 2). There were 13 different rice cultivars and 15 diseases of known cause recorded (Table 2). Sheath and stem diseases were again common in surveyed fields, primarily on the shorter cultivars. Maximum vertical development of sheath blight in any field noted was 100% of tiller height (rating 9 - Ahn et al., 1986), meaning the panicle was infected. This severity was noted on early-planted Cypress, and infection of the panicle appeared to occur while the rice was in late boot stage. Overall, however, this phenomenon was uncommon.

Stem rot was again widespread in surveyed fields but at damaging levels only in those where nutritional or other stress was suspected. Potassium deficiency was shown to be the underlying cause for both stem rot and brown spot damage in northeastern Arkansas fields of Bengal, Lemont, Newbonnet, 'Orion' and Cypress (Table 3). Many of these fields were not included in the survey but were diagnostically sampled for this determination. Additional affected fields of Alan and Lacassine were also noted in this region and suspected of potassium deficiency as well, but diagnostic samples were not taken.

Leaf and neck blast was again sporadic but much more common than in 1993 (Table 2). The disease was routinely observed on LaGrue, Lacassine, late-planted Lemont, Newbonnet and Alan fields in the survey. Across the state, blast was again primarily a problem on light (sandy) soils and drought-stressed rice fields. This was especially true in Clay County (R. Gipson, personal communication), Lonoke County (Q. Hornsby, personal communication), Prairie County (H. Chaney, personal communication), Lawrence County (R.L. Hunter, personal communication) and Cross County (R. Thompson, personal communication). While the newer cultivar LaGrue performed well overall, severe blast damage was observed in some of these areas (Q. Hornsby and R. Gipson, personal communication). It was painfully clear that LaGrue should not be grown on extremely light soils, where water management is a problem or on fields where blast has been a problem in the past. The cultivar Cypress, while somewhat susceptible to certain blast races, appeared to suffer little blast damage in 1994 (Table 2). Overall, drier weather during the heading phase probably helped avert major neck blast damage to Arkansas rice in 1994.

Kernel smut was widespread and sporadically severe in 1994. It was principally noted on overfertilized fields of Cypress, Alan, RT7015, Newbonnet and LaGrue (Table 2). Some farmers apparently overfertilized Cypress fields at mid-season based on its naturally light green color, leading to problems with lodging and kernel smut later on. This, however, was the exception rather than the rule, and in most instances Cypress yielded well and had good grain quality (R.S. Helms, personal communication). It remains true, however, that most new cultivar releases in the U.S. are quite susceptible to kernel smut.

Black (crown) sheath rot was again noted in 1994 but was of minor significance (Table 2). As in 1993, damage was observed in only first- or second-year rice fields or where no other diseases were significant.

This observation, plus the continued confusion with stem rot, has led us to reassess the perceived importance of this disease in Arkansas.

Scab (caused by *Fusarium graminearum*, same as head scab of wheat) was observed frequently in 1994 (Table 2). This disease was observed more frequently on early-season and medium-grain cultivars in the state and is of increasing concern as wheat is being more commonly grown on Arkansas rice farms.

A relatively rare disorder was also observed on the new medium-grain cultivar Bengal in northeastern Arkansas in 1994. Symptoms included a general blackening and eventual rotting of the roots, with resulting premature leaf death and partial or complete blanking of panicles. This disorder was diagnosed as autumn decline, caused by hydrogen sulfide (H_2S) toxicity. It was principally noted in fields with high soil sulfate levels, known H_2S in the well water, low soil potassium levels or where long-term use of sulfate fertilizers was suspected. Draining the field to aerate roots was an effective short-term remedy; however, long-term solutions on certain farms may involve further study. Regardless, the cultivar Bengal seems very susceptible to this problem.

SIGNIFICANCE OF RESULTS

Results demonstrate the broad spectrum of rice diseases present in the state and their varying intensity as influenced by cultivar, location and management practices. Control of these many diseases from year to year will involve additional research and education of growers in regard to the influence of cultural practices on disease severity. The disease monitoring project will permit accumulation of comparative data from year to year and help researchers prioritize research needs and approaches. The value of this research is to provide supplemental data on cultivar response to diseases under grower conditions to the disease resistance research program, to help assess the overall impact of diseases on rice production in a given year and to provide early detection of new diseases or changes in current diseases. In 1993-94, this project added significant new information to our understanding of the susceptibility of current cultivars/lines to stem rot, kernel smut and brown spot. It also contributed to our knowledge of the effect of soil fertility on rice disease severity and assisted county agents and rice producers by providing hands-on exposure to new cultivars and disease problems.

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Table 1. Summary yield and disease reaction data from disease monitoring plots (eight locations) in 1994. Disease data are mean values for sites where particular diseases were present at fairly uniform levels.

Cultivar	Yield	CV	SHBI	SHB SEV	SR-DI	NB	LB	PB/ FB	KS	BSHR	BS	NBLS	SCAB	LS	FSHR	SCLD	BRNSH	LODG	SALT	BIRD
Adair	146	24	22	0.3	2.6	9	4	60	74	20	2	2	39	5			31	37		
Alan	127	25	48	0.4	1.9	8	5	28	58	12	9	17	46	67			23	50		30
Bengal	181	24	54	0.5	1.5	1	4	10	10	40	45		26	9	2	4				
Cypress	140	26	46	0.6	2.1	6	12	22	38	35	2		6	46		8	10			
Jackson	155	19	50	0.5	2.1	5	100	36	67	27	6	14	27	35		100	2		10	
Jasmine85	158	30	23	0.2	1.1						12		2			6				
Jodon	157	19	44	0.7	1.6	9	21	20	41	50	14	100	28	48			6			
Katy	149	16	47	0.4	1.4				8	40	36	82	2	34			13	10		
Kaybonnet	165	13	33	0.5	1.9	1		3	24	60	55	95	2	51		22	16	13	10	
Koshi-Hikari	149	13	16	0.3	2.3				8					16				100	40	
L203	139	34	63	0.5	1.5	22	35		47	12	24	2	36	38						38
Lacassine	160	20	47	0.6	1.4	3	30	16	6	100	27		2	26		60	14			
LaGrue	167	19	37	0.4	2.1	4	11	34	67	20	6	47	19	25			26	10		
Lemont	147	24	43	0.6	1.5	1	9	40	7	55	3	40	2	25			27			
M204	131	46	44	0.5	1.7	33	31		47	44	14		56	87						38
Mars	166	21	33	0.3	1.5	9	10	16	15	24	28		31	40	1			25		
Maybelle	110	36	69	0.7	2.3	13	42	16	64	96	12	15	46	41		64	84	100		25
Millie	145	13	45	0.3	1.3	4	1	8	28	16	2	38	12	21		20	34	28	10	7
Newbonnet	141	28	42	0.3	1.8	10	13	44	64	4	13	84	17	36			22	13		
RT7015	151	20	49	0.6	1.9	11	5	20	63	27	8	10	25	22		28	14			
RU9201176	165	11	48	0.3	2.4				33	22	16		33	42			12	5		
RU9201179	185	15	21	0.3	1.4				38	8	6	90	2	80			8	5		
RU9201191	176	8	42	0.3	1.5				37	10	4	100	2	80				10		

Notes: YIELD = mean bu/acre yield (8 sites); CV = coefficient of variation for mean yield (across sites) - low number = less variation across sites (more stable) and high numbers = more variation (less stable); SHBI = average sheath blight incidence (% infected tillers); SHBSEV = severity of sheath blight as ratio of disease symptom height/infected tiller height (e.g. 0.5 = disease symptoms 50% of tiller height); SR-DI = stem rot disease index (1= no disease, 5 = tiller killed prematurely). Unless otherwise noted, the remainder of the data represent % infected tillers. NB = neck blast; LB = leaf blast; PB/FB = panicle or floret blast; KS = kernel smut; BSHR = black (crown) sheath rot; BS = brown spot; NBLS = narrow brown leaf spot; SCAB = scab; LS = leaf smut; FSHR = fusarium sheath rot; SCLD = leaf scald; BRNSH = brown sheath (unknown cause - possibly sheath rot and other diseases); LODG = lodged (% of plot); SALT = salt damage (% stand reduction); BIRD = bird damage (% panicles).

Table 2. Summary of 1994 rice disease data from grower field survey (mean % positive stops by cultivar).[z]

Cultivar	Fields	SHB	SR	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	FSHR	SCLD	SHBL
Alan	1	14	26	6		22		6	18	34			20			
Bengal	9	28	7	6	12	2	18	51	2	16		5	7	11		
Cypress	10	41	19	8	8	51	21	16	7	5	31	10	52		2	2
Katy	6	23	13			4	35	8	91	4	4	11	9		7	
Kaybonnet	4	5	8	12		11	4	26	62	2	4		14			6
Koshi-Hikari	1	6	46			14		2		2		20				
Lacassine	2	51	22	36	46	3		66	12	2			15		8	
LaGrue	3	29	14	36	40	61		19	4	17	3	2	14			
Lemont	6	34	55	10	37	4	36	11	25	11	10	22	20		4	
M401	2		27	52	22	50						62				
Mars	1	12	2	60	48	2		22		26						
Millie	2	39	2	5		41		6	7	2		4	12		2	
Newbonnet	3	20	47	7	5	47	2	26	94	8	7	9	13		2	
	50															

Overall mean (percent positive stops) for each disease

SHB	SR	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	FSHR	SCLD	SHBL
23	22	18	17	24	9	20	25	10	5	11	13	0	2	0

Percent of fields with greater than 20% positive stops for each disease

SHB	SR	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	FSHR	SCLD	SHBL
50	32	16	14	32	16	36	32	10	2	8	28	0	0	0

Notes: All data presented as % positive stops in the field. SHB = sheath blight; SR = stem rot; NB = neck blast; LB = leaf blast; KS = kernel smut; BSHR = black (crown) sheath rot; BS = brown spot; NBLS = narrow brown leaf spot; SCAB = scab; BSS = bordered sheath spot; AgSS = aggregate sheath spot; LS = leaf smut; FSHR = fusarium sheath rot; SCLD = scald; SHBL = sheath blotch (*Pyrenochaeta oryzae*).

[z]A "positive stop" indicates that the particular disease was noted on that 1-m segment of row.

Table 3. Results of leaf tissue and soil analysis for diseased Bengal (and other) fields in northeastern Arkansas (1994).

	Leaf tissue analysis (near plant maturity)														
		Percent								mgKg					
Damage	Samples	N	P	K	N/K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	Cl	
None	8	1.75	0.18	1.16	1.6	0.71	0.20	0.16	488	132	1679	21	6.9	6124	
Low/Moderate	11	2.37	0.29	0.91	2.6	0.69	0.24	0.18	1490	99	1104	23	5.8	4756	
Severe	14	2.08	0.27	0.45	5.6	0.67	0.26	0.17	2627	117	899	26	6.1	4607	
Correlation with damage R =		.15	.27	-.86*	.67*	-.12	.33	.09	.59*	-.13	-.36	.19	-.12	-.19	
	Soil analysis (lb/acre unless otherwise noted)														
Damage	Samples	µmhos /cm EC	P	K	pH	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	meq /100 gm CEC	µmhos /cm Salt
None	5	212	27	164	6.1	2973	571	78	122	537	377	4.8	1.62	18	94
Low/Moderate	7	168	28	62	5.9	1744	280	56	91	669	127	10.3	0.97	11	74
Severe	9	145	22	62	5.8	1797	318	58	83	681	188	14.8	1.18	12	76
Correlation with damage R =		-.52*	-.15	-.64*	-.13	-.39	-.50*	-.31	-.27	.24	-.31	.29	-.26	-.75*	-.54*

Notes: Principal diseases were stem rot of rice (*Sclerotium oryzae*) and brown spot (*Bipolaris oryzae* = *Helminthosporium oryzae*) on the following cultivars - Bengal (10 fields), Cypress (1 field), Lemont (1 field), Newbonnet (1 field) and Orion (1 field). Both diseases were common on Bengal while only stem rot was consistently observed on other cultivars. Additional diseased fields of Bengal (13), Cypress (3), Newbonnet (2), Lemont (4), Lacassine (1) and Alan (1) were observed but samples not taken for analysis. Diseased fields were observed or reported in eight northeastern Arkansas counties and one southwestern Arkansas county.

* Correlation significant at $P = 0.05$. N (nitrogen); P (phosphorus); K (potassium); N/K (nitrogen to potassium ratio); Ca (calcium); Mg (magnesium); S (sulfur); Na (sodium); Fe (iron); Mn (manganese); Zn (zinc); Cu (copper); Cl (chloride); EC (electrical conductivity); CEC (cation exchange capacity).

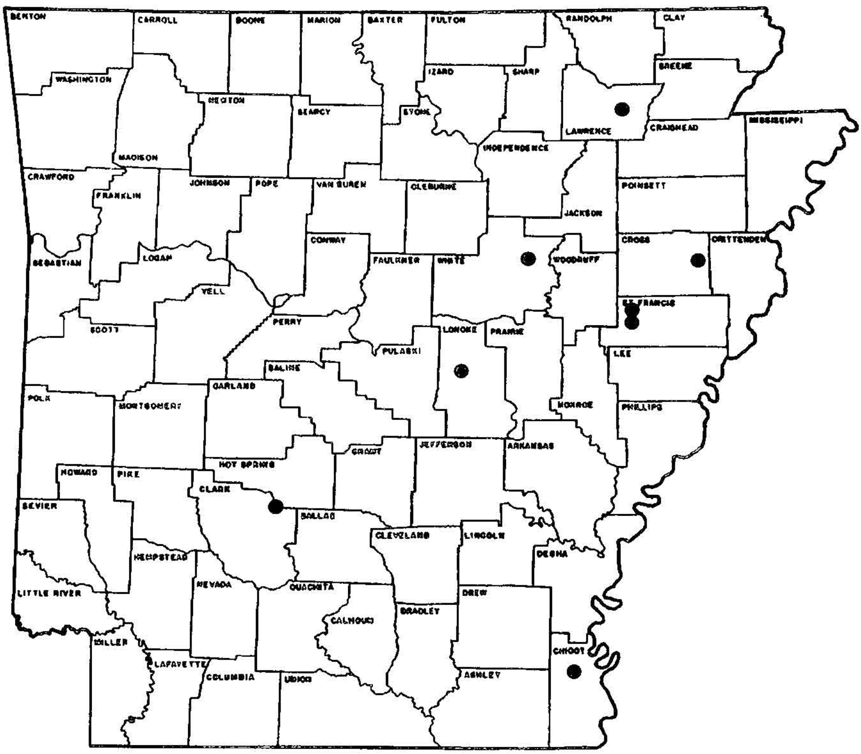

Figure 1. Rice Disease Monitoring Plot and Survey Locations in 1994.

Note: Disease monitoring plots (dots) were located in Chicot, Clark, Cross, Lawrence, Lonoke and White Counties and on the Pine Tree Experiment Station, Colt, Arkansas (2 sites). locations. The systematic grower field survey was conducted in Chicot, Lonoke, Cross and Lawrence Counties and included approximately 50 fields. Additional counties included in this research based on specific disease problems included Clay, Poinsett, Prairie, Randolph, and Arkansas Counties.

ECONOMIC EVALUATION OF FOLIAR FUNGICIDES AND METHOD OF APPLICATION USED TO SUPPRESS SHEATH BLIGHT

Gary L. Cloud

ABSTRACT

Sheath blight has for many years been a destructive disease in rice production in Arkansas. Although small-plot fungicide trials typically reveal significantly greater yield responses when compared to untreated check plots, these trials differ tremendously from that occurring in production fields which include disease uniformity and severity and method of fungicide application. This study was designed to evaluate the economic performance of fungicide applications in production fields and evaluate the interactions between method of fungicide applications and sheath blight severity. Results from the large-block fungicide trials conducted since 1992 revealed fungicide applications made in only one out of 11 fields tested provided an economic response. Although suppression of sheath blight was commonly shown in fungicide-treated plots, this suppression rarely translated into yield responses. Since tremendous differences in yield responses result from fungicide applications made in small-plot vs. large-block fungicide trials, it seemed logical to evaluate the influence method of fungicide application has on sheath blight severity. Results indicate that manipulations of the spray system of agricultural aircraft resulted in improved suppression of sheath blight in production fields. Although ground applications provide the best suppression, it appears these results provide us with a starting point to further refine the spray system and compare sheath blight suppression with currently used spray systems and untreated control plots.

INTRODUCTION

Sheath blight (*Rhizoctonia solani*) is considered the most prevalent and, in some years, the most destructive rice disease in Arkansas. The disease has received such status because of rotational programs that utilize crops susceptible to *R. solani* (Jones, 1989). Crops susceptible to *R. solani* include soybean, grain sorghum and corn.

Sheath blight suppression has been accomplished with fungicide applications and the use of tolerant rice varieties (Marchetti, 1983). Fungicide recommendations for sheath blight suppression were formulated from small-plot fungicide trials in which plots were artificially inoculated with the sheath blight fungus and fungicides were applied with ground equipment (Groth et al., 1992). In Arkansas, most if not all rice acreage treated with fungicides is treated with agricultural aircraft. Tremendous differences exist when comparing ground applications and aerial applications (Hollier and Groth, 1991). For the past few years, growers have questioned the economic benefits they were receiving with fungicide applications to suppress sheath blight (Moore, 1991).

This study was designed 1) to evaluate the economic performance of fungicides used to suppress sheath blight in rice production fields and 2) to evaluate the interaction between method of fungicide application and sheath blight suppression.

MATERIALS AND METHODS

Economic Evaluation of Foliar Fungicides

One commercial field located in Lonoke County was selected as a site for the large-block study. Fields were selected on the basis of the variety planted, size of field and uniformity of sheath blight severity. 'Katy', the rice variety grown at the test site location, is considered tolerant to sheath blight. Tolerance does not mean resistance; in sheath blight severity can be as great as with susceptible rice varieties. However, yield losses in tolerant varieties are not as great as in susceptible varieties.

Plots were 200 ft x 1000 ft and were arranged in a randomized complete block design with three replications per treatment. Fungicides included in the large-block fungicide trial included Tilt 3.6EC (10 oz/acre) followed by (fb) Benlate 50WP (1.5 lb/acre), Rovral 4F (1.0 pt/acre/application) and Moncut 50WP (0.35 lb ai/acre/application) (Table 1). Moncut 50WP was added because in 1994 this fungicide received an experimental use permit from the Environmental Protection Agency and appears to be close to registration. All fungicide applications were made at 0.5-in. internode elongation followed by a second application 10 days later. Penetrator Plus (Helena Chemical Co.) was added to all fungicide treatments at the rate of 1 pt/100 gal to improve penetration and coverage of the fungicide into the rice canopy. Untreated plots served as controls. Fungicides were mixed with enough water to deposit 10 gal of material per acre. Fungicides were applied with agricultural aircraft equipped with #D12-56 cone-hollow tip nozzles and 30 psi. Plots were treated during early-morning hours when wind speeds were less than 5 mph and dew was present on leaves to assist in the movement of the fungicide downward.

Sheath blight ratings were taken at 10 predetermined locations per plot (30 locations/treatment). Disease ratings taken at each of the 10 locations per plot included percent tillers infected (number of tillers exhibiting sheath blight lesions/total number of tillers within a 3 linear row ft length) and 0-9 rating (0 = no disease, 9 = sheath blight symptoms exhibited on the flag leaf/3 linear row ft). Disease ratings were taken four times during the growing season: 1) prior to fungicide application, 2) one week after the first fungicide application, 3) one week after the second fungicide application and 4) two weeks prior to harvest.

Once the rice reached physiological maturity, strips were harvested through the center of each plot with the cooperator's combine. The harvested rice was weighed in a weigh wagon to determine grain yield (bu/acre) with moisture adjusted to 12%.

Mean yield data was statistically analyzed to determine significant differences ($P = 0.05$ level) among grain yields.

Evaluation of Interactions Between Method of Application and Sheath Blight Severity

Two rice production fields in Lonoke County were chosen as sites for the method of application study. 'Millie' was the rice variety grown in each of the two rice fields. These fields were chosen because of their size and uniformity of sheath blight infestation.

Plots treated with agricultural aircraft were 200 ft wide x 1000 ft long. Plots treated with ground equipment were 10 ft wide x 100 ft long. All plots were arranged in a randomized complete block design with three replications per treatment. Spray systems and carrier volumes used in fungicide-treated plots are listed in Table 2. Ground-applied treated plots were treated with a CO_2 backpack sprayer. Rovral 4F (Rhone Poulenc Chemical Co.) was applied to all fungicide-treated plots at a rate of 1.0 pt/acre. Fungicide applications were made at 0.5-in IE fb by a second applications made 10 days later. Penetrator

Plus (Helena Chemical Co.) was added to all fungicide treatments at a rate of 1 pt/100 gal. Untreated plots served as controls.

Fungicide deposition into the rice canopy was determined by the cotton string method. Cotton string, used as a collector for a fluorescent tracer (Rhodamine WT), was placed prior to each fungicide application at two heights within each plot; at the top of the canopy and 4 in. above the water line. The fluorescent tracer was mixed with each fungicide treatment at a concentration of 1% v/v. The cotton string was collected immediately after the fungicide application and placed in a film canister to prevent sunlight from breaking down the fluorescent dye. The soiled string was sent through a specialized fluorometer to determine the relative amount of fluorescent dye present on the string.

Sheath blight ratings were taken at 10 predetermined locations per plot (30 locations/treatment). Disease ratings taken at each of the 10 locations per plot included +/- rating (+ = one or more sheath blight lesions/3 linear row ft), percent tillers infected (number of tillers exhibiting sheath blight lesions/total number of tillers within a 3 linear row ft length) and 0-9 rating (0 = no disease, 9 = sheath blight symptoms exhibited on the flag leaf/3 linear row ft). Disease ratings were taken three times during the growing season beginning approximately 10 days after the second application.

Plots were harvested in the locations rated for disease by hand-clipping panicles from 3-ft^2 areas (10 subplots/plot). Harvested panicles from each plot were thrashed in a stationary thrasher. Grain weights were taken and adjusted to 12% moisture and converted to bu/acre.

Mean yield data were statistically analyzed to determine significant differences (P = 0.05 level).

RESULTS AND DISCUSSION

Economic Evaluation of Foliar Fungicides

Fungicide treatments used in this year's large-block fungicide trial have performed the best over the previous two years than any other fungicide treatment or combination. The three fungicide treatments suppressed sheath blight in both the % tillers infected rating and 0-9 rating when compared to untreated check plots at the second, third, and fourth rating dates (Table 3). Greatest suppression appeared to be in plots treated with Tilt 3.6EC fb Benlate 50WP and Benlate 50WP applied twice. Although visual ratings appeared to suggest suppression of sheath blight, no significant differences (P = 0.05) in yield were found among the treatments. The lack of significant differences in yield data could be due to the rice variety grown, which is considered a variety tolerant to sheath blight.

Evaluation of Interactions Between Method of Application and Sheath Blight Severity

No significant differences (P = 0.05) were found in the quantification of fluorescent dye detected from cotton string suspended at the top of the canopy in all fungicide-treated plots.

Fungicide deposition into the canopy was affected by the method of fungicide application. Fluorescent dye detected on the cotton string was not significantly different when comparing the "ground" treatment and "aerial new" treatments (Table 4). However, significantly higher fluorescent dye concentration were detected on the cotton string when comparing "ground" treatments to "aerial old" treatments. No significant differences in the quantification of the fluorescent dye were observed between the "aerial new" treatments and "aerial old" treatments. All fungicide-treated plots had significantly higher concentrations of the fluorescent dye than the untreated check plots.

Sheath blight disease ratings from the "Big Field" revealed no differences in the +/- ratings and % tillers infected ratings at any of the three rating dates among the fungicide treated and untreated plots (Table 5). However, the 0-9 rating which indicates vertical movement of sheath blight on the rice plant, revealed the highest level of disease in untreated plots followed by "aerial old" treatments followed by "aerial new" treatments followed by "ground" treatments. Sheath blight ratings from the "Little Field" revealed the same trends particularly at the later ratings dates (Table 6).

No significant differences in yield were observed among the fungicide-treated plots when compared to the untreated check plots in the "Big Field" and the "Little Field" (Tables 7 and 8).

SIGNIFICANCE OF RESULTS

Fungicide applications can be a large portion of a grower's yearly budget, depending on the year and the disease pressure. It appears from this year's results in conjunction with 1992 and 1993 results that fungicide applications used to suppress sheath blight are not providing a true economic return. This lack of economic return with the applications of fungicides used to suppress sheath blight could be due to the method of application currently being used, tolerant rice varieties being planted over a large percentage of the total rice acreage and the timing of fungicide applications. Further research projects should be conducted to improve the efficacy of fungicides currently registered. This could save growers thousands of dollars by improving the probability of getting an economic return from fungicide applications when they are applied.

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Table 1. Fungicide rates and timing of applications in 'Katy' rice used in the large-block fungicide trials at Steck Farms, Lonoke County, 1994

Fungicide Treatment	Form. Rate/acre	Timing of Application[z]
Tilt 3.6EC (Ciba)	10 fl oz/acre	0.5-in IE
Benlate 50WP (DuPont)	1.5 lb/acre	0.5-in IE fb 10 days later
Moncut 50WP (AgEvo)	0.35 lb ai/acre	0.5-in IE fb 10 days later

[z]IE = internode elongation; fb (followed by) refers to the timing of the second fungicide application which was 10 days later.

Table 2. Spray system set-ups for agricultural aircraft and ground equipment

Method of Fungicide Application	Spray Nozzles	Carrier[z] Volume (gpa)
Untreated	------	------
Aerial Old	Cone-hollow Tip Nozzles	10 gpa
Aerial New	Flat-fan Nozzles	5 gpa
Ground	Flat-fan Nozzles	5 gpa

[z]gpa = gallons per acre.

Table 3. Sheath blight ratings in 'Katy' rice in response to various fungicide applications in large-block fungicide tests at Steck Farm, Lonoke County, 1994

Fungicide Treatment	1[z]	2	3	4
% Tiller Infected[y]				
Untreated	10%	22%	59%	100%
Tilt 3.6EC fb Benlate 50WP	18%	18%	31%	71%
Benlate 50WP (1.5 + 1.5)	11%	17%	30%	60%
Monocut 50WP (0.35 + 0.35)	6%	13%	39%	85%
0-9 Rating				
Untreated	1	4.2	6.1	7.1
Tilt 3.6EC fb Benlate 50WP	1	2.2	3.9	5.8
Benlate 50WP (1.5 + 1.5)	1	2.6	4.1	5.1
Monocut 50WP (0.35 + 0.35)	2	3.1	4.8	5.9

[z]1 = prior to fungicide application, 2 = one week after first fungicide application, 3 = one week after second application, and 4 = two weeks prior to harvest.

[y]fb (followed by) refers to the timing of the second fungicide application which was 10 days later.

Table 4. The effect of method of application on the deposition of fungicide into 'Millie' rice canopy at Fred Steck Farm, Lonoke County.

Method of Fungicide Application	Fluorescent Dye[z] Concentration
Untreated	0.0c
Aerial Old	27.8b
Aerial New	37.4ab
Ground	47.9a
LSD (0.05)	17.912
SD	8.96529
CV	31.66

[z]Concentration of fluorescent dye detected on cotton string located 4 in. above the water line.

Table 5. Sheath blight ratings in 'Millie' rice on three dates at the "Big Field" location in response to the method of fungicide application.

Method of	July 29			Aug. 4			Aug. 12		
Fungicide	+/-	% Tiller	0-9	+/-	% Tiller	0-9	+/-	% Tiller	0-9
Appl.	Rating	Infected	Rating	Rating	Infected	Rating	Rating	Infected	Rating
Untreated	73.3	20.0	5.8	100.0	20.4	6.4	100.0	47.6	6.9
Aerial Old	60.0	11.3	3.1	75.0	7.1	4.5	100.0	4.7	5.1
Aerial New	93.3	6.7	3.1	100.0	15.2	3.6	100.0	6.1	4.3
Ground	90.0	9.7	2.4	95.0	11.3	3.3	100.0	13.2	3.8

+/- rating refers to the positive stop method; + means sheath blight present, - means sheath blight not present.

Table 6. Sheath blight ratings in 'Millie' rice at the "Little Field" location in response to the method of fungicide application.

Method of	July 29			Aug. 4			Aug. 12		
Fungicide	+/-	% Tiller	0-9	+/-	% Tiller	0-9	+/-	% Tiller	0-9
Appl.	Rating	Infected	Rating	Rating	Infected	Rating	Rating	Infected	Rating
Untreated	86.6	16.2	4.2	100.0	28.8	5.4	100.0	32.6	5.8
Aerial Old	83.3	9.3	3.6	100.0	11.6	3.8	100.0	14.5	4.7
Aerial New	73.3	12.0	3.1	83.3	8.7	3.7	93.3	9.3	4.2
Ground	46.6	7.4	3.0	73.3	7.0	3.3	93.3	11.7	4.0

+/- rating refers to the positive stop method; + means sheath blight present, - means sheath blight not present.

Table 7. The effect of method of application on 'Millie' yield (bu/acre) in large-block fungicide trial at the "Big Field," Steck Farm, Lonoke County, 1994.

Method of Fungicide Application	Yield[z] (bu/acre)
Untreated	146.1a
Aerial Old	147.6a
Aerial New	143.1a
Ground	154.0a
$LSD_{(0.05)}$	32.87
SD	15.6592
CV	10.60

[z]Numbers in a column followed by the same letter are not significantly different ($P = 0.05$)

Table 8. The effect of method of application on 'Millie' yield (bu/acre) in large-block fungicide trial at the "Little Field," Steck Farm, Lonoke County, 1994.

Method of Fungicide Application	Yield[z] (bu/acre)
Untreated	139.2a
Aerial Old	137.2a
Aerial New	127.8a
Ground	143.3a
$LSD_{(0.05)}$	16.67
SD	8.34507
CV	6.10

[z]Numbers in a column followed by the same letter are not significantly different ($P = 0.05$)

IMPROVING DISEASE RESISTANCE IN RICE THROUGH GENE TRANSFER AND THE PRODUCTION OF TRANSGENIC PLANTS

Edwin J. Anderson, Jameel M. Al-Khayri and Rose C. Gergerich

ABSTRACT

Our research involved the establishment of a system suitable for the in vitro regeneration of Arkansas rice cultivars to facilitate the production of somaclonal variants and transgenic rice. Induction of callus and regeneration of plants were accomplished for several Arkansas commercial rice cultivars ('Katy', 'LaGrue', and 'Alan') and breeding lines (RU9101001 and RU9201191). To our knowledge, these genotypes have not previously been regenerated. Callus proliferation was dependent upon the concentration of the 2,4-D added to the culture medium. Plant regeneration from callus was highly variable among genotypes, ranging from 10% to 80%. The amounts and types of sugar added to the culture medium also affected callus proliferation and the regenerability of the resultant callus. Regenerated plants were evaluated for possible somaclonal variations that may engender some level of resistance to fungal pathogens. To date, no resistant regenerants have been identified. When callus tissues were bombarded with microprojectiles coated with DNA plasmid solutions harboring the β-glucuronidase (GUS) marker gene, transient expression of the transgene was obtained. We are currently working toward stable transformation and the regeneration of transgenic plants.

INTRODUCTION

Efforts to improve crops through selection and classical breeding have resulted in the development of countless plant varieties that are high yielding, disease and insect resistant, stress tolerant, easier to process and more nutritional. With the advent and refinement of recombinant DNA and tissue culture techniques, molecular biologists and plant breeders now have additional methods for introducing desirable traits into cultivated crops.

Recombinant DNA techniques facilitate the identification, characterization and manipulation of genetic information in a very precise manner. Plant transformation and regeneration procedures make it possible to bring about potentially beneficial mutations in plant genomes and to introduce and express genetic information in plants by methods that do not require sexual compatibility (Harms, 1992; Hall et al., 1993). As a result, breeding efforts are enhanced by reducing the time required to develop varieties with desirable traits and by providing a larger gene pool from which those traits can be obtained. Two critical prerequisites for making use of these techniques are 1) the development of a reliable system for transforming and regenerating the target plant and 2) the identification, characterization and introduction of genes responsible for specific traits.

Individual plant cells contain all of the genetic information necessary to produce whole plants; thus they are totipotent. Under the appropriate tissue cultural conditions, specific to every plant species and cultivar, these cells can be induced to produce whole plants. While regenerated plants are nearly identical to the parent plants, spontaneous mutations occasionally occur during the regeneration process, resulting in the production of somaclonal variants. Researchers can make use of this phenomenon to evaluate regenerated plants for desirable phenotypic attributes.

There is a growing number of examples in which "foreign" genes from plant, microbial and even animal sources have been genetically engineered into (transgenic) plants to engender pest/pathogen resistance, stress tolerance, enhanced yields and nutritional value, as well as other beneficial traits. Recently, some of these transgenic (genetically engineered) plants have been approved for commercial use. These examples, although limited, provide promise for the future of this technology. As beneficial genetic information is identified and characterized, methods for incorporating those genes into transgenic plants will be essential. With the support of the Arkansas Rice Research Promotion Board (ARRPB), we are developing methods for introducing and expressing foreign genes in rice. This work utilizes the process of microparticle bombardment to introduce DNA containing selectable marker genes and genes for desirable traits (Jefferson et al., 1987; Christou, 1992). We have been successful in regenerating a number of Arkansas-grown rice cultivars and breeding lines and in obtaining transient expression of genes introduced into rice callus tissues by the methods of microparticle bombardment. We are working to optimize the efficiency of rice transformation and regeneration systems for the specific genotypes under investigation.

PROCEDURES

Callus Induction and Plant Regeneration of Arkansas Rice

The process of plant regeneration is comprised of four basic stages:

1) **Seed Sterilization**. Rice seeds were dehusked manually to preserve the embryos from mechanical damage. The caryopses were surface sterilized in 70% ethanol and 2.6% (w/v) sodium hypochlorite. Seeds were then thoroughly rinsed in sterile water.

2) **Callus Induction**. The seeds were cultured on MS medium (Murashige and Skoog, 1962) supplemented with 0.5 to 4 mg/L 2,4-dichlorophenoxyacetic acid (2,4-D) and 0 or 0.5 mg/L 6-furfurylaminopurine (kinetin). The medium was adjusted to pH 5.8 and solidified with 10 g/L agar. The effect of sugar supplements (4% sucrose or 1% sucrose combined with 3% sorbitol) was also investigated. The cultures were incubated at 12-h photoperiods and 24C.

3) **Plant Regeneration**. Calli were transferred to regeneration media consisting of the same components as the callus induction media but varied in the levels of plant growth regulators. Regeneration media contained 0 or 0.1 mg/L NAA and 0 or 2 mg/L kinetin. Regenerated plantlets, 1 cm long, were separated and transferred to a hormone-free medium for further growth.

4) **Plant Acclimatization**. Plants were removed from culture vessels, and the agar was washed from the root regions. The regenerants were planted in potting mix, placed in covered plastic containers and misted with water. The relative humidity inside the containers was gradually reduced to acclimatize the rice plants to ambient atmosphere. After 2 weeks the plants were transferred to a greenhouse where they were screened for somaclonal variation.

Genetic Transformation of Arkansas Rice

The Particle Delivery System (PDS, He-1000; Bio-Rad Laboratories) was used to bombard rice callus tissues with gold microparticles coated with a plasmid (pBI121; Clontech Laboratory) DNA solution containing the marker gene, β-glucuronidase (GUS) under the transcriptional control of the cauliflower mosaic virus 35S promoter and terminated by the nopaline synthase (NOS) polyadenylation signal. The DNA also contained the neomycin phosphotransferase II gene that confers resistance to kanamycin. Two days after bombardment, calli were transferred to callus medium supplemented with kanamycin. After several days, the surviving, potentially transformed cells were assayed for the expression of GUS by histochemical staining of the tissues with X-Gluc (5-bromo-4-chloro-3-indolyl β-D-glucuronic acid).

RESULTS AND DISCUSSION

Callus Induction and Plant Regeneration of Arkansas Rice

Within a species, variable responses to procedures for callus induction and subsequent plant regeneration are observed among genotypes that may reflect differences in nutritional or hormonal requirements. The research summarized in this report includes current results and anticipated studies of the conditions specific for Arkansas rice cultivars and breeding lines. The effects of the concentrations of 2,4-D and kinetin and the sugar supplements (sucrose and sorbitol) on callus induction and plant regeneration have been and continue to be evaluated. We have successfully regenerated several hundred plants representing the rice genotypes Alan, Katy, LaGrue, RU9101001 and RU9201191 (Al-Khayri and Anderson, 1994, 1995). These genotypes were chosen based on the recommendation of Arkansas Rice Research and Extension Center breeders because they are either commercial cultivars or germplasm lines that exhibit a good potential for the production of new cultivars. Other genotypes selected with the same criteria are currently being investigated.

Screening for Disease Resistance through Somaclonal Variation

Plants regenerated by tissue culture techniques may vary from the explant donor in some characteristics. This genetic variability, termed somaclonal variation, occurs through spontaneous mutations during the culturing procedures or as a result of chemical or radiation treatments. Through collaborative efforts, we have screened regenerated rice plants as possible somaclonal variants for resistance to rice diseases. Regenerants were challenged with spore inoculations of the sheath blight fungus, maintained in controlled-environment growth chambers and examined for resistance to the pathogen. To date, no resistant plants have been identified, but efforts in this area are continuing.

Genetic Transformation of Arkansas Rice

The genetic modification of crops has undergone a revolution since the development of genetic transformation technology. We are working to develop a reliable transformation system for several rice cultivars and breeding lines using the microparticle bombardment technology. Our aim is to deliver and incorporate foreign genes into the rice genome for improved disease resistance and other important agronomic traits. This work builds on the regeneration procedures and depends on the identification and availability of genes from other plant and microbial sources.

We are making progress toward this goal. Our investigations have resulted in the production of rice callus that survived on a kanamycin-containing medium, indicating that a genetic transformation event had occurred. The transformation was confirmed with X-Gluc assay in which the development of a blue color indicated that the GUS enzyme was being transiently expressed. Enzyme expression was observed in several calli, but transformed plants have not yet been regenerated from these tissues. We are continuing to investigate and manipulate the parameters necessary to achieve a high-frequency, stable transformation for several Arkansas rice genotypes.

SIGNIFICANCE OF FINDINGS

Through the support of the ARRPB, our own efforts and the collaborations that have been established with other researchers* within the University of Arkansas system, the goals set forth for this year have been accomplished. Seeds from several Arkansas rice cultivars and breeding lines were induced to proliferate callus from which whole plants have been regenerated. To our knowledge, this is the first report of successful regeneration of these rice genotypes. Regenerants were entered into a screening program for evaluation of possible somaclonal variations that may engender resistance to sheath blight. To this point, no resistant plants have been identified. Because the variants arise through mutation, screening a large number of regenerants is necessary to identify resistant individuals. We are continuously producing new regenerants for evaluations.

Transient gene expression was obtained when rice callus was bombarded with a plasmid harboring the marker genes for β-glucuronidase and the neomycin phosphotransferase II. To our knowledge, this is the first report of transient expression of a transgenes in cells derived from Arkansas rice.

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*Our collaborators are R.D. Cartwright, Research Assistant Professor, Plant Pathology, Fayetteville; K.K. Moldenhauer, Professor, Agronomy, Stuttgart; K.A. Gravois, Assistant Professor, Agronomy, Stuttgart; F.N. Lee, Professor, Plant Pathology, Stuttgart.

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RICE GROWTH RESPONSE TO WATER SEEDING

C.A. Beyrouty, R.J. Norman and E.E. Gbur

ABSTRACT

Plant response to water seeding was compared to that to dry seeding. Water-seeded rice was 13 to 25% taller and produced 30 to 68% more shoot dry weight than dry-seeded rice between maximum tillering and milk stage. Although grain yields were not affected by water seeding, head rice yield of water-seeded 'Lacassine' was significantly lower than that of water-seeded 'Katy' or dry-seeded Katy and Lacassine. Nitrogen timing as a three-way split or a single application prior to flooding had little effect on plant response except plant height. Thus it would appear that water seeding may be a viable water management technique for rice production, as long as appropriate cultivars are selected.

INTRODUCTION

Water seeding is being viewed as a fairly common management practice in Arkansas. A preliminary study last year showed that morphological changes in water-seeded rice do occur but that grain yields are comparable to those of dry-seeded rice. Because of these morphological changes, fertilizer and pest management practices may need to be adjusted. Consequently, a field study was initiated in order to more fully quantify the shoot and root growth changes in rice that follow water seeding and to determine the significance of these changes in altering traditional management of rice.

PROCEDURES

A field study was conducted to identify the growth and yield response of rice to two planting treatments: dry seeding and water seeding. Two cultivars ('Katy' and 'Lacassine') were either dry seeded or water seeded on a Crowley silt loam at the Rice Research and Extension Center near Stuttgart, Arkansas. All plots were 32 ft long and approximately 5.3 ft wide. This provided nine rows spaced 7 in. apart in the dry-seeded rice. Rice was drill seeded at a rate of 110 lb/acre. Recommended practices for timing of the application of the flood water for dry-seeded rice were followed. A drill was initially passed through non-flooded plots designated for water seeding to provide depressions for seed broadcast into standing water. Prior to water seeding, plots were flooded to 5 cm, and seed placed in mesh bags were submerged in buckets for 24 hours to initiate germination. Pregerminated seed was hand broadcast into flooded plots at a rate that was 20% greater than for dry-seeded rice. It was anticipated that lower emergence would result from poorer soil contact by water seeding. Final stand counts were about 30% greater for water-seeded rice than for dry-seeded rice. Following water seeding, the floodwater was removed until seedling emergence, after which the flood was re-applied. Subsequent floodwater management paralleled that for the dry-seeded rice. Urea nitrogen was applied as either a single preplant incorporation to the water-seeded rice and pre-flood to the dry-seeded rice or a three-way split application to the water- and dry-seeded rice. Rates of N recommended for the two rice cultivars were applied. Measurements of plant height, leaf area, shoot dry weight and root length were made at maximum tillering, 0.5-in. internode elongation, heading and milk stage.

RESULTS AND DISCUSSION

Grain yield was not affected by either planting treatment or N management. Only cultivar affected yields. Lacassine yielded an average of 7358 lb/acre and Katy 6815 lb/acre. Total milled rice yields were 68 to 69% and did not differ among treatments. Head rice yields were affected by planting treatment but not by N timing. Dry-seeded Katy and Lacassine and water-seeded Katy had head rice yields between 62 and 63%. Head rice yield for water-seeded Lacassine was 57%. Total shoot dry weight was affected by seeding and growth stage but not cultivar or N treatment. Shoot dry weight was 30 to 68% greater for water-seeded rice than for dry-seeded rice (Fig. 1). Differences were greatest at maximum tillering and progressively decreased by milk stage. Tiller formation was also affected by water management. Dry-seeded rice produced 58% more tillers by internode elongation stage than did water-seeded rice. No differences in tiller formation were observed at the other stages of development, however. Water-seeded rice was 25% taller than dry-seeded rice at maximum tillering and 13% taller at heading (Fig. 2). No differences were measured by milk stage. Nitrogen timing also affected plant height. Plant height of water-seeded rice exposed to a single application of N averaged 86 cm in contrast to 79 cm for water-seeded rice exposed to a three-way split. Plant height of dry-seeded rice averaged 72 cm for both N timing treatments.

Water-seeded rice produced more total root length than dry-seeded rice up to heading. By milk stage, however, root length of the water- and dry-seeded rice were similar. The pattern of root length development was similar for both water- and dry-seeded rice. Maximum root length was measured at heading with a reduction in root length at milk stage. Consequently, although total root length was affected by seeding management, the pattern of root development was not. Thus, it would appear that N management may not have to be altered to accommodate water-seeded rice.

SIGNIFICANCE OF RESULTS

Results from this first-year study showed that water seeding resulted in plants that were taller and produced more shoot biomass up to heading. Differences in shoot morphology became insignificant by milk stage. Although grain and milled rice yields were not affected by seeding or nitrogen timing, head rice yields of water-seeded Lacassine were reduced. Consequently, water seeding appears to be a viable alternative management practice that might be incorporated into the rice production scheme; however, it appears that cultivars may respond differently to water seeding. Thus, research must evaluate this practice for the major cultivars grown in Arkansas.

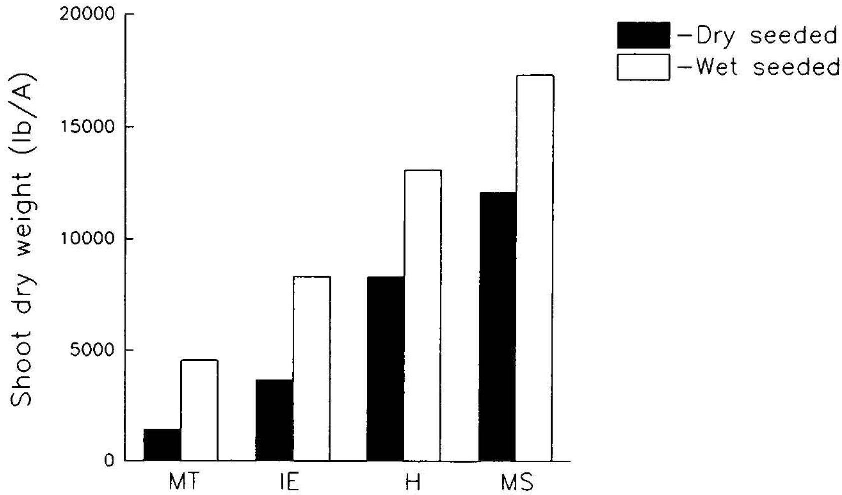

Fig. 1. Shoot dry weight response at four stages of development to water and dry seeding. MT = maximum tillering; IE = 0.5-in. internode elongation; H = heading; MS = milk stage.

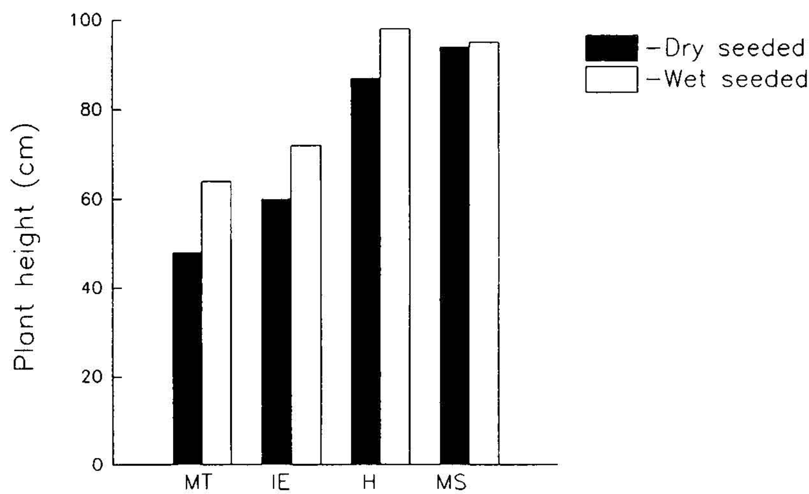

Fig. 2. Plant height response at four stages of development to water and dry seeding. MT = maximum tillering; IE = 0.5-in. internode elongation; H = heading; MS = milk stage.

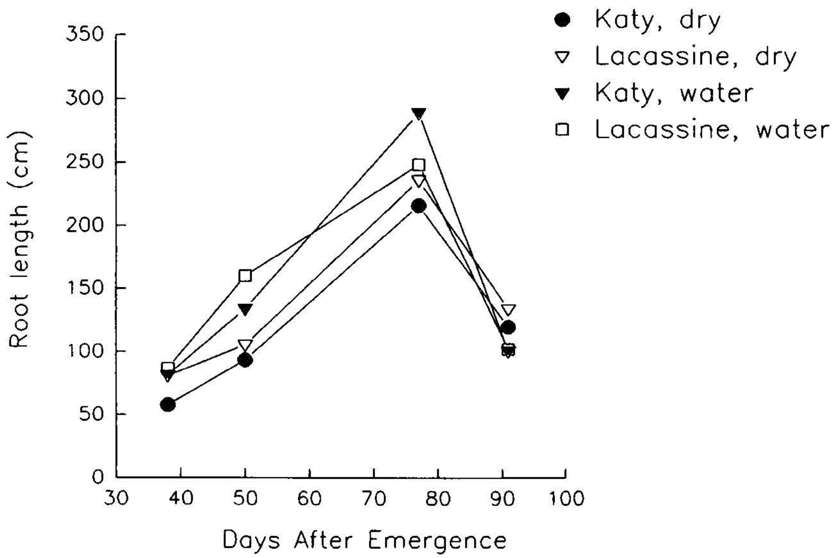

Fig. 3. Root length of water- and dry-seeded rice. MT = maximum tillering; IE =0.5-in. internode elongation; H = heading; MS = milk stage.

SALINITY EFFECTS ON SOIL CHEMISTRY, POTASSIUM UPTAKE AND RICE PRODUCTION

C.E. Wilson, Jr., D.B. Stephens, C.A. Beyrouty and D.M. Miller

ABSTRACT

In a laboratory experiment, effects of repeated additions of salinized water to a soil were evaluated. Salinized water with an EC of 0.77 dS/m was added to a Crowley silt loam every 3 to 4 days for a total of 14 additions. As a comparison, single additions of 2.31, 4.62, 6.93 and 9.24 dS/m salinized water were added to other soil samples. Resultant soil EC's from the repeated additions of salinized water were comparable to the soil EC's from the single additions of salinized water. Therefore, the rate of salinization of soil can be predicted from the EC of the water added. Two rice cultivars, a salt-tolerant genotype, 'Jasmine 85', and a salt-sensitive genotype, 'Newbonnet', were selected to evaluate K uptake response to salinity. A study was conducted to select an appropriate nutrient solution for future hydroponic salinity studies. It was observed that in a solution containing elevated levels of Na, Jasmine shoot tissue contained 54% more Na than Newbonnet, slightly depressed levels of N, S and Fe and a three-fold increase in Zn. Kinetic uptake parameters influencing K uptake by rice in saline solutions are being evaluated. Initial results suggest that under non-saline conditions, Newbonnet appears to absorb K at a faster rate than Jasmine 85. Results from a field study showed that P and poultry litter increased rice plant dry matter on saline soils; however, grain yields were not influenced by either P or poultry litter applications. Soil samples collected from these fields show that about 30% of the added chloride remained within the top 36 in. of the soil profile, and the remainder of the applied salt had probably been lost by leaching or surface runoff.

INTRODUCTION

The occurrence of salinity continues to be a problem for Arkansas rice producers. High salt concentrations in soils and irrigation water can affect plant development and reduce crop yields. Research has shown that rice cultivars are sensitive to salinity, especially at the seedling stage. Understanding the interaction between the salt and essential nutrients for rice growth will give a more fundamental knowledge of the salinity problem. Studies on the impact of repeated applications of saline irrigation water will help determine the severity of the salinity problem for the future. Research involving preplant application of phosphorus and poultry litter may help to reduce the growth-inhibiting effects from soil salinity and provide management strategies that reduce the effects of salinity and optimize grain yields.

MATERIALS AND METHODS

Experiments were conducted in the laboratory to gain a better understanding of plant and soil response to salinity and in the field to evaluate methods of ameliorating saline soils.

Laboratory Experiments

Experiment 1. The effects of repeated additions of salinized water to a soil were evaluated. At the Rice Research and Extension Center near Stuttgart, Arkansas, samples of Crowley silt loam were collected to a depth of 15 cm, dried, ground and sieved to 2 mm. In the laboratory, salt solution consisting of equal concentrations of NaCl and $CaCl_2$ with an EC of 0.77 dS/m was added to 50 g of soil to make a saturated paste. Following the addition of the salinized water, the soil was allowed to dry under heat lamps at 30 C for 3 to 4 days. Resultant soil EC was measured by a 1:2 soil to solution ratio with a conductance meter. This process was repeated for a total of 14 applications with measurement of soil EC after each salt addition. As a comparison to the repeated additions, a single addition of salinized water containing equal concentrations of $CaCl_2$ and NaCl with EC's of 2.31, 4.62, 6.93 and 9.24 dS/m were added to soil samples. These EC's corresponded to 3, 6, 9 and 12 additions of the salinized water with an EC of 0.77 dS/m used in the repeated addition study.

Experiment 2. A preliminary study was conducted to select an appropriate nutrient solution for hydroponic salinity studies. Several modifications of a rice nutrient solution suggested by the International Rice Research Institute were tested. Two rice genotypes, 'Newbonnet', a salt-sensitive rice cultivar, and 'Jasmine 85', a salt-tolerant rice cultivar, were grown in the modified nutrient solutions for eight weeks. Plants were harvested and shoot tissue analyzed for cation uptake.

Experiment 3. Preliminary nutrient depletion studies have been conducted on Jasmine 85 and Newbonnet in a growth chamber to evaluate K uptake response to the presence and absence of salinity. Seedlings of each genotype were germinated for 10 to 12 days and placed in quarter-strength (25% concentration of standard) nutrient solution. At the three-leaf stage, seedlings were placed into full-strength (standard) nutrient solution. Rice was grown for 56 days prior to the initiation of the depletion study. After 24 hours of starving the plant of K^+, plants were placed in a solution containing a low concentration of K, and the solution was sampled continuously for a period of 10 hours. Potassium concentration in the solution samples was measured by atomic absorption spectrophotometry. Kinetic uptake parameters that describe K uptake were obtained from these measurements. Measurements of root length, fresh weight, dry weights and tissue analyses were obtained for all plants and will be used to calculate K influx kinetic parameters.

Field Studies

Experiment 4. An experiment was conducted at the Southeast Research and Extension Center near Rohwer, Arkansas, during the 1994 growing season to evaluate the effects that poultry litter and phosphorus (0-46-0) fertilizer have on rice grown on saline soils. Three salt levels were evaluated. The salts were added in 1991, 1992 and 1993. No salt was added during 1994 because it was believed that the salinity levels should be sufficient to evaluate the various treatments. The test was arranged in a split plot design with the level of induced salinity as the main plot and the poultry litter and phosphorus treatments as the subplots. Six rates of fresh poultry liter applied were 0, 250, 500, 1000, 2000 and 4000 lb poultry litter/acre. Four rates of P fertilizer were 0, 40, 60 and 80 lb P_2O_5/acre. The P and poultry litter were broadcast and lightly incorporated. Plots were established by drill seeding 'Lacassine' rice into 15-ft rows on 6-in. spacings. Stand density was determined at the three- to four-leaf growth stage. Plant samples were collected 7 days after flooding, and grain yields were measured at maturity.

Experiment 5. Core soil samples were collected from the test area described above to monitor the location of the salt and to estimate the amount of salt removed from the soil profile. Two-inch soil cores were collected to a depth of 36 in. the spring of 1992, 12 in. in the spring of 1993, 24 in. in the spring of 1994 and 36 in. in the fall of 1994 following the rice crop. The samples were collected and analyzed in 6-in. depth increments for chloride, nitrate and sulfate.

RESULTS AND DISCUSSION

Laboratory Experiments

Experiment 1. Resultant soil EC's from the sequential additions of salinized water were compared to the soil EC response to single additions (Fig. 1). The soil EC responded similarly to repeated and single additions of salinized water. The rate of salinization of the soil can be predicted from the total EC of the water that is added, either as a one-time application or as multiple applications, if the leaching fraction, or amount of loss from the soil profile, is known.

Experiment 2. Visually, the Jasmine 85 plants showed a burning of the leaf margins and tips in the nutrient solution containing high concentrations of Na, suggesting that Jasmine 85 was more sensitive to Na, although burning of the leaf tips is a typical growth characteristic of the Jasmine genotype even under non-saline conditions (Dr. Wells, personal communication). Shoot tissue analysis showed that Jasmine tissue contained 54% more Na and a three-fold increase in Zn and slightly increased Ca tissue concentrations compared to Newbonnet. Jasmine also had a 10, 15 and 40% reduction in N, S and Fe shoot tissue concentrations, respectively, compared to Newbonnet. Thus, it would appear that Jasmine may selectively absorb Na under conditions of elevated Na solution concentrations, resulting in changes in uptake of other nutrients.

Experiment 3. Initial depletions suggest that, under non-saline conditions, Newbonnet appears to absorb K from solution at a faster rate than Jasmine 85 (Fig. 2). The approximate depletion rate for the first 330 minutes was 0.126 µmol/L/min for Jasmine 85 and 0.146 µmol/L/min for Newbonnet. Nearly complete depletion of K required about 330 minutes for Newbonnet and 450 minutes for Jasmine 85. Additional depletions are being conducted to obtain K kinetic uptake parameters for these rice cultivars grown in the presence and absence of 25 and 50 mol/m^3 of chloride applied as 100/0, 50/50 and 0/100 mixtures of Na and Ca, respectively.

Field Studies

Experiment 4. The salinity effects were not as severe on the growth of field-grown rice as anticipated from the amount of salts applied in recent years (Table 1). Stand density was significantly reduced by increasing levels of salinity. The shoot dry matter measured 7 days after flooding (DAF) was significantly reduced with increasing salinity. Although a trend for decreased grain yields existed for the highest salt rate, the yields were not different with the different salt treatments.

A significant response to poultry litter was measured in plant dry matter 7 DAF (Table 2). However, application of poultry litter did not significantly influence grain yields. The P treatments also increased plant dry matter (Table 3). However, the grain yields were not influenced by P applications. Previous data suggested that poultry litter was inconsistent as an amendment to improve rice production on saline soils (Miller et al., 1994; Wilson et al., 1994). However, other experiments (N. Slaton et al., unpublished data, 1994) suggest that P has some potential for reducing the effects of salinity, particularly when potassium fertilizers are applied to saline soils.

Experiment 5. Chemical analyses of all of the soil samples taken from the treated field plots are not yet complete. However, partial results from two 1994 sample dates are presented (Table 4). During the spring of 1994, approximately 35 to 40% of the total chloride applied over the previous 3 years was recovered within 24 in. of the soil surface for both the 1-ton and 2-ton salt rates. During the fall of 1994, approximately 39 to 58% of the chloride was recovered within the top 36 in. of soil. These data illustrate the variability of the salinity levels at a particular depth as a function of time. Salts move as the soil water content changes. These data indicate that less than 60% of the chloride applied over a three-year period remained within the top 36 in. of the soil profile within one year after the last application. The remainder of the applied chloride has either moved below the 36-in. depth or been lost by surface runoff.

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2. Wilson, C.E., Jr., D.M. Miller, P.A. Moore, Jr., R.J. Norman and B.R. Wells. 1994. Influence of soluble salt on rice production. *In* B.R. Wells (ed.). Ark. Rice Res. Studies 1993. Ark. Agr. Exp. Sta. Res. Ser. 439:151-157.

Table 1. Influence of applied salt (NaCl) on rice stand density, plant dry matter 7 days after flooding (DAF), and grain yields.

Salt Treatment	Stand Density	Plant Dry Matter (7DAF) Shoot	Root	Total	Grain Yield
	plt/ft²	---------------	g ft²	---------------	lb/acre
Control	17	18.3	6.9	25.2	5593
1 ton/acre/year	15	13.6	5.4	19.0	5525
2 ton/acre/year	6	--[z]	--	--	5081
$LSD_{(0.05)}$	3	4.4	3.6	8.0	n.s.[y]

[z]Data not collected
[y]n.s. = non significant

Table 2. Influence of poultry litter applications to rice produced on saline soils.

Litter rate	Stand Density	Plant Dry Matter Shoot	Root	Total	Grain Yield
	plt/ft²	---------------	g ft²	---------------	lb/acre
0	12	12.8	4.9	18.6	5360
250	13	15.3	6.0	23.0	5137
500	13	15.8	5.6	23.1	5599
1000	14	18.0	7.2	26.5	5543
2000	12	16.6	6.5	24.0	5585
4000	13	17.2	6.9	25.1	5197
$LSD_{(0.05)}$	n.s.[z]	2.5	1.5	4.0	407

[z]n.s. = non significant

Table 3. Influence of phosphorus applications to rice grown on saline soils.

Phosphorus Treatment	Stand Density	Plant Dry Matter Shoot	Root	Total	Grain Yield
	plt/ft²	---------------	g ft²	---------------	lb/acre
0	12	15.2	5.5	21.8	5461
40	12	14.6	5.6	21.3	5239
60	14	17.3	6.9	25.9	5338
80	13	16.6	6.6	24.0	5560
$LSD_{(0.05)}$	n.s.[z]	2.0	1.2	3.2	332

[z]n.s. = non significant

Table 4. Chloride retention according to depth in the soil profile following three applications of either 1 ton NaCl/acre/year (1 TON) or 2 ton NaCl/acre/year (2 TON).

Soil depth	Spring 1994 1 TON	Spring 1994 2 TON	Fall, 1994 1 TON	Fall, 1994 2 TON
in.	-------------	% of applied Cl^-	-------------	
0-6	5.9	13.8	14.1	10.2
6-12	8.9	10.6	10.7	10.4
12-18	10.8	9.6	11.1	7.1
18-24	9.3	6.6	8.8	7.1
24-30	--[y]	--	7.5	4.5
30-36	--	--	6.0	4.9
TOTAL	34.9	40.6	58.2	39.3

[y]Data not collected.

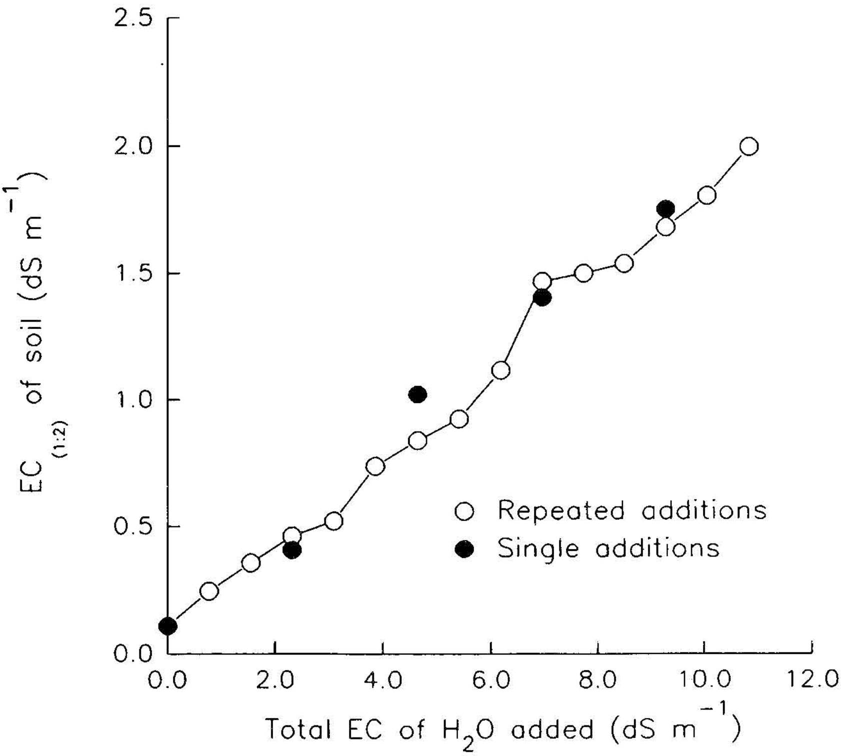

Fig. 1. Electrical conductivity ($EC_{1:2}$) of soil vs the electrical conductivity of the salinized water.

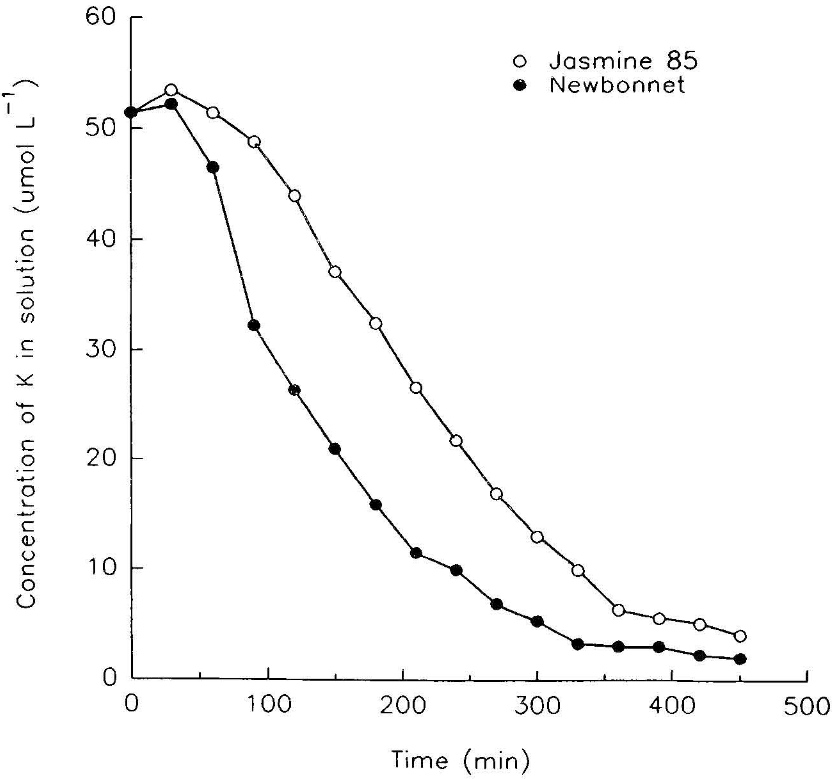

Fig. 2. Depletion curve for 'Jasmine 85' and 'Newbonnet' cultivars.

DEVELOPMENT OF THE DD50 DATABASE FOR NEW RICE CULTIVARS

B.R. Wells, R.J. Norman, K.A. Gravois, R.S. Helms and K.A.K. Moldenhauer

ABSTRACT

The DD50 computer program, to be effective, must be continually updated as new cultivars are named and released. We conduct studies each year to develop data for promising new lines. The 1994 study, conducted on a Crowley silt loam at the U of A Rice Research and Extension Center, Stuttgart, Arkansas, included two seeding methods (drill and water), two seeding dates and three replicates. The drill-seeded study included 11 cultivars/lines; the water-seeded study contained eight of the most common cultivars. Data from this study will be combined with data from previous years to formulate updated threshold values for the 1995 DD50 computer program.

INTRODUCTION

The DD50 computer program has been one of the most successful programs developed by the University of Arkansas Division of Agriculture. At present, approximately 70% of the Arkansas rice farmers utilize this program as a management tool in rice production. The program requires data for all cultivars grown on significant acreage in Arkansas with plant development based on accumulation of DD50 units from date of seedling emergence. These data are developed by conducting studies that include all promising new rice lines for two to three years prior to naming and releasing the line as a rice cultivar. When the new cultivar is released to farmers, the data developed from these studies are used to provide threshold DD50 values for the computer program. Therefore, the objective of this study is to develop databases for promising new rice lines, to verify databases for existing cultivars and to assess the effect of seeding date on DD50 accumulations. Additional studies are being conducted to determine if we need to add a water-seeded database to the program.

MATERIALS AND METHODS

The 1994 study was conducted at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas, on a Crowley silt loam soil. Eleven cultivars/lines were seeded in the drill-seeded portion of the study on 14 April and 11 May. Eight cultivars were seeded on 18 April and 13 May in the water-seeded study. The rice was seeded at a rate of 100 lb/acre in nine row plots (7-in. spacing), 15 ft in length. The design of the experiment for each study and seeding date was a randomized complete block with three replications. The cultural practices were as normally conducted for either drill- or water-seeded rice culture. Data collected included maximum and minimum daily temperatures, length of elongating internodes at 3-day intervals beginning 35 days after seedling emergence, date of 50% heading and grain yields at maturity. The temperature data were then converted into DD50 accumulations from seedling emergence until the specific developmental stage of interest.

RESULTS AND DISCUSSION

Cultivars included in both the drill- and water-seeded studies included 'Adair', 'Bengal', 'LaGrue', 'Alan', 'Katy', 'Kaybonnet' and 'Maybelle'. Also included in the drill-seeded study were several promising experimental lines that are likely to be released as cultivars within the next two or three years plus the new cultivar, 'Jodon', released in 1994 from the LSU Experiment Station. 'Cypress' was included in the water-seeded study but not in the dry-seeded study. Degree day accumulation from seedling emergence to internode elongation (0.5 in.) varied with cultivar and method of seeding (Table 1). The 1994 results differed from those for 1993 in that water seeding in 1993 resulted in significantly lower accumulation of DD50 units from emergence to internode elongation than for drill seeding for LaGrue, Maybelle and Katy with similar trends occurring for several of the other cultivars. This did not occur in the 1994 study. This 1993 difference may have resulted from higher average temperatures at the growing point of the rice plants during seedling development when the flood was in place with the water-seeded rice but not for the drill-seeded rice in 1993. Date of seeding had a much greater effect under dry seeding as compared to water seeding in 1994 with lower accumulations of DD50 units occurring when rice was drill seeded in May as compared to April dry seeding or either date for water seeding.

Degree day accumulations from seedling emergence to heading varied mainly among cultivars with only minor differences across date or method of seeding within a cultivar (Table 2). There was a trend to lower accumulations of DD50 units under dry seeding culture for the May seeding date as compared to the April seeding date.

Several of the cultivars had very high grain yields under both dry- and water-seeded cultural systems (Table 3). Maybelle tended to have the lowest yields of any entry across both seeding dates for the dry-seeded system and for the April seeding under water seeding. Statistical comparisons between methods of seeding and dates of seeding cannot be made for grain yields as these were separate tests; however, yields appeared to be highest with drill seeding across both seeding dates. This may have been the result of our limited experience with water seeding.

SIGNIFICANCE OF THE FINDINGS

Data from this study combined with data from the 1993 study indicate only limited differences in DD50 accumulations for a given cultivar between dry and water seeding cultures. Therefore, for most rice cultivars, the existing DD50 database can be used for either water or dry seeding. Maybelle and LaGrue have shown variations in DD50 accumulations between dry- and water-seeding cultures; however, these differences were not consistent between 1993 and 1994, so additional years of data will be necessary to determine if separate databases are needed for these two cultivars.

Table 1. Degree Day accumulations from emergence to internode elongation as influenced by cultivar, method of seeding and date of emergence, Rice Research and Extension Center, Stuttgart, Arkansas, 1994

	Drill Seed		Water Seed	
Variety/Line	26 April[z]	18 May	24 April	18 May
	DD50 units			
Adair	1312	1097	1254	1282
Bengal	1343	1191	1378	1344
LaGrue	1218	1066	1160	1221
Alan	1095	1066	1160	1191
Kaybonnet	1281	1129	1285	1221
Maybelle	1188	1066	1192	1221
Katy	1373	1221	1378	1376
Cypress	--	--	1192	1191
RU9201176	1312	1191	--	--
RU9201179	1373	1191	--	--
RU9201191	1312	1161	--	--
Jodon	1218	1097	--	--

[z]Emergence dates

Table 2. DD50 accumulations from emergence to heading as influenced by cultivar, method of seeding and date of seedling emergence, Rice Research and Extension Center, Stuttgart, Arkansas, 1994

	Drill Seed		Water Seed	
Variety/Line	26 April[z]	18 May	24 April	18 May
	DD50 units			
Adair	2029	1953	1898	1996
Bengal	2147	2099	2242	2128
LaGrue	2179	1974	1898	1996
Alan	2058	1926	1868	2071
Kaybonnet	2207	2019	2036	2071
Maybelle	1863	1721	1744	1721
Katy	2236	2157	2123	2234
Cypress	--	--	2009	2185
RU9201176	2266	2099	--	--
RU9201179	2266	2071	--	--
RU9201191	2297	2128	--	--
Jodon	2117	1974	--	--

[z]Emergence dates

Table 3. Grain yields as influenced by cultivar, method of seeding and date of emergence, DD50 study, Rice Research and Extension Center, Stuttgart, Arkansas, 1993.

	Drill Seed		Water Seed	
Variety/Line	26 April[z]	18 May	24 April	18 May
	---------lb/acre---------			
Adair	8107	6869	6948	5887
Bengal	7917	7339	6754	6191
LaGrue	7410	8021	7029	5778
Alan	7377	7320	5934	5837
Kaybonnet	7174	7724	6634	4557
Maybelle	6632	6438	4884	6039
Katy	7538	6510	5741	5763
Cypress	--	--	6351	5295
RU9201176	7579	6717	--	--
RU9201179	8434	7928	--	--
RU9201191	7961	7490	--	--
Jodon	8109	7936	--	--
$LSD_{(0.05)}$	828	1540	1288	1918
C.V. (%)	6.35	12.38	11.70	19.32

[z]Emergence dates

MANAGEMENT OF AGRONOMIC FACTORS IN RICE PRODUCTION

R.J. Norman, C.E. Wilson, Jr., B.R. Wells, S. Ntamatungario, N.A. Slaton, K.A. Gravois and K.A.K. Moldenhauer

ABSTRACT

The cultivar x nitrogen (N) fertilizer interaction study is an ongoing project in the rice soil-fertility research program. This study determines the proper N fertilizer rates for the new cultivars across the array of soil and climatic conditions that exist in the Arkansas rice growing region. The two new cultivars, 'Jodon' and 'Kaybonnet', produced similar grain yields when the N fertilizer was applied in a single preflood (SPF) compared to a three-way split application (3WS). Both produced maximum grain yields when 90 to 120 lb N/acre was applied at most locations except the Northeast Research and Extension Center, Keiser, Arkansas, when higher N rates were required. In general, the three experimental rice lines studied showed a preference for the N fertilizer to be applied in a SPF compared to the 3WS application. Two years of research on the evaluation of the diagnostic methods for assessing the N status of the rice plant during the vegetative growth stage clearly shows that the plant area method ('Rice Gauge') is superior to the SPAD Meter and the Y-leaf N concentration methods. A ^{15}N-tracer study conducted in Arkansas and Louisiana found that the uptake of N at midseason is dependent on the preflood N uptake. Consequently, if the preflood N is not taken up adequately and efficiently, the midseason N will not be either. Thus, one of the reasons that midseason N cannot make up for poor preflood N uptake is that its uptake is dependent on how much preflood N is taken up.

INTRODUCTION

The major strength of the rice-soil fertility research program has been the delineation of N fertilizer response curves for the promising new rice cultivars. This study determines the proper N fertilizer rates for the new cultivars across the array of soils and climatic conditions that exist in Arkansas. Promising new rice selections from breeding programs in Arkansas, California, Louisiana, Mississippi and Texas are entered into this study. The Arkansas breeding program has the new long grain, blast-resistant cultivar 'Kaybonnet' plus three experimental rice lines, RU9201176, RU9201179 and RU9201191, in the study. In addition, the Louisiana program has a new semidwarf, long grain cultivar, 'Jodon', included in the study this year.

An accurate method to monitor the N status of the rice plant during the vegetative and early reproductive growth stages has been sought for quite some time. Several diagnostic methods have been proposed over the years and have seen some limited use. The most viable methods used to date are the Y-leaf N concentration, the plant area ('Rice Gauge') and the chlorophyll content (SPAD Meter) methods. Comparisons among these methods have not been made, and the objective of this study was to evaluate and compare these methods.

Newer rice cultivars do not respond the same to midseason N applications as their predecessors. Consequently, researchers in Louisiana and Arkansas developed a joint project to evaluate the uptake of midseason N by one of the new rice cultivars as influenced by preflood N rate, midseason N rate and midseason N application time.

PROCEDURES

Locations where the cultivar x N rate study was conducted and corresponding soil type are as follows: Rice Research and Extension Center (RREC), Stuttgart, Arkansas, Crowley silt loam (Typic Albaqualf); Northeast Research and Extension Center (NEREC), Keiser, Arkansas, Sharkey clay (Vertic Haplaquept); Pine Tree Experiment Station (PTES), Colt, Arkansas, Calloway silt loam (Glossaquic Fragiudalf); and the Southeast Branch Experiment Station (SEBES), Rohwer, Arkansas, Perry Clay (Vertic Haplaquept). Jodon and Kaybonnet were studied at the four locations, but because of limited seed, the three experimental rice lines (RU9201176, RU9201179, RU9201191) were studied only at RREC. The experimental design was a split-plot with three replications. The main plot was application method, and the subplot was N fertilizer rate. The two N application methods used were a single preflood (SPF) and the recommended three-way split application (3WS) method. Nitrogen fertilizer rates used were 0, 60, 90, 120, 150 and 180 lb N/acre. The rice was drill seeded at a seeding rate of 100 lb/acre in nine-row plots (row spacing of 7 in.), 15 ft. in length. All plots were flooded at each location when the rice was at the four- to five-leaf stage and 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 lb/acre at 12% moisture. Statistical analyses were conducted with SAS, and mean separations were based upon LSD where appropriate.

The diagnostic N methods were studied at RREC in 1993 and 1994. Rice was seeded into 9-row plots of 22 ft x 5 ft with a row spacing of 7 in. in both years. The N fertilizer treatments were arranged in a split-plot design. The main plot was a factorial combination of rates of preflood N (0, 30, 60, 90, 120 lb N/acre) with midseason N (0, 60 lb N/acre) applications. The subplot treatments were the cultivars ('Lacassine' and 'LaGrue'). The rice plants were sampled weekly, beginning 1 week after the preflood N application, until heading and biweekly after heading for 3 weeks. Plant dry matter above the ground was measured for a 3-ft row. Nitrogen concentration was determined on 40 Y-leaves and on the total plant (stems, leaves, panicles). At each sampling time, plant area and chlorophyll meter readings were measured. Plant area was measured with the 'Rice Gauge'. Chlorophyll readings were obtained with a Minolta SPAD meter 502. Plant and leaf samples were dried at 65 C and ground to pass a 1-mm sieve for N analysis by a LECO analyzer. Linear correlation coefficients (r) were determined by using the PROC CORR procedure in SAS (SAS Institute, 1985). Analysis of variance procedures were performed by the PROC GLM procedure utilizing PC-SAS to evaluate the preflood N, midseason N and cultivar effects.

Evaluation of the midseason N uptake by one of the newer rice cultivars (Lacassine) was conducted at RREC and at the Louisiana Rice Station, Crowley, Louisiana. The experimental design was a split plot with three replications. The main plot was preflood N rate (0, 60 and 120 lb N/acre as urea, nonlabeled), and the subplot was midseason N treatment. The midseason N treatments consisted of application of ^{15}N-labeled urea (2 atom% ^{15}N) in a single application of 60 lb N/acre at panicle initiation (PI) or panicle differentiation (PD) or split applications of 30 lb N/acre at PI and PI + 10 days, or PD and PD + 10 days. Microplots (76 X 76 cm) were bordered with galvanized steel collars. Experimental parameters measured were total N experiment uptake, fertilizer ^{15}N uptake, total dry matter and grain yield. Statistical analyses were conducted with SAS, and mean separations were based upon LSD where appropriate.

RESULTS AND DISCUSSION

Response of the new rice cultivars to the preflood N fertilization resulted in the addition of a SPF N application in the rice cultivar x N starting in 1993. The new semidwarf cultivar, Jodon, responded similarly at all locations when the N fertilizer was applied in a SPF or in a 3WS application (Table 1). In addition, there was no interaction between application method and N rate. Consequently, data from the two methods were pooled and analyzed together. The influence of N fertilizer rate on Jodon grain yields is shown in Table 2. Jodon reached peak grain yields when 90 to 120 lb N/acre was applied at PTES, RREC and SEBES. However, at NEREC, 150 lb N/acre had to be applied before grain yields of Jodon no longer increased significantly.

Kaybonnet, a new blast-resistant, long-grain cultivar, reacted similarly when the N fertilizer was applied in a SPF or in a 3WS application (Table 3). There was no interaction between application method and N rate; therefore, data from the two application methods were pooled and analyzed together. Table 4 shows the influence of N fertilizer rate on grain yields of Kaybonnet rice at the four locations. Kaybonnet grain yields showed no significant increase when more than 90 lb N/acre was applied at PTES and RREC and when more than 120 lb N/acre was applied at SEBES. Like Jodon, Kaybonnet required more N fertilizer (150 to 180 lb N/acre) to reach peak grain yields at NEREC than at the other locations.

The three experimental rice lines, RU9201176, RU9201179 and RU9201191, were studied only at RREC because of a limited amount of seed. The three rice lines did not respond significantly better to one application method over the other across all N fertilizer rates (Table 5). In general, when data from both application methods were combined, all three experimental varieties had top grain yields when 120 lb N/acre was applied (Table 6). Rice lines RU9201176 and RU9201191, however, had a significant interaction between application method and N fertilizer rate (Table 7). Both lines showed a preference for the SPF application method by displaying a trend towards obtaining peak grain yields with 30 lb/acre less N with the SPF compared to the 3WS application method. Similarly, rice line RU9201179 had a tendency to favor the SPF application method.

The research on the evaluation of the diagnostic methods for determining the N status of the rice plant during the vegetative and early reproductive growth stages is beginning to produce some interesting data. The linear relationships between the various parameters of N status are shown in Tables 8 and 9. Plant area correlated highly with dry matter in 1993, displaying r values of 0.813, 0.775 and 0.746 at 41, 55 and 62 days after emergence (dae), respectively (Table 8). There is no explanation available for the low r value of 0.530 (expected to be between 0.7 and 0.8 in this study) at 48 dae. In 1994, the r values were 0.862, 0.842 and 0.741 at 41, 48 and 55 dae, respectively. SPAD readings showed the closest relationship with leaf N concentration, resulting in r values of 0.914 and 0.737 in 1993 at 41 and 48 dae, respectively, and in 1994, 0.883 and 0.665 at 41 and 48 dae, respectively. The r values tended to become low at 62 dae in both years. The linear relationships between SPAD readings and leaf N concentration and between SPAD readings and plant N concentration followed the same pattern.

The coefficients of linear correlation between total N uptake and the other parameters of plant N status were significant (Table 9). Plant area correlated highly with total N uptake ($r > 0.7$) during the period from 41 to 62 dae in 1993 and 1994. This was true also with the r values between total N uptake and dry matter or plant N concentration. However, the r values between total N uptake and SPAD readings were high only at 41 or 48 dae. Similarly, the r values for the Y-leaf N concentration method were high only at 41 and 48 dae in 1993 and at 41 dae in 1994. This indicates that the plant area method appears to be superior to the SPAD meter and Y-leaf N concentration methods in assessing the N status of the rice plant throughout the vegetative growth period.

Preliminary data (not presented) from the ^{15}N tracer study conducted in Louisiana and Arkansas investigating the midseason N uptake has given more insight into why the midseason N applications cannot make up for poor preflood N uptake. The study clearly showed that the uptake of the midseason N is dependent on the uptake of the preflood N. The poorer the uptake of the preflood N, the poorer the uptake of the midseason N. Data from this study are being compiled and will be presented in fall next year.

SIGNIFICANCE OF FINDINGS

The two new cultivars, Jodon and Kaybonnet, produced similar grain yields when the N fertilizer was applied in a single preflood (SPF) compared to a three-way split (3WS) application. Both produced maximum grain yields when 90 to 120 lb N/acre was applied at most locations except NEREC. In general, the three experimental rice lines studied showed a preference for the N fertilizer to be applied in a SPF compared to the 3WS application. Two years of research on the evaluation of the diagnostic methods for assessing the N status of the rice plant during the vegetative growth stage clearly shows that the plant area method ('Rice Gauge') is superior to the SPAD Meter and the Y-leaf N concentration methods. A ^{15}N-tracer study conducted in Louisiana and Arkansas found that the uptake of N at midseason is dependent on the preflood N uptake. Consequently, if the preflood N is not taken up adequately and efficiently, neither will the midseason N. Thus, one of the reasons that midseason N cannot make up for poor preflood N uptake is that its uptake is dependent on how much preflood N is taken up.

LITERATURE CITED

1. SAS Institute. 1985. SAS user's guide: Statistics. 5th edition. SAS Institute, Cary, North Carolina.

Table 1. Influence of application method on grain yields of 'Jodon' rice at four locations in 1994.

Application Method	Location			
	PTES[z]	RREC	SEBES	NEREC
	lb/acre			
SPF[y]	7534	7136	6267	6246
3WS	7621	7342	6002	6362
$LSD_{(0.05)}$	ns[x]	ns	ns	ns

[z] PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.
[y]SPF = Single preflood; 3WS = three-way split.
[x]ns = not significant.

Table 2. Influence of nitrogen (N) rate on grain yields of 'Jodon' rice at four locations in 1994.

N rate	PTES[z]	RREC	SEBES	NEREC
	lb/acre			
0	5122	4920	3750	3363
60	7660	7334	5781	5436
90	8223	7941	6614	6298
120	8397	7869	7184	6963
150	8100	7805	6786	7594
180	7963	7566	6802	7672
$LSD_{(0.05)}$	705	587	797	569
C.V.[y](%)	7.7	6.7	10.2	7.4

[z]PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.
[y]CV = coefficient of variation.

Table 3. Influence of application method of nitrogen (N) fertilizer on grain yields of 'Kaybonnet' rice at four locations in 1994.

Application Method	Location			
	PTES[z]	RREC	SEBES	NEREC
	----------lb/acre----------			
SPF[y]	7123	6329	6100	7102
3WS	7381	6676	5368	6415
$LSD_{(0.05)}$	ns[x]	ns	ns	ns

[z]PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.

[y]SPF = Single preflood; 3WS = three-way split.

[x]ns = not significant.

Table 4. Influence of nitrogen (N) rate on grain yields of 'Kaybonnet' rice at four locations in 1994.

N rate	PTES[z]	RREC	SEBES	NEREC
	----------lb/acre----------			
0	4799	3899	1231	3276
60	7246	6760	5371	6146
90	7764	7731	5860	6686
120	7956	7764	7184	7658
150	7998	6759	7455	8209
180	7749	6102	7079	8577
$LSD_{(0.05)}$	460	812	1094	706
C.V.[y](%)	5.3	10.4	14.9	8.7

[z]PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas; NEREC = Northeast Research and Extension Center, Keiser, Arkansas.

[y]CV = coefficient of variation.

Table 5. Influence of application method on grain yields of selected experimental rice lines at Stuttgart, Arkansas, in 1994.

Application Method	RU9201176	RU9201179	RU9201191
	----------lb/acre----------		
SPF[z]	7254	7658	7365
3WS	7101	7418	7205
$LSD_{(0.05)}$	ns[y]	ns	ns

[z]SPF = Single preflood; 3WS = three-way split.

[y]ns = not significant.

Table 6. Influence of nitrogen (N) rate on grain yields of selected experimental rice lines at Stuttgart, Arkansas, in 1994.

N rate	RU9201176	RU9201179	RU9201191
	----------lb/acre----------		
0	3676	4021	3747
60	7109	7600	7292
90	7722	8146	7912
120	8523	8932	8628
150	8383	8782	8229
180	7652	7746	7902
$LSD_{(0.05)}$	975	629	823
C.V.[z](%)	11.3	6.9	9.4

[z]CV = coefficient of variation.

Table 7. Influence of nitrogen (N) rate and application method on grain yields of selected experimental rice lines at Stuttgart, Arkansas, in 1994.

	RU9201176		RU9201179		RU9201191	
N rate	SPF[z]	3WS	SPF	3WS	SPF	3WS
	----------lb/acre----------					
0	3666	3685	3842	4201	3896	3597
60	7771	6447	8136	7064	7928	6657
90	8540	6904	8461	7830	8487	7337
120	8688	8358	9230	8634	8707	8550
150	8167	8600	8479	9086	7904	8553
180	6693	8612	7802	7690	7271	8533
$LSD_{(0.05)}$ within Mains	1481		ns[y]		1540	
$LSD_{(0.05)}$ between Mains	1400				1685	

[z]SPF = Single preflood; 3WS = three-way split.
[y]ns = not significant.

Table 8. Linear correlation coefficients (r) between parameters of plant nitrogen (N) status in 1993 and 1994 in experiments at Stuttgart, Arkansas.

Parameters of	Growth stage (days after emergence)			
plant N status	41	48	55	62
1993				
Dry matter vs plant area	0.813	0.566	0.775	0.746
SPAD readings vs leaf [N][z]	0.914	0.737	0.671	0.597
SPAD readings vs plant [N]	0.881	0.626	0.518	0.610
1994				
Dry matter vs plant area	0.862	0.842	0.741	0.580
SPAD readings vs leaf [N]	0.883	0.665	0.631	0.527
SPAD readings vs plant [N]	0.699	0.496	0.655	0.434

[z][N] = Nitrogen concentration.

Table 9. Linear correlation coefficients (r) between total nitrogen (N) uptake and parameters of plant N status in 1993 and 1994 in experiments at Stuttgart, Arkansas.

Parameters of plant N status	Growth stage (days after emergence)							
	1993				1994			
	41	48	55	62	41	48	55	62
Dry matter	0.895	0.897	0.836	0.862	0.868	0.913	0.901	0.838
Plant Area	0.804	0.530	0.767	0.711	0.767	0.799	0.729	0.639
Leaf [N][z]	0.866	0.863	0.611	0.499	0.782	0.354	0.409	0.390
SPAD	0.823	0.634	0.491	0.399	0.801	0.612	0.387	ns[y]
Plant [N]	0.804	0.922	0.932	0.846	0.791	0.881	0.588	0.659

[z][N] = Nitrogen concentration.
[y]ns = Not significant at the 5% level of probability.

1994 RICE RESEARCH VERIFICATION TRIALS

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ABSTRACT

Fifteen Rice Research Verification Trials (RRVT) were conducted during 1994 in 11 rice producing counties. Counties participating in the 1994 RRVT were Arkansas (two fields), Ashley, Crittenden, Cross (two fields), Jefferson, Lee, Mississippi, Monroe, Phillips, Poinsett, and Woodruff (three fields). Agronomic and economic data for specified operating costs were collected for each verification field. The fifteen fields totaled 817 acres, and field size ranged from 19 to 139 acres. The mean yield adjusted to 12% moisture was 132 bu/acre. Yields ranged from 97 to 170 bu/acre. Seven different varieties were seeded. Eight of the fields were drill seeded; the remaining seven fields were water seeded either for stand establishment or due to a severe red rice infestation. Nine fields were established using either stale seedbed or no-tillage practices. Seeding dates ranged from 8 April to 6 May. The break-even price for each field, excluding charges for land, overhead and management, ranged from $2.00 to $3.88/bu. Based on the weighted means for yield and total specified operating ($292.06/acre) and fixed cost ($50.42/acre), the average break-even price was $2.60/bu. Herbicide cost represented 15.5% of the specified operating cost followed by fertilizer 13.7%, drying 12.0%, aerial application 9.8%, seed 9.5% and fungicide 2.2%.

INTRODUCTION

The Rice Research Verification Trials (RRVT), initiated in 1983, use an interdisciplinary approach that stresses management intensity. The program objectives are to increase the potential for profitable rice production by identifying data gaps, accumulating a database for rice economic programs, providing training to county agents and assisting in the transfer of research technology. Verification projects involving water seeding and conservation tillage were expanded in 1994 to obtain economic and agronomic information on these cultural practices.

PROCEDURES

Each verification field was selected prior to seeding. Farm cooperators agreed to pay production expenses, provide crop expense data for economic analysis and implement the recommended production practices in a timely manner from seedbed preparation to harvest. A designated Extension agent from each participating county served as a field technician who assisted the Area Rice Specialist in collecting data, scouting the verification field and maintaining regular contact with the grower. Management decisions were made by the Area Rice Specialist based on current University of Arkansas recommendations during weekly field inspections. Additional assistance was provided by the appropriate Extension specialist or researcher as needed.

Fifteen RRVT were established during 1994 on 817 acres. Seven different varieties, 'Alan', 'Cypress', 'Katy', 'Lacassine', 'LaGrue', 'Mars' and 'Newbonnet', were seeded in the verification fields (Table 1). Eight of the 15 fields were drill dry seeded; the remaining fields were water seeded. Nine of the fields were planted in either a stale or no-till seedbed. Fields ranged in size from 19 to 139 acres. Counties participating in the 1994 RRVT were Arkansas (two fields), Ashley, Crittenden, Cross (two fields), Jefferson, Lee, Mississippi, Monroe, Phillips, Poinsett, and Woodruff (three fields). Woodruff County had one no-till water-seeded field that was divided into three separate fields each with a different variety. Field size, previous crop, soil series and yields for each field are listed in Table 1.

RESULTS AND DISCUSSION

Grain yield on the RRVT fields averaged 132 bu/acre (Table 1). The highest yield recorded in 1994 was 170 bu/acre produced at the Woodruff-C location followed by the Woodruff-N location at 168 bu/acre. The no-till water-seeded fields produced both the highest and lowest yields in the RRVT program. The Cross-I site produced the lowest yield, 97 bu/acre. The low yield was attributed primarily to severe rice water weevil larvae damage that resulted in stand loss. Furadan was recommended for application, but ten days passed before insecticide was applied. Late application was due to pilot error. Precise water management was also difficult and contributed to seedling stress after larvae damage.

Seeding dates ranged from 8 April to 6 May (Table 2). The dry spring allowed for early planting, but it also slowed emergence due to lack of adequate moisture for germination. Presoaked seed was used for the water-seeded fields. A John Deere model 750, 15-ft no-till drill was used in all conservation till fields except Crittenden County. A three-point hitch 20-ft Marliss conventional drill was used on the fall-prepared, clay seedbed. Normal seeding rates were used on no-till fields (Table 2).

Fertility recommendations were based on soil test results and variety requirements. Replicated research plots were established in several RRVT fields to examine rice response to zinc, phosphorus and potassium fertilization. Research plots examining different zinc sources indicated that rice did not benefit from zinc fertilization. Poultry litter (1500 lb/acre) was applied to a portion of the Poinsett County field due to spring land leveling. Phosphorus and/or potassium fertilizer was applied to 10 of the 15 verification fields. A greater emphasis was placed on soil sampling in 1994. The three Woodruff sites and the Arkansas-2 site were grid soil sampled to determine variability in soil fertility.

Nitrogen was applied in a variety of methods due to different tillage and cultural practices (Table 2). Nitrogen was preplant incorporated and followed by a single midseason application in all water-seeded fields except for those in Woodruff County. Woodruff County fields were fertilized using the three-way split method since water seeding was performed for stand establishment only. Nitrogen application was delayed two weeks after the last date on the DD50 for early N application due to wet soil conditions at the Poinsett and Woodruff locations. Normal yields were produced at both sites. Urea was used as the N source for all except one application at the Poinsett County location. Ammonium sulfate, 100 lb/acre, was applied at midseason to 20 acres in an area that was leveled. A single preflood N application was attempted at the Jefferson and Monroe County locations (Table 2). A single midseason application was needed at the Monroe field. The Rice Gauge (Plant Area Board) was used to evaluate midseason N needs at all locations. Fertilizer cost averaged $40/acre, which was the second highest operating cost, representing 13.7% of the total.

Residual herbicide programs were used extensively for the third consecutive year on verification fields. Propanil was tank-mixed with Facet on three fields (Table 3). Residual herbicides, namely Bolero, Facet and Prowl, were tank-mixed or applied alone, delayed preemergence at several locations. Excellent grass control resulted. Facet also provided excellent control of northern jointvetch and coffeebean. Bolero was pre-plant surface applied on four of the water-seeded fields. Ordram 8E was preplant incorporated for grass control and red rice suppression at the Cross-B site. Aquatic weeds and sprangletop were troublesome where the Ordram was applied. Londax was applied for aquatic weed control in all water-seeded fields. In general, excellent weed control was obtained at all locations.

Residual herbicide programs have been successful in controlling grass in the RRVT program for three consecutive years. Reduced rates of two herbicides have been tank-mixed and provided broader-spectrum weed control than a single residual herbicide. Preplant or pre-emergence applications of Roundup D-Pak were applied to all no-till fields (Table 3). Herbicide cost averaged $45.29/acre, which was the single highest operating cost.

A foliar fungicide was applied to four of the 15 RRVT fields (Table 3). Sheath blight was present in all fields, but only the Jefferson, Monroe and Phillips County fields required treatment. Blast required treatment at the Woodruff-N location seeded in Newbonnet. Blast or sheath blight did not cause severe yield losses in any RRVT. Fungicide cost averaged $6.46/acre, representing only 2.2% of the total.

Furadan insecticide was applied to four water-seeded fields for control of rice water weevil larvae. Larvae treatment thresholds, 10 larvae/core, were reached about four weeks after seedling emergence. Soil core samples were taken every week from emergence until insecticide was applied. Dry-seeded fields and the three Woodruff County fields did not require insecticide.

ECONOMIC ANALYSIS

The break-even price for each field, excluding charges for land, overhead and management, ranged from $2.00 to $3.88/bu (Table 4). Based on the weighted means for yield and total specified operating ($292.06/acre) and fixed cost ($50.42/acre), the average break-even price was $2.60/bu (Table 4). Specified operating costs were 11% higher than in 1993. Greater specified production costs were due to greater operating costs in all areas except costs related to machinery fuel, repair and labor. Reduced-tillage practices were responsible for reducing machinery-related expenses. The highest yielding field, Woodruff-C, also had the lowest break-even price in 1994. Herbicide costs increased due in part to burndown herbicide applications.

SIGNIFICANCE OF FINDINGS

1) In 1994 the RRVT average yield was 132 bu/acre. The RRVT program continues to evaluate cultural practices used in Arkansas rice production, including water seeding, reduced-tillage practices and reduced-rate herbicide treatments. Grain yields for the program have been above the state average and will continue to increase as the experience and knowledge base grow with the acceptance of these practices.
2) Comparative work was performed in several RRVT locations including Arkansas, Monroe and Woodruff County sites. Tillage systems, herbicide treatments and varieties were compared at these locations in 1994.
3) The no-till water-seeded RRVT field in Woodruff County was successful in establishing a stand and reducing time, labor and fuel associated with seedbed preparation. The field was no-till water seeded for stand establishment.
4) Herbicide applications averaged 2.16 applications/acre, including burndown applications, or 1.7 applications/acre, excluding burndown, in 1994. Total herbicide applications per acre in previous years were 2.16 (1991), 1.85 (1992) and 1.67 (1993). Residual herbicide programs continue to produce outstanding results.

Table 1. Acreage, soil series, previous crop, yield and variety for the 1994 Rice Research Verification Trials.

County-Seeding Method[z]	Acre	Soil Series	Previous Crop	Yield[y] Grain	Milling	Variety
				bu/acre	%	
Arkansan-1-ntd	41.5	Amagon &	Soybean	123	57/67	Katy
Arkansan-2-ssd	36.5	Rilla silt loam	Soybean	124	55/65	Katy
Ashley-cws	35	Perry clay	Soybean	142	NA	Cypress
Crittenden-ssd	56	Sharkey silty clay	Soybean	107	62/70	Alan
Cross-B-cws	40	Henry silt loam	Soybean	144	NA	Newbonnet
Cross-I-ntws	45	Henry silt loam	Soybean	97	62/70	Cypress
Jefferson-ssd	75	Portland&Perry clay	Grain Sorg	142	61/69	Cypress
Lee-cd	60	Calloway silt loam	Soybean	151	61/68	Mars
Mississippi-cd	40	Steele & Tunica	Soybean	131	44/66	LaGrue
Monroe-ntd	103	Foley silt loam	Soybean	133	60/69	Cypress
Phillips-cws	75	Dubbs silt loam & Sharkey silty clay	Rice-leveled	128	60/69	Lacassine
Poinsett-cd	139	Henry & Calloway silt loam	Soybean-leveled	122	NA	Katy
Woodruff-N-ntws	18.8	Henry silt loam	Soybean	171	59/69	Newbonnet
Woodruff-C-ntws	28.5	"	"	169	61/69	Cypress
Woodruff-L-ntws	23.7	"	"	140	58/70	Lacassine
Average	54.5			132.00		

[z]cd - conventional drill; ssd - stale seedbed drill; ntd - no-till drill; cws - conventional water seed; ntws - no-till water seed

[y]Grain yields reported at 12% moisture; Milling yield = whole kernel/total

Table 2. Stand density, seeding rate, fertilizer rates and important dates during the 1994 season.

Location	Stand Density	Seeding Rate	Nitrogen Rate Urea (45%)[z]	Fertilization $N-P_2O_5-K_2O-Zn$	Plant Date	Emergence Date	Harvest Date
County	plants/ft^2	lb/acre	lb/acre	lb/acre	month-day	month-day	month-day
Arkansas-1-ntd	36	99	175-100-100	169-0-60-0	4-20	4/29	9/15
Arkansas-2-ssd	35	99	175-100-65	153-0-60-0	4-20	5/05	9/20
Ashley-cws	17	135	300-100	180-0-0-0	5-05	5/11	9/10
Crittenden-ssd	11	113	208-80	130-0-0-0	4-14	4/30	8/27
Cross-B-cws	22	110	265-65-65[y]	163-0-80-0	4-25	4/30	9/09
Cross-I-ntws	24	135	300-100	212-0-80-0	5-03	5/12	10/3
Jefferson-ssd	13	110	300	135-0-0-0	4-08	4/23	8/27
Lee-cd	26	133	110-65-100	124-30-60-0	4-19	5/01	9/11
Mississippi-cd	20	92	150-100-100	158-0-0-0	4-18	5/01	9/02
Monroe-ntd	16	110	300-60	162-0-90-0	4-19	4/30	9/12
Phillips-cws	16	113	211-100	140-0-0-0	5-04	5/09	9/09
Poinsett-cd	51	135	220-100-20	147-40-60-10	5-06	5/15	10/3
Woodruff-N-ntws	26	135	270-100-100	212-41-83-0	4-30	5/10	9/30
Woodruff-C-ntws	24	135	270-100-100	212-41-83-0	4-30	5/10	9/30
Woodruff-L-ntws	24	135	270-100-100	212-41-83-0	4-30	5/10	9/30

[z]First number always indicates preflood N rate. Numbers that follow indicate midseason application(s) of N fertilizer at internode elongation.

[y]Nitrogen fertilizer applied to only a portion of the field on the final treatment.

Table 3. Pesticide[z,y] treatment rate/acre and dates of application on 1994 RRVT fields.

Location	Pesticide Treatments and (Dates) of Application
Arkansas-1-ntd	Roundup D-Pak 20 oz (4/07); Propanil 3 qt + Facet 50WP 0.75 lb (4/30); Ordram 15G 20 lb (5/30)
Arkansas-2-ssd	Propanil 3 qt + Facet 50WP 0.75 lb (4/30); Arrosolo 3 qt + Londax 0.75 oz (5/23)
Ashley-cws	Roundup D-Pak 20 oz (4/20); Bolero 3 pt (5/03); Londax 1 oz (6/02); Furadan 3G 20 lb (6/09)
Crittenden-ssd	Facet 0.5 lb + Bolero 3 pt (4/19); Ordram 15G 20 lb 15 acres (6/15)
Cross-B-cws	Ordram 8E 4 pt (4/18); Londax 1 oz (5/09); Furadan 3G 20 lb (6/09); 2,4-D 2 pt (6/17)
Cross-I-ntws	Roundup D-Pak 24 oz + Bolero 4 pt (4/16); Londax 1 oz (5/30); Furadan 3G 20 lb (6/15)
Jefferson-ssd	Bolero 2 pt + Roundup D-Pak 20 oz (4/13), Facet 50WP 0.6 lb (4/13), Benlate 1.25 lb (7/03)
Lee-cd	Propanil 3 qt + Facet 50WP 0.5 lb (5/06)
Mississippi-cd	Bolero 2 pt + Facet 50WP 0.7 lb (4/27)
Monroe-ntd	2,4-D 1.5 pt (3/15); Roundup D-Pak 20 oz, 50 acres (4/20); [Facet 50WP 0.75 lb 10 acres, Facet 50WP 0.4 lb + Bolero 2 pt 65 acres, Facet 50WP 0.4 lb + Prowl 2.4 pt 20 acres, Prowl 2.4 pt 20 acres (4/27)]; Propanil 3 qt + Londax 0.75 oz (5/20), 40 acres; Benlate 1.25 lb, 73 acres (6/25); Benlate 1.25 lb, 38 acres (7/16)
Phillips-cws	Bolero 3 pt (4/27); Londax 1 oz (5/24); Ordram 15G 20 lb, 45 acres (5/26); Furadan 3G 20 lb (6/13); Benlate 1.25 lb, 38 acres (6/30); Benlate 1.25 lb, 38 acres (7/12)
Poinsett-cd	Facet 50WP 0.5 lb + Bolero 2 pt (5/18); Arrosolo 3 qt + Londax 0.75 oz (6/21) 60 acres; Ordram 15G 25 lb (6/28) 95 acres
Woodruff-N-ntws	Roundup D-Pak 24 oz + Bolero 2 pt (4/23); Propanil 4 qt + Londax 0.75 oz (6/11); Benlate 1 lb (8/15) 19 acres (Newbonnet only)
Woodruff-C-ntws	"
Woodruff-L-ntws	"

[z]Levee treatments are not included. Dates of treatment in ( ). If only a portion of the field was treated, the acreage is stated; otherwise assume the entire field was treated.

[y]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the University of Arkansas and does not imply its approval to the exclusion of other products that may be suitable.

Table 4. Selected economic information for the 1994 Rice Research Verification Trials.

County	SCI[z]	SOC[y]	SFC[x]	TSC[w]	Break-even[v]
	------$/acre------				$/bu
Arkansas-1-ntd	156.31	303.33	43.98	347.31	2.82
Arkansas-2-ssd	144.46	296.56	51.30	347.86	2.81
Ashley-cws	144.46	284.78	52.89	337.67	2.24
Crittenden-ssd	112.55	235.95	49.82	285.78	2.67
Cross-B-cws	145.78	304.46	50.91	355.37	2.47
Cross-I-ntws	207.38	331.44	44.61	376.06	3.88
Jefferson-ssd	152.43	293.40	57.78	351.18	2.47
Lee-cd	106.10	268.21	60.80	329.00	2.18
Monroe-ntd	155.01	289.33	47.24	336.56	2.53
Mississippi-cd	134.65	271.80	52.41	324.21	2.47
Phillips-cws	160.74	291.44	45.22	336.67	2.63
Poinsett-cd	157.14	307.80	55.87	363.66	2.98
Woodruff-N-ntws	192.32	322.91	38.26	361.17	2.15
Woodruff-C-ntws	172.57	301.12	38.26	339.38	2.00
Woodruff-L-ntws	172.57	289.66	37.93	327.59	2.34
Mean	151.00	292.06	50.92	342.48	2.60

[z]SCI = Specific crop inputs from specified operating cost including seed, herbicide, fungicide, insecticide, fertilizer, custom spreading, desiccant and aerial application cost.

[y]SOC = Specified operating cost includes SCI costs, irrigation, machinery operation, hauling, drying and interest on operating capital.

[x]SFC = Specified fixed cost including depreciation, interest, taxes and insurance

[w]TSC = Total specified operating and ownership cost

[v]Break-even price calculated by dividing yield in bu/acre by TSC.

PERFORMANCE TESTING OF RICE IRRIGATION PUMPING PLANTS

P.L. Tacker, E.D. Vories and J.M. Langston

ABSTRACT

Preliminary studies reveal that the average irrigation pumping plant is operating at less than 70% of optimum efficiency (Tacker and Langston, 1989). This results in an excess average pumping cost of $3 to $6/acre-ft of water or approximately $10 to $20/acre of rice. The cost of pumping rice irrigation water is a significant production input. This cost is determined by many factors, some of which are beyond the control of the rice producer. However, the selection and performance of the irrigation pumping plant is a cost factor over which the producer has some control.

The goal of pumping plant testing is to provide information to producers that helps them make decisions related to improving the operation of their irrigation pumping equipment. This is accomplished through performance testing of pumping plants in rice producing counties during the production season. The field tests provide the measurements necessary for evaluating the performance of each pumping plant and developing recommendations for improving performance.

Pumping plant evaluations during the 1994 growing season involved 93 tests on 47 different wells. The overall average efficiency was 74% for 13 of the 47 wells and varied from 54% to 96%. All of the cooperating producers received information on fuel use and pumping capacity, and recommendations for improvements were made for 12 of the wells. This information is also made available to other producers through publications and meetings.

INTRODUCTION

Preliminary testing of irrigation pumping plants has established sound performance testing techniques, and additional work is needed to provide the best information to the rice producer (Irrigation Pumping Plant Performance Handbook, 1982). The objectives for the project are as follows:

1) to provide producers with information on irrigation pumping plant performance and to make suggestions for improving this performance when appropriate;
2) to provide producers with information on selection of new equipment for optimum performance and efficiency; and
3) to reduce the cost per acre-ft of water pumped for rice irrigation by improving pumping plant selection and performance.

Most producers have either limited or outdated information on the different performance aspects of their irrigation pumping plant. The variability of fuel prices over the past few years has caused some producers to make pumping equipment changes in hopes of reducing pumping costs. Unfortunately, this decision is often made without knowing if the original pumping performance could have been improved to the point of reducing pumping cost. In fact, it is possible that new equipment might reduce the pumping cost but still not exhibit a desirable level of pumping performance or efficiency. Data from this project help Arkansas rice producers make more informed decisions relative to their pumping equipment and costs.

PROCEDURE:

Pumping plant evaluations were continued during the 1994 growing season. Ninety-three tests were conducted on 47 wells in 10 counties: Arkansas, Ashley, Clay, Crittenden, Drew, Greene, Lee, Lonoke, Mississippi and Woodruff. Fifty-eight of the evaluations were on diesel-powered wells, 30 on electric-powered wells, three on a propane-powered well and two on a natural gas-powered well.

The specific information gained from the pumping plant performance test and made available to the producer is as follows:

1. Depth to water*
2. Flow rate
3. Specific yield of well*
4. Fuel consumption
5. Cost per acre-ft of water pumped
6. Power unit efficiency
7. Pump/well efficiency*
8. Overall efficiency*

*These data are not always obtainable for every installation--particularly when the well is sealed.

This information is evaluated to determine what recommendations can be made to the producer. If a recommendation is implemented, then a follow-up performance test is conducted, if possible, to determine if performance improved.

The investigators, a technician and county agents are involved in conducting the performance tests, primarily during the rice production season. The testing locations are scheduled and coordinated through the county Extension staff on a first-come, first-served basis; however, efforts are made to service all of the rice-producing counties and to test all types of rice irrigation pumping plants. Irrigation equipment dealers and well drillers are involved when appropriate and necessary.

RESULTS

Useful information on pumping capacity and fuel consumption was provided to 19 rice producers. A summary of this information is presented in Table 1 with a more complete presentation of the data in Tables 2-4. Table 2 presents the data from the propane-powered well and the natural gas-powered well tests. Table 3 shows the data from 30 pumping plant tests conducted on 27 electric-powered wells. Table 4 presents the data from 51 pumping plant tests conducted on 17 diesel-powered wells.

Table 5 shows the results of seven tests conducted on a diesel-powered well to document the effect of using blasting caps to relieve suspected well screen plugging. The plugging was thought to be due to mineral incrustation on the well's intake screen. Measurements were made before and after blasting on the same day it occurred. Before blasting, a speed above 2100 RPM was not obtainable because of surging; however, a higher RPM was possible after blasting. This indicated that the blasting was effective, and the other test data support this conclusion. The flow increased after blasting, resulting in a decreased fuel use per acre. Even though the blasting effort improved the well's performance, it is still not performing at an optimum level. Monitoring of this well's performance will be continued next year, and further recommendations will be forthcoming.

A well pumping 1,650 gpm in 1993 was pumping 1,660 gpm, or essentially the same, in 1994. On each occasion, the flows were measured at the end of approximately 1,000 ft of underground irrigation pipe. The well installer made a flow measurement of 2,200 gpm at the well without the influence of the underground pipe in 1993 after our test. We made a similar flow measurement at the well during 1994 and found it to be 2,000 gpm. Depth-to-water measurements revealed that the pumping depth was approaching the pump setting depth and that surging could be occurring. This information resulted in a recommendation that the well owner have the well screen treated to relieve possible plugging that may be causing additional drawdown of the water level. If this effort does not give satisfactory results, then the next step is to pull the pump to determine if it can be rebuilt to the performance level necessary for the existing pumping conditions. If not, a different pump will be needed. The choice will be between a new single-stage pump installed at the same depth or a two-stage pump set deeper in the well to accommodate dropping water table conditions in the future. Plans are to do a follow-up test in 1995 after the above steps have been taken.

An electric well tested in 1993 and found to be pumping only 895 gpm was retested in 1994 after the owner had it repaired. The well is now pumping 50% more water and using only 8% more electricity.

Calculations were made on an electric-powered well to assist the grower with a decision on converting to a natural gas-powered unit. The producer planned to use this information to determine if he wanted to make this conversion.

Wiring at two different electric submersible wells exhibited missing insulation and exposed wire. This was not necessarily affecting the well's performance, but it did pose a safety hazard, as was pointed out to the producer. Measurements on two electric wells indicated that our readings differed from the power company's meter. The growers planned to contact the power company about this possible problem.

Several electric submersibles appeared to be pulling more horsepower (hp) than the design specifications. Growers were made aware of this since it can possibly result in premature failure of pump and/or motor components.

Twenty-five tests on 13 wells provided adequate information for determining the specific yield. Specific yield is the ratio of the well's flow rate to the drawdown depth in the well. This is commonly reported as gpm/ft (gallons per minute/foot) and ranged from 26-122 gpm/ft and averaged 53 gpm/ft on these tests. The specific yield varies for different areas of the delta, but, when measurable, it can help explain possible problems with a well's performance. The depth to water in the well was measured at 18 locations and ranged from 13 to 95 ft, with the average at 36 ft. The depth to water while pumping at these locations varied from 45 to 109 ft, and the average was 60 ft. This also varies across the Delta and greatly impacts the pumping hp required.

The specific performance of three diesel-powered units was determined. Power unit performance is commonly reported as the horsepower hours (hp-hrs) delivered per gallon (gal) of fuel (hp-hrs/gal). The performance achieved for these three units ranged from 7.2-17.2 hp-hrs/gal. Nebraska performance standards report that a satisfactorily performing unit should achieve 16.66 hp-hrs/gal. This information helps a producer determine if the power unit is a major part of a well's poor performance or if the problem is related to other components of the system.

Data for calculating pumping plant efficiency were collected on four electric line shaft turbine (LST) wells, six electric submersible wells and three diesel-powered wells. The range for the electric LST wells was 68-86% with an average of 75%. The range for the electric submersible wells was 65-96% with an average of 76%. The range for the diesel-powered wells was 54-78% with an average of 72%.

SIGNIFICANCE OF FINDINGS

Producers need to know how existing pumping plants are performing to determine options for reducing pumping cost. They also need information on selecting new pumping plant equipment for performance and efficiency. Not all pumping plants can be tested, but all producers can benefit from the information being collected from these studies.

This direct involvement with producers on their farms provides opportunities for making suggestions and recommendations concerning irrigation water management. The experience and information gained from the program also benefit the communication and coordination associated with irrigation equipment dealers and well drillers.

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LITERATURE CITED

1. Tacker, Phil, and John Langston. 1989. Arkansas Pumping Plant Efficiency Testing, 1987-1988. Final Report. University of Arkansas Cooperative Extension Service, Little Rock.
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Table 1. Summary of 93 pumping plant tests conducted on 47 wells in 1994.

Energy Source	No. of Tests	Pumping Capacity Range (GPM)[Z]	Fuel Consumption Range	Season Fuel Consumption Range[V]
Electric	30	340 - 1990	7-29 KWH/acre-in.[Y]	210-870 KWH/acre[U]
Diesel	58	480 - 2710	0.44-1.73 gal/acre-in.[X]	13.2- 51.9 gal/acre[T]
Propane	3	985 - 1550	1.30-1.41 gal/acre-in.	39.0-42.3 gal/acre
Natural Gas	2	965 - 1045	98-109 ft^3/acre-in.[W]	2940-3270 ft^3/acre[S]

[Z]GPM - Gallons per minute
[Y]KWH/acre-in - Kilowatt hours of electricity per acre-in. of water pumped
[X]gal/acre-in - Gallons of fuel per acre-in. of water pumped
[W]ft^3/acre-in - Cubic feet of gas per acre-in. of water pumped
[V]Assumes 30 in. pumped per acre
[U]KWH/acre - Kilowatt hours of electricity per acre
[T]gal/acre - Gallons of fuel per acre
[S]ft^3/acre - Cubic feet of gas per acre

Table 2. 1994 pumping plant test results on a propane well and a natural gas well - LST.[Z]

Power Unit Type	Power Unit	Flow	Fuel Use	Fuel Use	Seasonal Fuel Use
	RPM[Y]	GPM[X]	gph[W]	gal/acre-in.[V]	gal/acre[U]
6 cyl Propane	1500	985	2.85	1.30	39.0
	1700	1355	4.11	1.36	40.8
	1800	1550	4.84	1.41	42.3
			ft^3/hr[T]	ft^3/acre-in.[S]	ft^3/acre[R]
4 cyl Natural Gas	1090	965	209	98	2940
	1150	1045	254	109	3270

[Z]LST - Line shaft turbine pump
[Y]RPM - Revolutions per minute
[X]GPM - Gallons per minute
[W]gph - Gallons of fuel per hour
[V]gal/acre-in - Gallons of fuel per acre-in. of water pumped
[U]gal/acre - Gallons of fuel per acre. Assumes 30 in. pumped per acre
[T]ft^3/hr - Cubic feet of gas per hour
[S]ft^3/acre-in - Cubic feet of gas per acre-in. of water pumped
[R]ft^3/acre - Cubic feet of gas per acre. Assumes 30 in. pumped per acre

Table 3. Results of 30 pumping plant tests conducted on 27 electric wells in 1994.

System Type[Z]	Motor	Flow	Fuel Use	Fuel Use	Seasonal Fuel Use
	RPM[Y]	GPM[X]	KWH[W]	KWH/acre-in.[V]	KWH/acre[U]
1) 50 hp-LST	1765	1050	39.0	16.74	502.2
2) 30 hp-LST	1200	1355	39.0	13.00	390.0
3) 60 hp-LST	1765	1560	39.0	11.24	337.2
4) 60 hp-LST	1765	1660	48.0	13.00	390.0
	1765	1990	48.0	10.86	325.8
5) 60 hp-LST	1770	1110	46.0	18.65	559.5
6) 20 hp-LST	1750	485	9.6	8.90	267.0
7) 50 hp-LST	1760	1295	40.0	13.90	417.0
8) 60 hp-LST	1775	800	49.0	27.50	825.0
9) 75 hp-LST	1775	965	63.0	29.40	882.0
10) 60 hp-LST	1765	1210	49.0	18.20	546.0
11) 60 hp-LST	1765	755	37.0	22.00	660.0
12) 60 hp-LST	1770	1130	52.0	20.70	621.0
13) 40 hp-LST	1770	820	30.0	16.50	495.0
	1770	700	30.0	19.20	576.0
14) 50 hp-LST	1765	1500	49.0	14.70	441.0
	1765	1255	49.0	17.60	528.0
15) ----SUB[T]	3450	650	31.0	21.50	645.0
16) ----SUB	3450	585	32.0	24.60	738.0
17) 30 hp-SUB	3450	600	25.0	18.80	564.0
18) 25 hp-SUB	3450	1225	27.0	9.90	297.0
19) ----SUB	3450	480	9.5	8.60	258.0
20) 10 hp-SUB	3450	530	10.1	8.60	258.0
21) 10 hp-SUB	3450	435	7.2	7.40	222.0
22) 10 hp-SUB	3450	620	11.3	8.20	246.0
23) 15 hp-SUB	3450	765	14.8	8.70	261.0
24) ----SUB	3450	900	30.0	13.50	405.0
25) 10 hp-SUB	3450	340	9.5	12.60	378.0
26) 7.5 hp-SUB	3450	375	8.6	10.40	312.0
27) 10 hp-SUB	3450	550	12.5	10.20	306.0

[Z]LST - Line shaft turbine pump; SUB - submersible
[Y]RPM - Revolutions per minute
[X]GPM - Gallons of water per minute
[W]KWH - Kilowatt hours
[V]KWH/ac-in - KWH of electricity per acre-in. of water
[U]KWH/ac - KWH of electricity per acre. Assumes 30 in. pumped per acre
[T]----Data unavailable

Table 4. Results of 51 pumping plant tests conducted on 17 diesel wells in 1994 - LST[z]

Power Unit	Power Unit	Flow	Fuel Use	Fuel Use	Seasonal Fuel Use
	RPM[Y]	GPM[X]	gph[W]	gal/ac-in.[V]	gal/ac[U]
1) 6 cylinder	1700	945	2.96	1.41	42.3
	1800	1130	3.54	1.42	42.6
	1900	1380	4.40	1.43	42.9
2) 4 cylinder	1700	480	1.84	1.73	51.9
	1800	600	2.12	1.59	47.7
	1900	720	2.48	1.55	46.5
3) 4 cylinder	1800	710	2.00	1.27	38.1
	2000	940	2.70	1.29	38.7
	2150	1115	3.40	1.37	41.1
4) 4 cylinder	1600	560	1.38	1.11	33.3
	1800	700	1.80	1.16	34.8
	2000	735	2.18	1.33	39.9
5) 4 cylinder	1900	625	1.26	0.91	27.3
	2000	685	1.64	1.08	32.4
6) 4 cylinder	1600	1270	2.20	0.78	23.4
	1800	1520	2.80	0.83	24.9
	1950	1720	3.50	0.92	27.6
7) 6 cylinder	1600	1925	2.88	0.67	20.1
	1700	2050	3.40	0.75	22.5
	1800	2210	3.88	0.79	23.7
8) 6 cylinder	1800	1035	2.04	0.89	26.7
	1950	1200	2.50	0.94	28.2
9) 4 cylinder turbo	1450	685	1.35	0.89	26.7
	1600	835	1.68	0.91	27.3
	1750	1105	2.24	0.91	27.3
	1850	1270	2.66	0.94	28.2
10) 4 cylinder	1500	1335	2.20	0.74	22.2
	1650	1440	2.13	0.67	20.1
	1900	1800	3.36	0.84	25.2
11) 4 cylinder turbo	1350	1760	1.72	0.44	13.2
	1500	2160	2.34	0.49	14.7
	1700	2670	3.44	0.58	17.4
12) 4 cylinder turbo	1600	1740	1.80	0.47	14.1
	1725	2025	2.24	0.50	15.0
	1900	2465	3.16	0.58	17.4
	2100	2710	3.94	0.65	19.5
13) 4 cylinder	1550	1375	2.48	0.81	24.3
	1650	1590	2.92	0.83	24.9
	1750	1775	3.54	0.90	27.0
14) 6 cylinder	1600	1045	2.30	0.99	29.7
	1750	1285	2.86	1.00	30.0
	1900	1645	3.94	1.08	32.4
15) 4 cylinder	1820	890	2.12	1.07	32.1
	2000	1120	2.76	1.11	33.3
	2200	1350	3.70	1.23	36.9
16) 4 cylinder	1830	550	1.85	1.51	45.3
	2010	855	2.38	1.25	37.5
	2200	1125	3.24	1.30	39.0

continued

Table 4. continued.

Power Unit	Power Unit	Flow	Fuel Use	Fuel Use	Seasonal Fuel Use
	RPM[Y]	GPM[X]	gph[W]	gal/ac-in.[V]	gal/ac[U]
17) 6 cylinder	1700	595	1.83	1.38	41.4
	1900	865	1.98	1.03	30.9
	2100	1075	2.50	1.05	31.5

[Z]LST - Line shaft turbine pump
[Y]RPM - Revolutions per minute
[X]GPM - Gallons per minute
[W]gph - Gallons of fuel per hour
[V]gal/ac-in - Gallons of fuel per acre-in. of water pumped
[U]gal/ac - Gallons of fuel per acre. Assumes 30 in. pumped per acre

Table 5. Results from blasting the intake screen of a diesel well in 1994.

6-cylinder Power Unit RPM[Z]		Flow GPM[W]		Fuel Use gal/ac-in.[V]		Fuel Use gal/acre[U]	
Before[Y]	After[X]	Before	After	Before	After	Before	After
1620	1628	1140	1340	0.82	0.72	24.6	21.6
1806	1810	1370	1590	0.95	0.83	28.5	24.9
2084	2086	1620	1990	1.11	0.96	33.3	28.8
----[T]	2229	----	2460	----	0.93	----	27.9

[Z]RPM - Revolutions per minute
[Y]Before - Before blasting well's intake screen
[X]After - After blasting well's intake screen
[W]GPM - Gallons of water per minute
[V]gal/ac-in - Gallons of fuel per acre-in. of water pumped
[U]gal/ac - Gallons of fuel per acre. Assumes 30 in. pumped per acre
[T]----Data unavailable. Pump began surging at 2100 RPM

DEVELOPMENT OF GROUND-BASED PEST CONTROL STRATEGIES IN RICE

Joel T. Walker, William W. Casady and Bill M. Barnes

ABSTRACT

The effect of wheel traffic, such as may occur due to application of chemicals, on rice yield was studied for rice grown on both a silt loam soil and a Sharkey silty clay soil in Arkansas. Generally, wheel tracks made late in the season caused significant reductions in rice yield. Passes made at pre-flood (PF) and internode elongation (IE) were generally not found to produce significant yield reductions. Individual passes made immediately before heading (BH) and after heading (AH) on the silt loam soil produced a larger reduction in yield than either BH or AH passes combined with earlier passes. Individual passes made on the clay soil produced lower yield losses than multiple passes made in the same wheel track, probably due to a poor initial stand.

INTRODUCTION

Ground-based chemical application in rice may offer some advantages over aerial application and should be developed for use where aerial application may be prohibited by regulations or practical limits. Aerial application of some chemicals has been severely restricted in certain areas, and ground application has become the only alternative. Ground-based pest control in rice presents several challenges, including poor traction in flooded fields, levees that interfere with travel, crop damage or loss of production area in wheel tracks and environmental conditions. A study was initiated to determine the feasibility of using a tractor-like machine to apply chemicals in a flooded rice field. The objective of the research was to determine the effects of a wheel-type chemical applicator on the yield of rice grown under flood considering the number and timing of passes through the field as well as row orientation and soil type. An additional object was to observe the performance of a ground-based applicator (GBA) in a flooded rice field, noting tractive performance, ability to cross levees and the effects of the GBA on the soil surface.

PROCEDURES

This study was conducted in 1994 on the Northeast Research and Extension Center at Keiser, Arkansas, on a Sharkey silty clay soil and on the Rice Research and Extension Center at Stuttgart, Arkansas, on a Stuttgart silt loam soil. Seven plots each 13 ft x 13 ft were marked off, and treatments were randomly assigned for study of travel both parallel and perpendicular to the grain drill rows. The seven wheel-track treatment combinations (Table 1) were made at four stages in the development of the rice to test the cumulative effects of wheel tracks and also the effects of single wheel-tracks made at different times in the growing cycle. The four growth stages included 1) pre-flood (PF, rice was approximately 6 in. tall); 2) internode elongation (IE, approximately 0.5 in. IE); 3) approximately 10 days before heading (BH); and 4) approximately 10 days after heading (AH). The wheel-traffic treatments were made with an experimental four-wheel-drive, high-clearance spray tractor (the GBA, Fig. 1). The GBA was equipped with four Goodyear 12.5L-15 tires inflated to 15 psi with a center-to-center wheel base of 78.5 in.

At Stuttgart, 'Cypress' rice was planted 23 May 1994, emerged 30 May 1994 and received 150 units of nitrogen 14 June 1994. Pre-flood, IE, BH and AH treatments were made 16 June 1994, 7 July 1994, 26 July 1994 and 24 August 1994, respectively. The rice was flooded 18 June 1994 and harvested 29 September 1994.

At Keiser, Cypress rice was planted 25 May 1994, emerged 9 June 1994 and received 150 units of nitrogen 24 June 1994. PF, IE, BH and AH treatments were made 23 June 1994, 18 July 1994, 6 August 1994 and 30 August 1994, respectively. The rice was flooded 28 June 1994 (the day after the pre-flood passes were made) and harvested 6 October 1994.

The rice grain from each of the four observations on each plot was harvested using a plot combine with a 28-in.-wide header. The combine was allowed to run for 20 sec at the end of each plot before the rice was collected in separate 1/6-barrel brown paper sacks. The weight of the rice in the sacks was recorded, and a sample of rice was placed in a double-sealed plastic bag for later analysis of moisture content.

Oven-dry moisture content was determined on two 15-g (0.5-oz) samples from each sack. The weight of the rice from each of the plots was adjusted to a 12% moisture content for grain yield determinations. A statistical analysis was performed on the differences in the averages for the yield from the control and the wheel track samples using the SAS (1985) GLM procedure.

RESULTS AND DISCUSSION

The reduced plant growth caused by PF wheel tracks was still visible in the rice after the IE pass but was not visible at the time of the BH pass. When the soil was flooded, the tires seemed to displace soil to the sides, leaving many of the rice plants intact and viable. At harvest, the plant canopy had closed over the IE-only wheel track. The AH wheel track was still quite obvious at harvest.

The levees on silt loam soil compacted approximately 6 to 8 in. on the first pass but did not appreciably compact further with subsequent passes. Pre-compacting the levee would prevent the tractor from further compacting the levee during later treatments and eliminate the need to repair the levees after crossing. Under muddy or flooded field conditions, the tires would sink down approximately 4 in. in the silt loam soil. This was also about the maximum depth of the levee borrow ditch, thus providing a smoother transition of the tires onto the levee slope, in some cases.

The levee borrow ditches for the clay soil were approximately 12 in. deep. At slower speeds, the tires fell off into these steeper ditches and had difficulty continuing on to cross the levee because of a lack of wheel torque from the hydrostatic drive. The ditches were then backfilled by hand with loose clay to make a ramp, but the ramp failed when wet. A culvert (aluminum irrigation pipe) was placed on both sides of the levee and covered with soil to make a ramp. The tractor still sunk into the ramps repaired with loose clay. The soil of the levees compacted approximately 6 to 8 in. with the first pass and continued to compact 0.5 in. or more with subsequent passes. Compacted clay was then used to repair the ramps and levees. This proved to be barely adequate to support the tractor for the four treatments. There was a slight hard pan in the clay soil at approximately 6 in., but the wheel tracks grew deeper with each pass of the tractor. Following a straight line through the field when the soil was muddy or flooded was somewhat difficult. On subsequent passes, the tractor tires fell into the previous wheel tracks and did not wander. Steering out of the track sometimes proved difficult.

The tractor could not move more than short distances through muddy, unflooded clay before the tires lost traction and became ineffective. Driving through flooded fields proved quite easy because the flow of water around the tires cleaned the mud from the tires on both types of soil.

Tires on the tractor were approximately 32 in. in diameter. The levees were approximately 32 in. tall from the bottom of the borrow ditch to the top of the levee. In order to have enough momentum to cross the levees, the tractor generally had to be traveling about 4 mph. Crossing the levees at this speed put significant stresses on the tractor frame, and the steering arms were broken and had to be rewelded several times. Spraying speed may need to be reduced while crossing levees to reduce these stresses. However, accurate spraying usually requires a steady speed.

Crossing the silt loam levees at 4 mph usually made it difficult for the driver to retain control of the tractor. The ramps installed over the borrow ditches at Keiser made crossing the clay levees somewhat easier. The axles of the GBA often had a lateral displacement (sliding sideways) of 24 in. when crossing a levee. When equipped with a long boom, the boom angle and elevation would change significantly while crossing the levees and, with less severity, also while driving across the field. The boom would, therefore, need to be self-leveling and have a rather fast response time to keep the application uniformity associated with a uniform boom height and to prevent damage to the boom. A 60-ft self-leveling boom has been obtained for this project and is now being evaluated. Development of an active suspension is indicated by this year's observations. An active suspension will allow the driver to stay in control and reduce the forces on the boom and frame components while crossing levees.

The main purpose of this experiment was to measure the yield reduction caused by wheel tracks. The results of the yield differences at the two locations are given in Table 1. Each location (soil type) was analyzed separately. At the Stuttgart location, treatment type was found to be significant, indicating that at least some of the treatments produced a change in yield. Row direction was not found to be significant, indicating that changing the direction of travel relative to the row direction did not significantly affect yields. The yield reductions as a result of the passes made at PF and at IE were not significant. This was probably because early passes allowed the rice plants to recover and allowed rice plants adjacent to the wheel tracks more time to compensate. Single passes made BH and AH reduced yields significantly. This was probably because the rice plants did not have time to recover from the damage and adjacent plants had only a short period of time to compensate. BH and AH passes made in the same wheel tracks as PF and IE passes produced smaller yield reductions than single passes made at BH and AH. Considering yield losses averaged over row direction, the yield loss resulting from a single pass BH was 15% compared to a yield loss of 9% for a PF, IE and BH combination of passes all made in the same wheel track. These yield losses were not significantly different from each other. The yield loss resulting from a single pass AH was 26% compared to a yield loss of 14% for the PF, IE, BH and AH combination of passes all made in the same wheel track. These yield losses were significantly different from each other.

At the Keiser location, treatment type was found to be significant, indicating that at least some of the treatments produced a change in yield. Row direction was found to be significant, indicating that changing the direction of travel relative to the row direction did change yields. This effect was probably the result of a very poor initial stand. In several plots, the tires did not even come into contact with growing plants when the passes were made on the row. Significant increases in yield were reported in some plots for a pass made at PF. This was probably because of a poor plant stand in the control plots. Since passes made across the row should be more independent of a poor stand, passes made across the row direction will be discussed first.

Multiple passes made in the same wheel track had higher yield losses than single passes at the Keiser location; the opposite observation was made for the data from the Stuttgart location. The combination of passes made at PF, IE and BH in the same wheel track had higher yield loss than for the same group of individual wheel passes. The combination of passes made at PF, IE, BH and AH in the same wheel track had lower yield losses than the same group of individual wheel passes. When the passes were made on the row, multiple passes made in the same wheel tracks had higher yield losses than the same passes made in single wheel tracks. Strong emphasis cannot be placed on the results from Keiser due to a the weak plant stand.

Assuming that plants adjacent to the wheel track were not damaged, the theoretical maximum yield loss for a 11.5-in.-wide tire track in a 28-in.-wide header is 41%. The maximum observed yield loss, which resulted from four passes made in the same wheel track in a clay soil at Keiser, was 34%. Figure 2 is a graph that shows both the theoretical maximum yield loss and projected yield loss for a range of boom widths. The theoretical maximum was based on total loss of yield in wheel tracks, and projected yield loss was based on the observed maximum yield loss of 34% for a 28-in. header. When adjusted for the use of a 60-ft boom, the projected yield loss in the field would be 2.6%. This yield loss would be equal to a $20 loss/acre based on data for Arkansas in 1992. Considering the Stuttgart data alone, a more reasonable maximum observed loss of 15% in the sample strip could be used. This would represent a yield loss of 1.2%, or $9/acre, for a 60-ft boom. If this loss were offset by lowered application costs, a GBA should be able to compete on an economic basis with present aerial methods of application.

SIGNIFICANCE OF FINDINGS

On the silt loam soil in Stuttgart, passes made before flooding and at internode elongation did not significantly reduce yields. Wheel tracks resulting from the three single passes made at pre-flood, internode-elongation and before-heading growth stages caused an average yield reduction of 9%. An additional pass after heading brought the yield reduction to 14%. A single pass made before heading reduced the yield by 15% while a single pass after heading caused a yield reduction of 26%. These yield losses are for 28-in.-wide sample areas. If the ground-based applicator were equipped with a 60-ft boom, the 26% sample yield loss would represent a 2% reduction in yield in a production field. Passes made early in the rice growth cycle appear to allow the injured plants to recover and possibly allow adjacent plants to compensate. The largest yield reductions were observed when the first pass was made late in the growth cycle. Additional research should be performed to gather data from a more representative plant population and to explain the differences due to row direction in the clay soil.

The crossing of levees will be a serious concern for ground-based applicators. Damage to levees must be repaired, particularly in clay soil. Slowing to cross levees will cause uneven chemical application. Tilting of the machine can cause boom tips to strike the ground. Rough ride for the operator and damage to the machine must also be considered. To minimize these factors, as well as to reduce loss of yield due to wheel tracks, a wide, self-leveling boom with automatic sprayer controls is indicated. An active self-leveling suspension system would also be of benefit.

Table 1. Mean reduction of yield due to traffic at indicated stage of growth and row orientation.

Stuttgart Location

Growth stage[z]					Mean[y] yield reduction		
PF	IE	BH	AH	TMT#	Perpendicular to drill rows	Parallel to drill rows	Combined average
X				1	-2ab	2a	0a
X	X			2	2ab	6ab	4ab
X	X	X		3	9bc	8abc	9bc
X	X	X	X	4	15cd	14bc	14c
	X			5	-3a	0a	-1a
		X		6	15cd	14c	15c
			X	7	24d	29d	26d

Keiser Location

Growth stage					Mean yield reduction		
PF	IE	BH	AH	TMT#	Perpendicular to drill rows	Parallel to drill rows	Combined average
X				1	-6a	-14a	-10a
X	X			2	15bc	6bc	11bc
X	X	X		3	25cd	14bc	19bc
X	X	X	X	4	34d	17c	25c
	X			5	4ab	4bc	4bc
		X		6	20cd	-4ab	9bc
			X	7	17bc	5bc	11bc

[z]PF - pre-flood; ID = internoted elongation; BH = before heading; AH = after heading
[y]Means followed by the same letter are not significantly different ($\alpha = 0.05$).

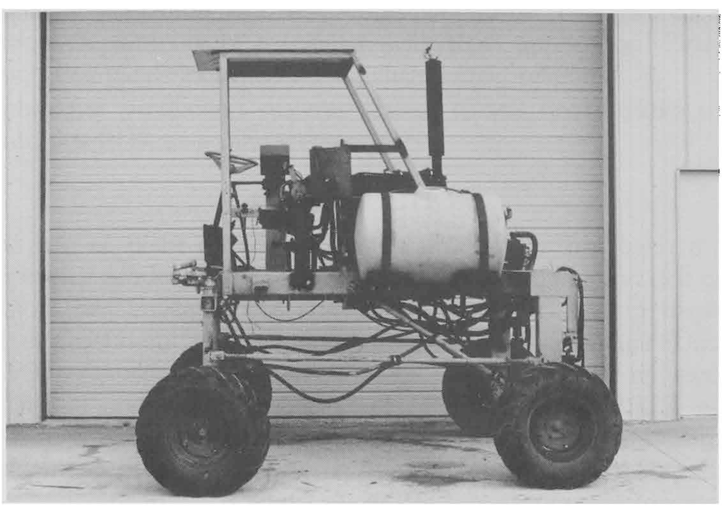

Fig. 1. The ground-based applicator (GBA) (tractor) for spraying in flooded rice.

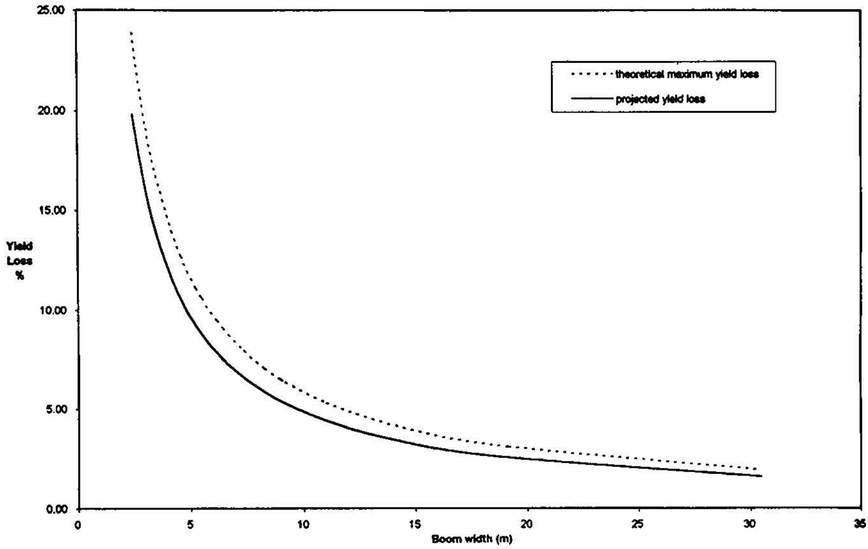

Fig. 2. Relative yield loss vs. boom width.

EFFECT OF CGA-163935 ON GROWTH AND YIELD OF RICE

D.C. Annis, Jr. and C.R. Shumway

ABSTRACT

Experiments were conducted to determine the effects of a plant growth regulator (PGR) (CGA-163935 CIBA[R], Greensboro, North Carolina, trinexapac-ethyl) on growth and development of rice. The experiments were conducted on three rice varieties. PGR application were made at three growth stages (internode elongation 0.5-1 in., 1-3 in. and >3 in.). Plant evaluations included phytotoxicity, plant height, lodging and rough rice yield. No visual phytotoxicity was detected at any location with any application time. Results indicated a reduction in plant height associated with PGR application. Evaluation of rough rice yields indicated no significant yield response.

Within the production systems tested, it was not possible to fully evaluate this PGR as a management tool.

INTRODUCTION

The use of plant growth regulators (PGRs) has not been a major factor in rice production. Recently published information on rice growth regulators has indicated the efficacy of gibberellic acid in respect to stand establishment and increased germination percentage (Dilday et al., 1991). Applications of mefluidide on rice significantly reduced both plant height and yield (Dunand et al., 1986). CGA-163935, a plant growth regulator, indicated a response in suppressing vegetative growth and seedhead production in turf species (Johnson, 1994). Unpublished research demonstrated that CGA-163935 has potential for reducing plant height in rice. The objective of this research was to evaluate

CGA-163935 as an anti-lodging agent and its effects on plant height and rough rice yield.

PROCEDURES

This research was conducted in five locations (Cross and Poinsett Counties) over two years (1992 and 1993). Research plots were established in producers fields in a randomized complete block design. Producers followed Arkansas Cooperative Extension recommendations for fertilization, weed control and disease control.

CGA-163935 was applied at three application timings after the start of internode elongation (IE). The application timings were at IE + 0.05 to 1 in., IE + 1 to 3 in. and IE + >3 in. Chemical applications were made with a CO_2 backpack sprayer at a rate of 18 g active ingredient (ai)/acre with a carrier volume of 20 gallons/acre (GPA). Three varieties were evaluated: 'Alan', 'Rico 1' and 'Lemont'. Lemont and Rico 1 were grown on a silt loam soil in Poinsett County, Arkansas. Alan was grown on a clay soil in Cross County, Arkansas.

After application of CGA-163935, varieties were rated for phytotoxicity, plant height, yield and lodging. The varieties were rated for toxicity at 24 hours, 48 hours, 72 hours, 1 week and 2 weeks after application. Five plants were removed randomly from each treatment for plant height and internode length evaluation at 50% heading. Plant height was determined from the last root internode to the base of the panicle. Rough rice yield was measured by harvesting a random subplot from each treatment, approximately 11ft^2 in size..

RESULTS AND DISCUSSION

The locations used in this study did not experience significant levels of lodging. Therefore, evaluation of this variable could not be accomplished. Phytotoxicity due to application of CGA-163935 was not a problem. All tested varieties indicated no phytotoxicity at any application timing.

Data shown in Table 1 indicate that PGR treatments significantly reduced plant height of all three varieties in 1992 and of Rico 1 in 1993. This was attributed to a reduction in internode length (data not shown). CGA-163935 suppressed turfgrass growth by interfering with gibberellin biosynthesis and reducing cell elongation and subsequent plant organ expansion (Johnson, 1994) This mode of action may be responsible for the results observed in this study. Evaluation of rough rice yield indicates no significant difference in grain yield for any PGR treatments. However, PGR-treated Alan and Rico 1 had numerically increased yields in both production years. This may indicate that there is potential for yield response under certain production environments. Lemont yields were numerically reduced by PGR treatments. Apparently the reduced height of plants in the PGR-treated plots resulted in more severe damaged by sheath blight, causing the numerical yield reduction.

SIGNIFICANCE OF FINDINGS

In this study, a limited number of variables were tested to determine the efficacy of CGA-163935 as an anti-lodging agent. Data indicated that plant height was reduced significantly. Lodging could not be directly evaluated; therefore, the value of this material as a true anti-lodging agent was not determined. Further evaluations in respect to variety and agronomic inputs need to be conducted to determine if the material has potential for use on rice.

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Table 1. Effect of CGA-163935 application at three stages of development on plant height and rough rice yields.

Treatment	Height		Rough Rice Yield	
Stage	1992	1993	1992	1993
	------------ in. ------------		----------- lb/acre ----------	
Alan				
Untreated Check	35.6	30.6	4783	6741
0.5-1.0 in.	31.6	28.0	5250	6808
1.0-3.0 in.	29.3	28.7	5050	6960
>3.0 in.	31.8	28.8	5806	7007
LSD $_{(0.05)}$	2.1	NS[z]	NS	NS
C.V. 1992	10.29			
C.V. 1993	18.48			
Rico 1				
Untreated Check	30.6	26.8	7486	6799
0.5-1.0 in.	24.4	26.0	8982	5758
1.0-3.0 in.	28.9	24.3	9066	7520
>3.0 in.	23.7	27.0	8673	7334
LSD $_{(0.05)}$	2.2	1.5	NS	NS
C.V. 1992	12.92			
C.V. 1993	9.32			
Lemont				
Untreated Check	20.5	--[y]	7028	----
0.5-1.0 in.	16.6	--	6510	----
1.0-3.0 in.	15.9	--	6222	----
>3.0 in.	17.9	--	6486	----
LSD $_{(0.05)}$	2.6	--	NS	----
C.V. 1992	8.48			

[z]No significant difference.

[y]Lemont was not evaluated in 1993.

MILLING QUALITY AS AFFECTED BY BROWN RICE TEMPERATURE

T.J. Siebenmorgen and T.R. Archer

ABSTRACT

Three cultivars of long-grain rice were used to evaluate the effects of cooling brown rice before milling on head rice yield (HRY) and degree of milling (DOM). Brown rice at initial temperatures (T_i) ranging from 0 to 25 C was milled for either 15, 30, 45 or 60 sec in a McGill No. 2 laboratory mill. The HRY versus T_i and the HRY versus DOM relationships were inverse linear. The three cultivars showed HRY increases of 1.4 to 1.8 percentage points for T_i reduction from 25 to 0 C at the standard 30-sec milling time (MT). However, when HRYs were adjusted to equivalent DOMs using a commercial milling meter, there was no significant improvement in HRY due to cooling the brown rice.

INTRODUCTION

During milling, bran is being removed while simultaneously the bran remaining on the kernel is increasing in temperature. Rice processors and producers have posed the question as to the effects of rice temperature at the initiation of milling on milling quality. Bhatia (1969) reported that breakage decreases exponentially with the increase of initial grain temperature. In their experiment, rice was milled at three initial grain temperatures: 21.1, 26.7 and 32.2 C. No literature was found concerning the effects of cooling rice prior to milling. The purpose of this study was to quantify these effects in terms of milling quality.

OBJECTIVES

The objectives of this study were 1) to determine the effects of milling brown rice at various initial brown rice kernel temperatures (T_i) on head rice yield (HRY) and degrees of milling (DOM); and 2) to use the relationships between HRY and DOM for each T_i to adjust for DOM effects and determine if cooling brown rice before milling can increase HRY.

MATERIALS AND METHODS

Three long-grain rice cultivars, 'Adair', 'Alan' and 'Newbonnet', were used. The rough rice was cleaned and dried to 14% moisture content (MC[1]), wet basis, immediately after harvest. It was then bagged in paper sacks and placed in storage at 1 C for 10 months until being removed for milling. At the time of milling, the MC for each of the cultivars was measured by drying in an oven at 130 C for 24 hours. The MCs of the Adair, Alan and Newbonnet lots were 13.1, 13.6 and 14.0%, respectively.

After being removed from cold storage and the rough rice MC determined, 150-g rough rice samples were hulled with a Seedboro sheller-huller at a rate of approximately 500 g/minute (USDA, 1984) to yield a brown rice sample of at least 123 g. Each brown rice sample was placed in doubled, sealable plastic bags to prevent any change in MC. Twelve samples for each T_i to be tested within each cultivar were held at temperatures ranging from -10 to 25 C. Samples were held in the respective temperature conditions for at least 24 hours to allow all kernels to come to a uniform temperature. Samples were removed from their respective temperature conditions just prior to milling and placed in an insulated cup. The T_i was measured using a thermocouple. The mean temperature of the 12 samples taken from a set condition was reported as the T_i for those samples.

A McGill No. 2 mill was instrumented with thermocouples on the outside and inside of the mill chamber. The mill was warmed by milling approximately 120 g of brown rice until the external mill temperature reached at least 28.5 C. Milling of each of the subsequent samples began when the external mill temperature cooled to 28.5 C. This was done to reduce variability that might occur due to mill temperature. Brown rice samples of 123.0 g were milled for 15, 30, 45 or 60 sec. A 1500-g mass was placed on the mill lever arm, 15 cm from the center of the milling chamber. Immediately after milling, the rice was placed in an insulated cup, and the final milled rice temperature (T_f)

[1]All moisture contents are expressed on a wet basis.

was measured using a thermocouple. Three milling replications were done at each of the four milling times (MTs) for each T_i.

DOM of the head rice was measured using a Satake milling meter, Model MM-1B. The milling meter displays DOM as a value from 0 (brown rice) to 199 (pure white rice). Therefore, the larger the DOM number, the more completely milled the sample. DOM levels of 85 to 95 are target levels for most commercial rice mills. Three DOM readings were taken on a subsample of approximately 25 g. The meter displayed the average DOM value for the subsample. This procedure was repeated for two additional subsamples, and the mean of the three average DOM readings was reported as the DOM for the sample.

RESULTS AND DISCUSSION

Regression analyses that related HRY to T_i for Adair, Alan and Newbonnet showed HRY increases of 1.4, 1.6 and 1.8 percentage points, respectively, for T_i reduction from 25 to 0 C. Figure 1 shows the relationship of HRY to T_i for the three cultivars for the standard 30 s MT. HRY was linearly and inversely correlated with brown rice T_i.

Graphs of DOM versus MT for different T_is (not shown) showed that HRY for a given MT should not be directly compared from one T_i level to another because of large differences in DOM between the T_is. For a given MT, a sample with a lower T_i milled to a lesser DOM. HRYs for the various T_is needed to be adjusted to equivalent DOMs before comparisons could be made.

The regressions shown in Fig. 1 do not include an adjustment for DOM. A wide range of DOMs and associated HRYs was created by the various MTs. These data were used to regress HRY against DOM. The HRY versus DOM trend for Adair can be seen in Fig. 2. The model equations that correlated HRY (at a given T_i) to DOM was as follows:

$$HRY_{(Ti)} = a + b*DOM \qquad (1)$$

where a and b are regression coefficients. Values for a and b are given in Table 1. The relationship between HRY and DOM was found to be linear for each T_i, with most R^2 values being greater than 0.90. If all T_is were grouped together within each cultivar, the R^2 values were 0.91, 0.89 and 0.85 for Adair, Alan and Newbonnet, respectively. These high R^2 values indicate that the relationship between HRY and DOM was independent of T_i.

HRY was dependent on DOM, which in turn was affected by T_i. To directly compare the HRYs of samples with different T_is, the samples from each T_i were adjusted to equivalent DOMs. This was done by using Equations 1 and 2 for each T_i and inputting 80, 90 and 100 for the DOM level. This range encompasses the target DOM values for rice millers. The results of these calculations are found in Table 2. After HRYs were corrected for DOM, Table 2 shows that there was no significant improvement in HRY as initial milling T_is were decreased.

Regression analysis was performed to determine the relationship between MT and resulting DOM for each T_i within each cultivar. The trend was that the lower the T_i, the longer the sample had to be milled to reach a desired DOM level. For example, Alan rice at a T_i of 23.2 C reached a DOM of 90 in 31 sec, whereas 44 sec of milling was required to reach a DOM of 90 for a T_i of 1.7 C.

A strong relationship was found when T_f was regressed against DOM for each T_i in each cultivar. Figure 3 shows this relationship for Newbonnet. Most R^2 values for the three cultivars exceeded 0.92. No trends were noted when comparing sample T_f to T_i at given DOMs. The initial, wide spread in temperature between the T_i treatments was greatly diminished when comparing associated T_fs at equivalent DOMs. A 24 C difference in T_i for Adair was reduced to only 3.3 C difference in T_f at the DOM level of 80. The changes for the other cultivars were 21.5 to only 0.7 C for Alan and 18.8 to 6.2 C for Newbonnet.

SIGNIFICANCE OF FINDINGS

HRY was affected by brown rice T_i. This apparent effect was due primarily, if not totally, to resulting DOM of the samples. After HRYs were adjusted to given DOM levels, there was no change in HRY due to milling at different T_is. Thus, no practical improvement in HRY was obtained by cooling brown rice before milling when DOM was considered. Brown rice that had been cooled had a lower DOM after being milled for the same length of time as a sample that had not been cooled. Bran properties were apparently affected by kernel temperature as there was a strong correlation between T_f and DOM. At low temperatures, the oil in the bran is more viscous and more difficult to remove from the kernel than it is when it is in a warmer, less viscous state. It is speculated that the bran must reach a sufficiently high temperature before it can be removed readily from the kernel. Brown rice at lower T_is requires more energy input from the mill to reach the proper temperature range for bran removal than does rice at higher T_is and, therefore, must be milled longer to reach equivalent DOMs.

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Table 1. Coefficients of linear regression of Equation 1 relating head rice yields at measured initial brown rice temperatures (T_is) to degree of milling for 'Adair', 'Alan' and 'Newbonnet'.

	Coefficients		
T_i (°C)	a	b	R^2
Adair			
0.4	67.913	-0.0935	0.962
10.5	69.580	-0.1082	0.909
24.4	70.206	-0.1201	0.914
All[z]	68.914	-0.1046	0.910
Alan			
1.7	63.520	-0.0851	0.926
12.6	65.023	-0.1050	0.912
23.2	68.799	-0.1379	0.955
All	64.750	-0.0992	0.889
Newbonnet			
2.1	77.257	-0.1117	0.942
9.6	77.038	-0.1254	0.935
10.5	78.088	-0.1285	0.929
13.4	77.807	-0.1298	0.948
14.3	80.013	-0.1446	0.939
17.4	78.132	-0.1352	0.879
17.6	79.199	-0.1495	0.933
20.8	80.430	-0.1511	0.916
20.9	77.650	-0.1302	0.923
All	78.068	-0.1308	0.848

[z]"All" indicates the coefficients of regression if all T_is are grouped together in the regression analysis.

Table 2. Estimated head rice yields (HRYs) for measured initial brown rice temperatures (T_is) for given degrees of milling using Equation 1 for 'Adair', 'Alan' and 'Newbonnet'.

T_i (°C)	Degree of Milling 80	90	100
	----------HRY (%)----------		
Adair			
0.4	60	59	59
10.5	61	60	59
24.4	61	59	58
All[z]	61	59	58
Alan			
1.7	57	56	55
12.6	57	56	55
23.2	58	56	55
All	57	56	55
Newbonnet			
2.1	68	67	66
9.6	67	66	64
10.5	68	67	65
13.4	67	66	65
14.3	68	67	66
17.4	67	66	65
17.6	67	66	64
20.8	68	67	65
20.9	67	66	65
All	68	66	65

[z]"All" indicates the coefficients of regression if all T_is are grouped together in the regression analysis.

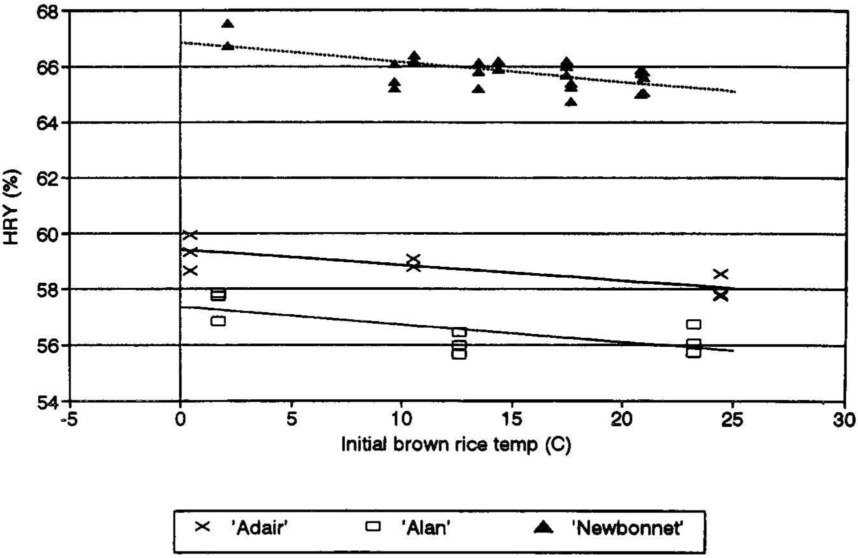

Figure 1. Head rice yield (HRY) versus initial brown rice temperature for 30 sec milling times for the three varieties tested. Data do not include an adjustment for degree of milling. Each data point represents a HRY determination.

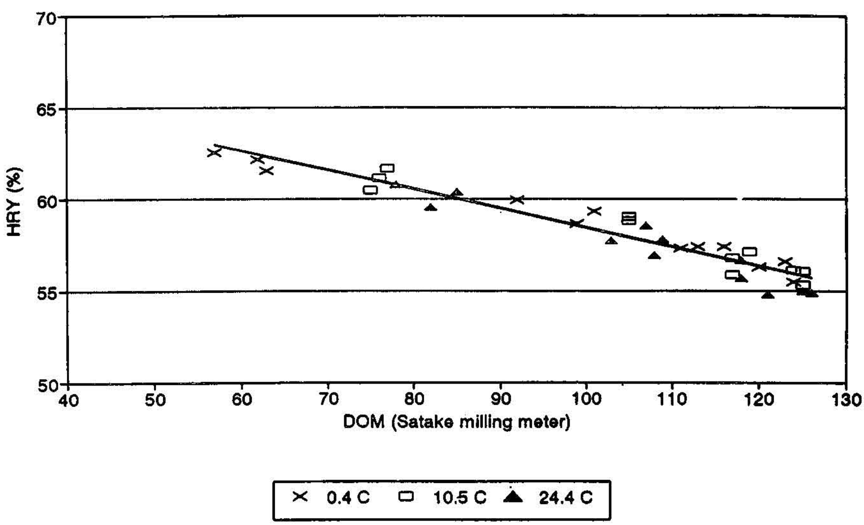

Figure 2. Head rice yield (HRY) versus degree of milling (DOM) for 'Adair' at the indicated initial brown rice temperature. The regression line fitting data from all initial brown rice temperatures across all milling times is shown.

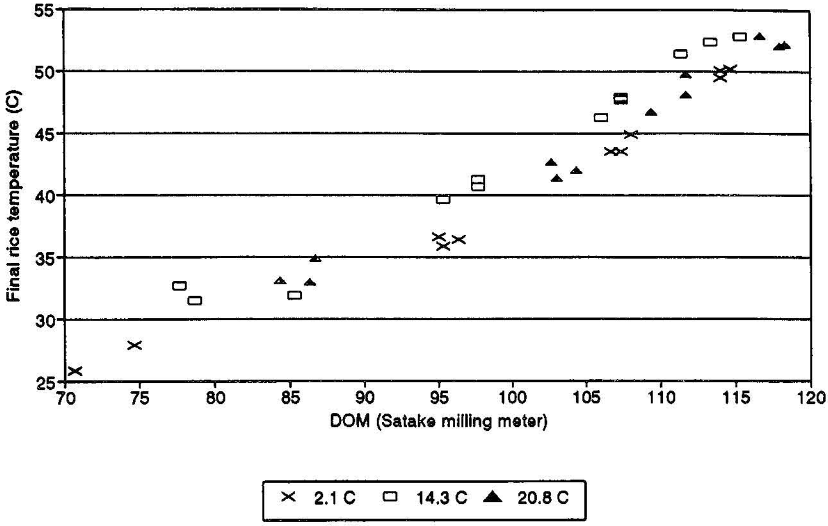

Figure 3. Final rice temperature versus degree of milling (DOM) for 'Newbonnet' at the indicated initial brown rice temperature. For clarity, data points only for a high, medium and low initial brown rice temperature are shown.

CAUSES OF MULTI-MODAL MOISTURE CONTENT FREQUENCY DISTRIBUTIONS AMONG RICE KERNELS

T.J. Siebenmorgen, P.A. Counce, G.E. Holloway and R. Lu

ABSTRACT

In a greenhouse study, individual kernel moisture content was measured for the main stem and for primary, secondary and tertiary tillers in five plants (replicates) per harvest day for nine harvest days. One of the objectives was to determine whether the multimodal distribution of number of kernels versus moisture content observed in the field (Kocher et al., 1990; Siebenmorgen et al., 1992) could be attributed to the location where the seed was borne with respect to main stem or tillers. The main stem and primary and secondary tillers exhibited very similar multimodal distribution patterns. Therefore, the different moisture content peaks or "modes" could not be explained by main stem or tiller influence. However, a possible explanation of the multimodal frequency distribution pattern, based upon the change in moisture content of an individual rice kernel during its development, is presented.

INTRODUCTION

In previous studies (Kocher et al., 1990; Siebenmorgen et al., 1992), frequency distribution graphs revealed that kernel moisture contents (MCs)[1] fell into up to three groups or modes during the harvest season. In this paper, two possible explanations for these modes are explored. The first explanation was related to rice plant structure. Most kernels

[1]All MCs are expressed on a wet basis.

are formed on the main stem, the primary tiller and the secondary tiller of the rice plant. Furthermore, these three structures emerge successively. Thus, the first speculation explored was that the three modes could be explained by the emergence and development of kernels on these three plant structures.

MATERIALS AND METHODS

A greenhouse experiment was seeded in December 1989 and terminated with the final harvest in June of 1990. The MC of every kernel by tiller type on each of five plants (five replicates) was measured on each of nine dates during the harvest period: 30 May and 1, 4, 6, 8, 11, 13, 15 and 18 June. Therefore, 45 plants were sampled.

Each plant was grown in a 0.2-m-diameter, 5.8-L plastic pot filled with 4.7 kg of Sharkey silty clay soil (Vertic Haplaquepts, pH 6.7). The 45 plants were arranged in randomized complete blocks with five replications on a single greenhouse bench. Prior to flooding, plants were assigned to replicates by size, the largest plants being selected for the first replication and the remainder being grouped progressively down to the smallest plants, which were assigned to the fifth replication. Therefore, replicates were blocked by size, and the treatment was the harvest date. The harvest date was independent of plant size because one randomly selected plant from each of the five replications was harvested on each date.

The long-grain rice cultivar used in the experiment was 'Alan'. Conditions of the experiment were arranged so as to maximize tillering and differences in tiller ages within plants. Pots were fertilized with a dilute solution of urea (730 mg N/pot) at flooding, at panicle differentiation (365 mg N/pot) and seven days after panicle differentiation (365 mg N/pot). Temperatures in the greenhouse were maintained between 14 and 20 C between seeding and flooding. From the date of flooding onward, temperatures were maintained between 20 and 30 C until the final five harvest dates of the experimental period when temperatures ranged between 30 and 44 C. Supplemental radiation was supplied for the plants by metal halide lamps, operated from 5:00 a.m. to 7:00 p.m. daily. The irradiance without sunlight was measured to be 150-200 $\mu mol/m^2/sec$ at the top of the canopy. The bench was progressively lowered to maintain the height of the lamps above the plants at 1.5 m. On clear days, lamps were turned off from 9:00 a.m. to 3:00 p.m.

Beginning at flooding, individual tillers arising from each plant were tagged, mapped and identified as to order of emergence and tiller type. At harvest, the stubble and panicle were separated for each culm that produced a panicle. The number of kernels, weight of kernels and weight of stubble were recorded for each main stem and tiller bearing a panicle. Individual kernel MCs were determined with a Shizuoka Seiki Co., Ltd. Model CTR-800[2] single kernel moisture meter.

RESULTS AND DISCUSSION

MC Frequency Distribution as a Function of Tiller Type

Table 1 presents the average MC and associated standard deviation of kernels on each harvest day. For the most part, the average MC and the standard deviation steadily decreased throughout the harvest period, from 1 June to the end of the harvest season.

Table 2 presents the average number of panicles per main stem and tiller type and the total number of kernels per plant component. The secondary tillers produced approximately 43% of the total number of kernels followed by the primary tillers, which produced approximately 42% of the kernels. The main stem and tertiary tillers produced approximately 9% and 5% of the total number of kernels, respectively.

Figure 1 represents a summary of the MCs of all the kernels measured throughout the study. The three modes observable in Fig. 1 are more explicitly illustrated in Fig. 2, 3 and 4, which represent cross sections of Fig. 1 on harvest dates 1, 8 and 15 June, respectively. These plots include the MC frequency distributions for all the kernels combined (total) and each tiller type. The first mode centered at approximately 31% MC (Fig. 2 and 3), the second mode at approximately 24% MC (Fig. 3 and 4) and the third mode at approximately 15% MC (Fig. 2, 3 and 4). It was apparent from these figures that the primary and secondary tillers exhibited the same general MC distribution pattern. Because of the relatively small contribution of the main stem and tertiary tillers to the total number of kernels, it was not evident from Fig. 2, 3 and 4 if these tillers followed the same general pattern as the primary and secondary tillers. However, cumulative frequency graphs of number of kernels versus MC for the main stem and the various tiller types indicated that, even though there were fewer kernels on the main stem, the cumulative MC frequency distributions were similar to the other tillers. Since there were so few kernels collected from the tertiary tillers, it was difficult to determine a typical cumulative frequency distribution pattern. On 8 and 18 June, for instance, only 1.3% and 0.9% of the total number of kernels tallied were from tertiary tillers.

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[2]Mention of a commercial name does not imply endorsement by the University of Arkansas.

Therefore, it is evident from Fig. 2 through 4 that the multimodal MC distribution could not be attributed to where the seeds were borne with respect to main stem or tillers. The following section poses a possible explanation of why the multimodal MC distribution exists.

Multimodal Moisture Content Distribution Hypothesis

The hypothesis explored was related to individual rice kernel development. On a rice plant, florets (which later develop into kernels) do not all emerge at the same time. Anthesis or flowering usually starts at the top of the panicle and ends at the bottom. A typical anthesis pattern is shown in Fig. 5. Since some rice panicles emerge earlier than others, the process of flowering of an individual plant can occur over a period as long as 15 days (Luh, 1991). Yoshida (1981) recorded the changes in MC at successive stages of growth for two varieties of rice under three different temperature regimes. A characteristic pattern, illustrated in Fig. 6, was that there were periods during growth and maturation when the MC remained relatively constant compared to other periods. The plateau MCs and the times at which these plateaus occurred varied among the six plots. In other words, the MCs at which the plateaus, hence the expected modes, occurred differed depending on rice variety and temperature regime.

Because individual florets emerge at different times, if they all followed similar MC versus time relationships as depicted in Fig. 6, when the individual MCs for all kernels were tallied, the MC frequency distribution would display a mode corresponding to each plateau in the individual kernel MC versus time curve. In other words, if individual kernels remained at certain MCs for extended periods of time during development, when the MCs of the individual kernels were compiled, more kernels would tend to fall around these "plateau" MCs than at others. Therefore, it is possible that the multimodal MC distribution observed could be explained by MC plateaus that occurred during maturation of the individual kernels. A detailed analysis illustrating and quantifying this hypothesis is given by Holloway et al. (1995).

Further study is needed to evaluate this proposed explanation of multimodal MC frequency distribution among rice kernels and to understand how rice plant physiology and environmental factors affect the MC trend of individual kernels on a plant.

SIGNIFICANCE OF FINDINGS

Kernels from the main stem and all tillers of 'Alan' rice grown in a greenhouse exhibited similar MC frequency distribution patterns. Therefore, the different MC distribution modes could not be explained by differences in kernel MC patterns among main stem and tillers.

The multimodal MC frequency distribution may possibly be explained by the individual kernel MC plateaus observed during kernel development. When the MCs of all individual kernels are tallied at a given time to obtain the MC frequency distribution, modes would tend to form around the plateau MCs. This is because, at any given time, a greater number of kernels would tend to exist around the plateau MCs than at other MC levels.

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Table 1. Mean moisture content and standard deviation of all kernels harvested on each harvest day of the greenhouse study.

	Moisture Content (% w.b.)	
Harvest Date	Mean	Standard Deviation
30 May	30.7	6.6
1 June	26.7	7.8
4 June	26.2	7.4
6 June	23.8	6.5
8 June	21.8	5.6
11 June	19.1	4.5
13 June	18.4	3.9
15 June	18.5	4.1
18 June	19.7	4.2

Table 2. Average number of panicles and kernels per plant component for all plants harvested throughout the season.

Plant Component	Panicles Per Plant Component	Kernels Per Plant Component
Main Stem	1.00	200
Primary Tiller	6.00	893
Secondary Tiller	9.07	915
Tertiary Tiller	2.63	99

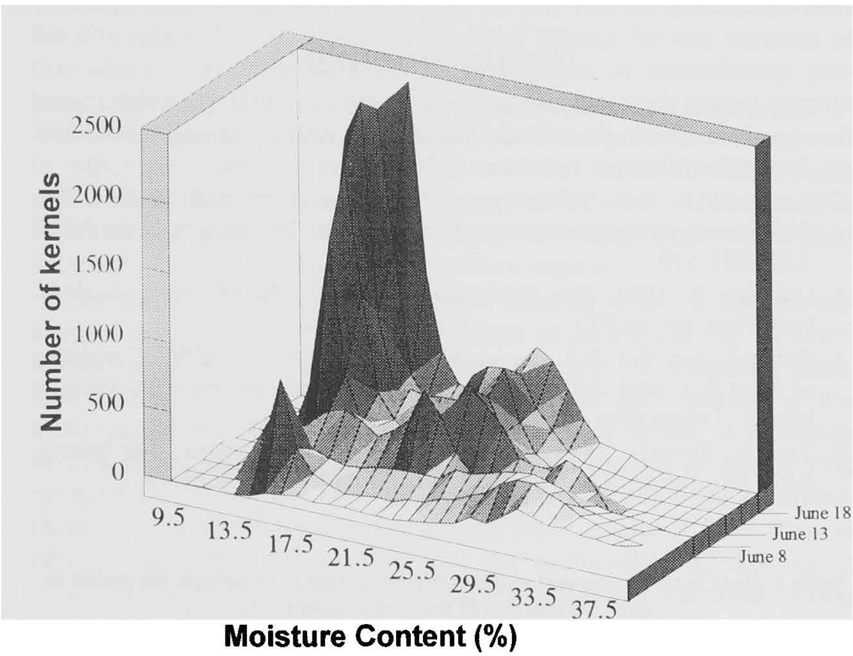

Figure 1. Rice kernel moisture content (% w.b.) distributions in 1990. Indicated dates are points of reference

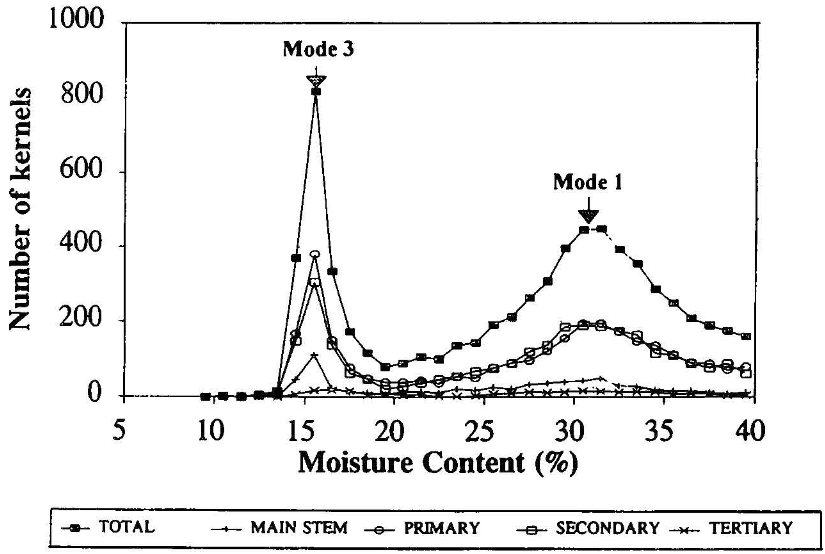

Figure 2. Moisture content distribution on 1 June by main stem and tiller type.

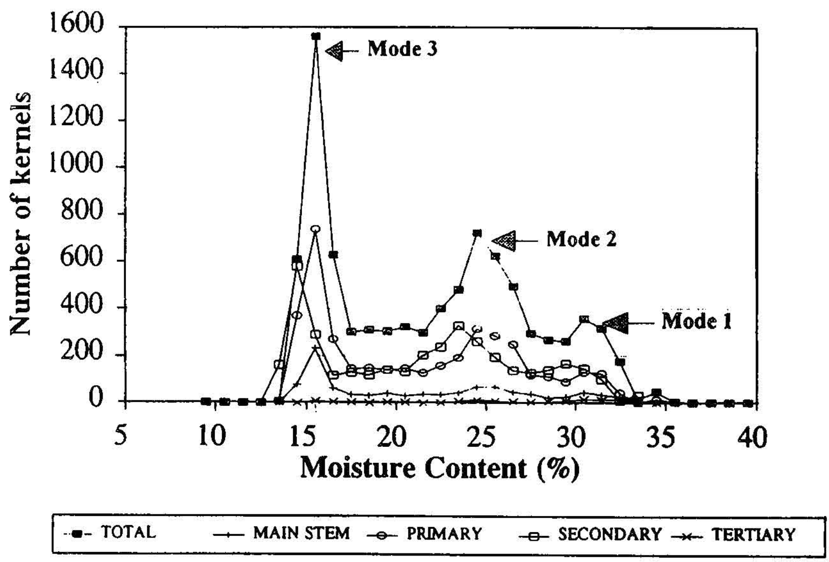

Figure 3. Moisture content distribution on 8 June by main stem and tiller type.

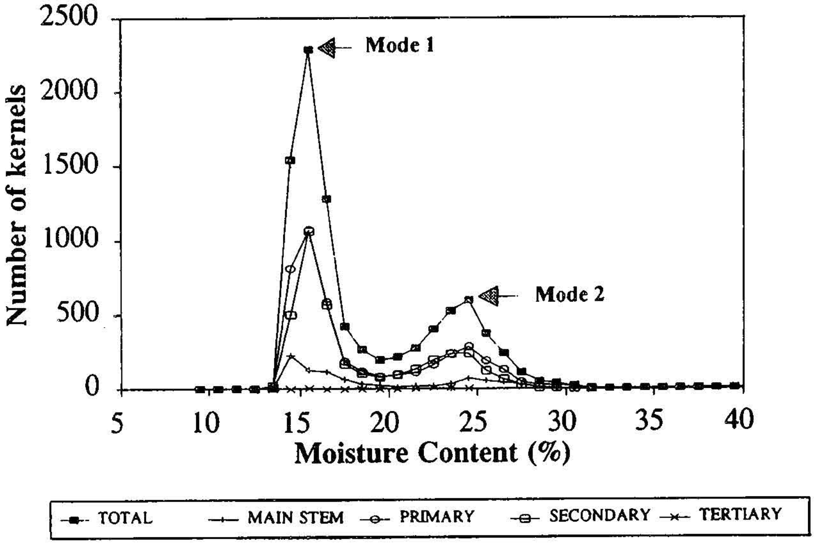

Figure 4. Moisture content distribution on 15 June by main stem and tiller type.

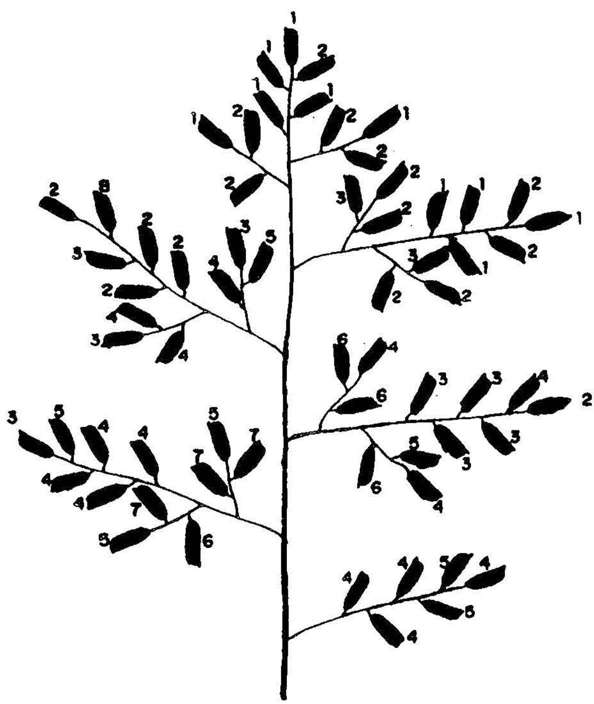

Figure 5. Anthesis or flowering pattern of a rice panicle with numerals indicating day of flowering (Luh, 1991).

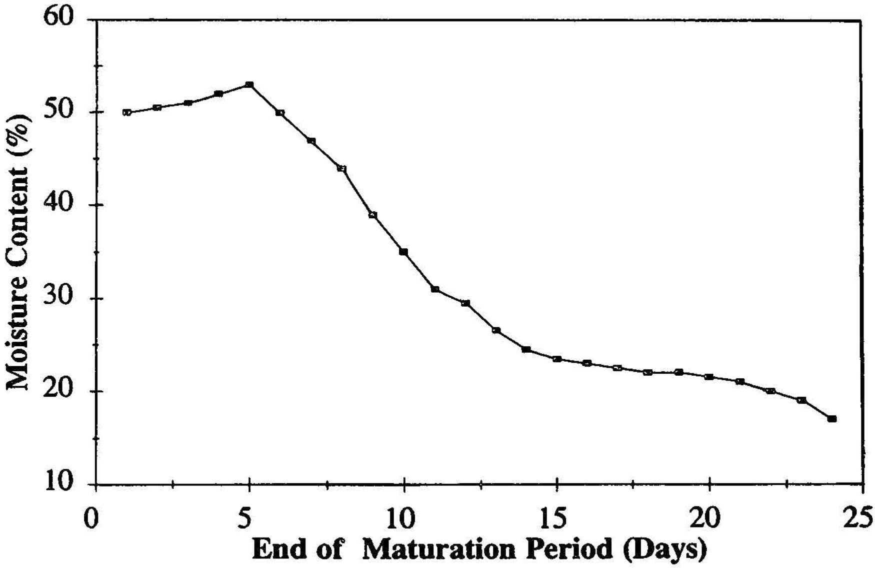

Figure 6. Water content of rice variety IR10 during growth and maturation under one temperature regime (Yoshida, 1981).

SIMPLE METHOD(S) TO DETERMINE RICE QUALITY AND INVESTIGATIONS OF NOVEL VALUE-ADDED USES OF RICE BRAN

PART A

I. DEVELOPMENT OF SIMPLE TESTING METHODS TO DETERMINE RICE QUALITY

N.S. Hettiarachchy, T. Siebenmorgen, K. Moldenhauer, R. Gnanasambandam and V.K. Griffin

ABSTRACT

It is important to develop simple testing methods to evaluate rice quality that might be useful in making specifications, quality control and varietal screening for breeding purposes. A method for measuring rice flour gels was developed, and a texture profile analysis (TPA) was obtained on each gel using a Texture Analyzer (TXT2). Gels from long-grains ('LaGrue' and 'Lemont') were harder than those from medium 'Bengal' or short-grain 'S201', as indicated by higher fracturability and hardness values. Gels from S201, a short-grain variety, were harder and had a higher fracturability value than those from Bengal. Gels from Bengal had the lowest values for fracturability, hardness, gumminess, cohesiveness and chewiness. The long-grain varieties (especially Lemont) were distinctly different in their pasting characteristics. The general trends in the pasting characteristics were more or less similar to textural properties of gels as measured by the Texture Analyzer. Bengal had the lowest values for most of the pasting characteristics studied. Studies were conducted to investigate in-vitro digestibility of rice starches treated with human salivary α-amylase. Long-grain samples (LaGrue and Lemont) showed slower sugar release than the short- and medium-grain samples during the first 15 min of hydrolyses. Information obtained on pasting characteristics, textural properties and

in-vitro digestibility can be used in development of suitable types and quality control of rice and rice products. Tests as developed in this study can be useful for varietal identification in breeding programs and quality control of rice and rice products.

INTRODUCTION

Consumption of rice in the U.S. has increased dramatically over the past decade, and there has been a steady increase in new processes and products involving rice as an ingredient: highly puffable rice, crispness-inducing agents in batters, hypoallergenic proteins and starch and fermentable substrates (Kohlwey, 1994). In each of these products, rice is used for a specific function. There has also been an increase in the use of rice flour as an ingredient in further-processed foods. Simple methods of testing are necessary to make specifications for use of rice and its products. These tests might be useful in varietal identification of rice for breeding programs and for quality control during further-processing of rice and its products. Tests used in this study are based on inherent differences in rice varieties. Amylography is routinely used in rice labs all over the world, including the Rice Quality Lab at Beaumont, Texas. Limitations in amylography (amylose content and concentration) may be overcome by using a Texture Analyzer. In-vitro digestibility has not been report as a routine test for quality evaluation.

Nutritional properties of rice varieties may be considered as another selection criterion to determine its quality. Increase in consumption of rice in the U.S. justifies investigations of nutritional significance of rice varieties.

Present studies were carried out to investigate textural properties of rice flour gels from four varieties, 'S201', 'Bengal', 'LaGrue' and 'Lemont', using the Universal Texture Analyzer and pasting characteristics of rice varieties using the Brabender Visco/amylograph. Studies were also conducted to investigate in-vitro digestibility of rice varieties using human salivary α-amylase.

PROCEDURES

Textural Properties

Textural properties of rice flour gels from four varieties were evaluated using a Texture Analyzer (TXT2). A method for measuring rice flour gels was developed, and a texture profile analysis (TPA) was obtained. Rice flours were cooked in water (8% w/v in distilled deionized water) at about 99 C for 2 min; the hot paste was poured into 50-mL beakers, covered and cooled to room temperature. Gels formed were stored for 24 hours at 4 C. Beakers containing gels were secured in a steel plate with a shallow hold for the sample (accessory specially designed for texture analyzer), and the gels were evaluated for fracturability, hardness, adhesiveness, cohesiveness, gumminess and chewiness. The accessory developed was necessary and useful to secure the sample container for the measurement of adhesiveness properties of gel.

Pasting Characteristics

A modified AACC procedure was used to measure pasting characteristics of the four varieties using a Brabender Visco/Amylograph (AACC, 1991). Forty-five grams of rice flour was blended with 300 mL of H_2O for 1.5 min. The flour slurry was washed with the remaining 150 mL of water into the viscometer bowl. The contents were heated at 95 C for 20 min and cooled to 50 C within 30 min. Peak viscosity (P), hot viscosity (H) and cool viscosity (C) of rice flour pastes were measured and used to determine the consistency (C-H), breakdown viscosity (P-H) and setback viscosity (C-P).

In-vitro Digestibility

In-vitro digestibility of whole, cooked rice grains from four rice varieties was determined by modified procedure of Yokoyoma et al. (1994). Rice samples were cooked in distilled, deionized water (dd water) (1:3) for about 20 min. Fifty grams of the whole, cooked rice was blended with 50 g of dd water in an 8-oz blender for 5 sec. Twelve grams of the slurry was weighed into a 250-ml erlenmeyer flask; 19 mL of dd water was added followed by 20 mL of 0.5M phosphate buffer (pH 4.9) and 5 ml of 30 mM $CaCl_2$, and the flask was swirled for about 5 sec to mix. A 5-ml sample was removed into a test tube, and human salivary α-amylase solution (100 units in 1 mM $CaCl_2$) was added and the flask swirled for about 2 sec to mix. The flask was covered and placed in a 37 C shaking waterbath, and a 5-ml sample was removed at 15-, 30- and 60-min intervals. The 5-ml samples were dispensed into a screw-cap test tube and placed in a beaker of boiling water for 8 min to inactivate the enzyme. After cooling to room temperature, the samples were centrifuged for 15 min at 25,000 x g. The supernatant was analyzed for maltose, and the results were expressed as mg maltose equivalents per gram sample.

Statistical Analyses

Experiments were conducted in a completely randomized design. Analysis of variance was performed, and least square means procedure was used to report differences in mean values if significant ($P < 0.05$) (SAS, 1988).

RESULTS AND DISCUSSION

Textural Properties

Textural properties of the four rice varieties evaluated are presented in Table 1. Gels from long-grain rice varieties (LaGrue, and Lemont) were harder than those from medium- (Bengal) or short-grain (S201) varieties, as indicated by a higher fracturability and hardness values. These long-grain gels were also more adhesive and had higher values for gumminess and chewiness. Gels from S201, a short-grain variety, were harder and had a higher fracturability value than those from Bengal.

S201 gels were also more gummy and chewy than gels from Bengal. While Bengal did not differ from S201 in adhesiveness scores, it had the lowest values for fracturability, hardness, gumminess and chewiness. No differences were observed in springiness and stringiness scores among rice varieties.

Positive correlations were observed between fracturability and hardness, hardness and gumminess and gumminess and chewiness (Table 2). All the traits measured for hardness were negatively correlated to cohesiveness, while there was a significant positive correlation between adhesiveness and cohesiveness in this study.

Pasting Characteristics

The two long-grain varieties showed numerous differences from the other varieties in their pasting characteristics (Table 3). Peak, hot and cool viscosities of Lemont, a long-grain variety, were significantly higher than those of LaGrue, also a long-grain. No differences were observed between LaGrue (long-grain) and S201 (short-grain) in peak, hot and breakdown viscosities.

Trends in the pasting characteristics were somewhat similar to textural properties of gels, as measured by the Texture Analyzer. Bengal medium-grain had the lowest values for almost all of the pasting characteristics studied, most notably the setback viscosity (a measure of difference between cool viscosity and peak viscosity).

In-Vitro Digestibility

In-vitro digestibility of rice varieties was evaluated to investigate differences in their susceptibility to human salivary α-amylase (Fig. 1). Differences were observed in the digestibility of starches. Both long-grain varieties (LaGrue and Lemont) showed slower maltose release than short-grain during the first 15 min, as indicated by a significantly lower amount of maltose released ($P < 0.05$). However, no differences among varieties in the amount of maltose released were observed at the end of 90 min of hydrolysis. All samples followed a similar trend in their susceptibility to enzymatic hydrolysis.

SIGNIFICANCE OF FINDINGS

Differences were observed among textural properties and pasting characteristics of the starch from different varieties. Tests developed to measure the textural properties can be used as standardized methods to monitor rice starch gels from different varieties. These tests might be useful for purposes of identification of different varieties of rice and also for quality control of rice products during further processing. Studies on pasting characteristics might be useful to predict functionality of rice starch from different varieties in different food formulations. In-vitro digestibility of rice starches provides an indication of their hypoglycemic response. Differences in the digestibility can be used to differentiate among rice varieties. Information on digestibility can also be useful to fabricate foods for diabetics and in infant food formulations.

ACKNOWLEDGMENT

Authors gratefully acknowledge the financial support provided by the Rice Research and Production Board for the above project.

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Table 1. Quality attributes of rice flour gels prepared from four varieties of Arkansas grown rice

	Variety			
Attribute	S201 S	Bengal M	LaGrue L	Lemont
Fracturability	0.045 b[z]	0.024 a	0.14 c	0.14 c
Hardness	0.058 b	0.038 a	0.14 c	0.15 c
Adhesiveness	-0.57 a	-0.59 a	-1.13 b	-1.11 b
Cohesiveness	0.70 b	0.78 c	0.51 a	0.49 a
Springiness	15.03	15.38	14.87	14.80
Stringiness	12.82	12.45	12.46	13.43
Gumminess	0.040b	0.03 a	0.07 c	0.07 c
Chewiness	0.611 b	0.46 a	1.06 c	1.07 c

[z]Mean values with different superscripts across the rows are significantly different ($P < 0.05$).

Table 2. Correlation coefficients of selected quality attributes of rice flour gels prepared from four varieties of Arkansas-grown rice.[z]

	FR	HA	AD	CO	SP	ST	GU	CH
FR	1.00	0.99*	-0.89*	-0.91*	-0.33	0.31	0.96	0.93
HA		1.00	-0.89*	-0.91*	-0.33	0.31	0.97*	0.95*
AD			1.00	0.81*	0.25	-0.08	-0.86*	-0.85*
CO				1.00	0.38*	-0.11	-0.81*	-0.78*
SP					1.00	0.06	-0.30	-0.16
ST						1.00	0.43	0.45
GU							1.00	0.99*

[z]FR, HA, AD, CO, SP, ST, GU and CH are Fracturability, Hardness, Adhesiveness, Cohesiveness, Springiness, Stringiness, Gumminess and Chewiness, respectively.

*Significant ($P < 0.001$).

Table 3. Pasting characteristics of rice varieties

Item	S201	Bengal	LaGrue	Lemont
Peak viscosity	543.33b[z]	436.67c	510.00b	603.33a
Hot viscosity	348.33b	270.0c	341.67b	422.33a
Cool viscosity	705.00c	518.33d	793.33b	926.67a
Consistency	356.67c	248.33d	451.67b	504.33a
Breakdown viscosity	195.00a	166.67a	168.33a	181.00a
Setback viscosity	161.67b	81.67c	283.33a	323.33a

[z]Mean values with different superscripts across the rows are significantly different ($P < 0.05$).

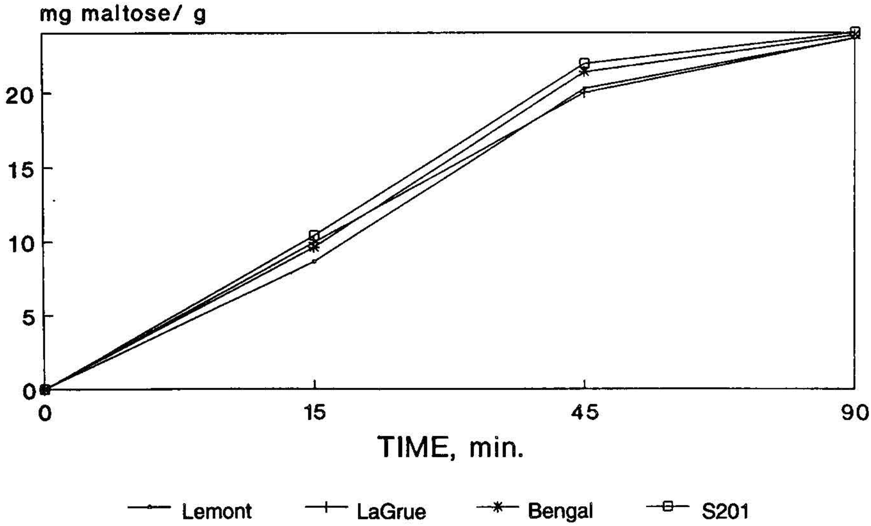

Fig. 1. In-vitro digestibility of rice flour from four varieties

SIMPLE METHOD(S) TO DETERMINE RICE QUALITY AND INVESTIGATIONS OF NOVEL VALUE-ADDED USES OF RICE BRAN

PART A

II. CALCIUM FORTIFICATION OF RICE: DISTRIBUTION AND RETENTION

N.S. Hettiarachchy and M.H. Lee

ABSTRACT

Studies were carried out to develop a method of fortification of rice by infusing calcium salt into the grain to evaluate calcium distribution, the form in which it exists and its retention in the infused grain. U.S. long-grain rough rice, 'Katy' variety (University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas), was dehulled, debranned and graded. Milled rice was soaked in 3.0% calcium lactate solution (CLS) (rice:CLS, 1.0:0.75 w/v) for 3 hr at room temperature followed by steaming at 10 psi for 10 min and drying to 10-11% moisture. Washing fortified rice (rice:water, 1:3 w/v) resulted in calcium loss of approximately 5%. Calcium-fortified rice, when milled into outer (8%) and inner (92%) endosperm fractions, contained 338 and 177 mg Ca/100g, respectively. Further, calcium-fortified flour, when dialyzed (with four changes of water), retained approximately 50% of the total calcium, indicating that this amount is bound to rice component(s). It is concluded that this infusion technique is an effective method of fortifying rice with calcium that results in minimum washing losses.

INTRODUCTION

Rice provides up to 75% of the dietary energy and protein for 2.5 billion people (Juliano, 1990). Good nutritional quality of rice is of primary interest to consumers all over the world. In the United States, consumer recognition of brown rice as a healthy food has shifted interest toward a greater consumption of brown rice (Marshall and Wadsworth, 1994). Milling processes designed to produce a palatable commodity result in loss of nutrients (Misaki and Yasumatsu, 1985).

Calcium has been recognized as an important component in the body, constituting approximately 2% of the total weight, about 99% of which is present in the skeleton (Ranhotra, 1986). The Recommended Dietary Allowance (RDA) of calcium for adults and pregnant or lactating women is 800 mg and 1200 mg, respectively, per day (U.S. Food and Nutrition Board, 1974). Calcium deficiency has been shown to cause osteoporosis, affecting about 24 million Americans annually (National Institute of Arthritis and Musculoskeletal and Skin Diseases, 1991). Niewoehner (1988) stated that increasing the intake of a variety of calcium-containing foods might be safer than calcium supplementation since the ingestion of large quantities of calcium concentrated in tablet form may suppress bone remodeling and thus suppress bone formation as well as bone resorption. The consumption of rice as food in the U.S. has doubled during the past decade (1980-21.0 million cwt, 1990-40.4 million cwt) (USDA, 1992). Therefore, milled rice could be considered a suitable vehicle to fortify the diets of many American foods with calcium. Enrichment and fortification of rice is in the best interest of consumers and food processors.

Limited information is available on fortifying rice with calcium. The objectives of this study were to fortify milled rice with calcium and to investigate its distribution and retention in the grain.

PROCEDURES

U.S. long-grain rough rice, 'Katy' variety, was provided by the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Calcium lactate (U.S.P.-F.C.C. food grade, J.T. Baker Chemical Co., Phillipsburg, New Jersey) was used as the source of calcium in the soak solution.

Calcium Fortification of Rice

Rough rice (8 kg) was dehulled by using a Satake Testing Husker THU-35A (Satake Engineering Co., Tokyo, Japan). The hull was discarded, and the brown rice was debranned using a McGill No. 2 Mill (McGill, Brookshire, Texas) for 30 sec. Broken rice kernels were separated from the head rice by using a Satake Test Rice Grader TRG-05A (Satake Engineering Co., Tokyo, Japan).

Trials were conducted to optimize conditions that would allow maximum uptake of calcium into milled rice. These conditions included varying 1) calcium lactate concentration (3%, 5% and 10%); 2) the ratio of rice to calcium lactate solution (1.0:0.5, 1.0:0.75, 1.0:1.0, 1.0:1.5 and 1.0:2.5); and 3) soaking time (0.5, 1.0, 2.0, 3.0, 5.0 and 10.0 hours).

Milled head rice (260 g) was soaked in water (rice:water 1.0:0.75 w/v) for 3 hr. The soaked product was drained and spread less than 0.5 in. deep on cheesecloth in a shallow stainless steel basket (9 in. x 11 in. size, containing 0.25-in.-diameter holes at the bottom) and autoclaved in a retort at 10 psi for 10 min. The rice was removed and dried at 35 C to about 16% moisture followed by drying at ambient temperature to a moisture content of approximately 11-12% (Fig. 1). The above procedure was followed for treatments, where 1.5% and 3.0% calcium lactate solutions were used instead of water.

Preparation of Rice Flour

Samples (120 g) of calcium-fortified/non-fortified milled rice were ground into flour using a Tecator Cyclotec 1093 Sample Mill with a 0.5-mm screen (Tecator, Hoganas, Sweden). The flour was sieved in an Alpine Air Jet Siever (Alpine, Augsburg, Germany) through a 60-mesh sieve.

Preparation of Endosperm Flour

Samples (100 g) of calcium-fortified/non-fortified milled rice were milled into outer (8%) and inner (92%) endosperm fractions using a McGill No. 2 Mill (McGill, Brookshire, Texas).

Rinsing

Calcium-fortified and unfortified rice samples were rinsed in distilled deionized water (1:3). Rice samples were placed in a beaker, and three volumes of water was added to the beaker. The samples were rinsed three times, the water was drained immediately, and rice samples were dried in an oven at 45 C to a moisture content of 60%, and dried at room temperature to a moisture content of 11%.

Dialysis

Rice flour (10-g) samples of calcium-fortified/non-fortified milled rice were each mixed with 50 ml of deionized water and transferred into Spectra/Por molecularporous membrane dialysis tube (Baxter Diagnostics Inc., McGaw Park, Illinois). The dialysis tube with its contents was immersed in 4 liters of deionized water for 24 hr. under constant stirring and dried.

Moisture Content

The percentage moisture content of rice flour was determined by an air oven method (AACC, 1976).

Calcium Content

Calcium content was determined by the atomic absorption spectrophotometric method (AOAC, 1990).

Statistical Analysis

A completely randomized design was followed, and three replications were performed. Two-way analysis of variance was conducted, least square means procedure was used to separate treatment means, and differences were considered significant at $P < 0.05$ (SAS, 1989).

RESULTS AND DISCUSSION

Calcium Content

Soaking milled rice in 3.0% calcium lactate solution for 3 hr in a rice:calcium lactate solution ratio of 1.0:0.75 (w/v) resulted in four-fold increase in the calcium content of milled rice (Table 1). Therefore, this treatment was used for the remainder of the study. Calcium lactate at 3% level was selected for fortification owing to its non-metallic and pleasant mouthfeel, as perceived by the investigators. Fortification of brown rice at 3% calcium lactate solution resulted in a two-fold increase in the calcium content (Table 2).

Extent of Calcium Infusion

Rice samples milled into outer 8% and inner 92% endosperm were evaluated for calcium content. Calcium contents of fractions from unfortified rice samples were not different from each other for the calcium content while significant differences were observed in the calcium content of different portions of fortified rice kernels (Fig. 2). The outer 8% of the endosperm had significantly higher calcium content than the inner 92% ($P < 0.05$). Distribution of calcium in milled rice of the Katy variety was uniform. The process developed in this study resulted in the infusion of calcium in the outer 8% of the milled kernel.

Effect of Rinsing

Rinsing of rice samples with water resulted in a reduction in the calcium content of fortified rice, while no such effect was observed in non-fortified samples (Fig. 3). Calcium content of fortified samples after rinsing with water was 210.62 (mg/100g rice). However, the reduction was only about 5% of the original content.

Effect of Dialysis

Calcium fortified and unfortified samples were subjected to dialysis to investigate whether the fortified calcium exists unbound or bound to the kernel constituents. No differences were observed in the calcium content of unfortified rice samples due to dialysis (Fig. 4). Calcium content of fortified samples was significantly reduced after dialysis from 226.38 to 131.17 (mg Ca/100 g rice). In spite of a 50% reduction due to dialysis, the calcium content of fortified rice was still about twice as much as that of the control samples.

SIGNIFICANCE OF FINDINGS

Method of fortification of rice developed in this study resulted in rice kernels with 226 mg Ca/100g (dry weight basis), while the control (non-fortified) contained 62 mg Ca/100g. Washing fortified rice (rice:water, 1:3 w/v) resulted in calcium loss of approximately 5%. Most of the infused calcium was found to be retained in the outer 8% of the kernel. Further, calcium-fortified flour, when dialyzed (with four changes of water), retained approximately 50% of the total calcium, indicating that this amount is bound to rice component(s). This infusion technique may be an effective method of fortifying rice with calcium that results in minimal washing losses.

ACKNOWLEDGMENT

Authors gratefully acknowledge the financial support provided by the Rice Research and Production Board for the above project.

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Table 1. Calcium content of fortified milled rice (mg/100g).

Sample	Bengal	LaGrue	S 201	Katy
Control	99.45 a[z]	116.15 a	95.90 a	63.64 a
Water	95.15 a	103.5 a	95.47 a	54.74 a
Ca 1.5%	166.62 b	146.15 b	160.88 b	105.28 b
Ca 3.0%	235.93 c	191.48 c	221.03 c	138.52 c

[z]Mean values in the same column with different superscripts are significantly different ($P < 0.05$)

Table 2. Calcium content of fortified brown rice from 'Katy' variety (mg/100g).

Sample	Calcium content
Control	206.68 a[z]
Water	194.03 a
3% Ca	440.53 b
5% Ca	464.55 c
10% Ca	499.02 d

[z]Mean values in the same column with different superscripts are significantly different ($P < 0.05$)

Rough rice

↓

Dehull (Satake Testing Husker)

↓

Debran (McGill No. 2 Mill)

↓

Grade (Satake test rice grader)

↓

Milled Head rice

↓

Soak (rice and calcium lactate 0.5-3.0%, in the ratio of 0.5 -2.5 w/v, and soaking time 0.5-5.0hr)

↓

Steam (10 psi, 10 min)

↓

Dry (35°C to 11% moisture)

Fig. 1. flow chart of calcium fortification process.

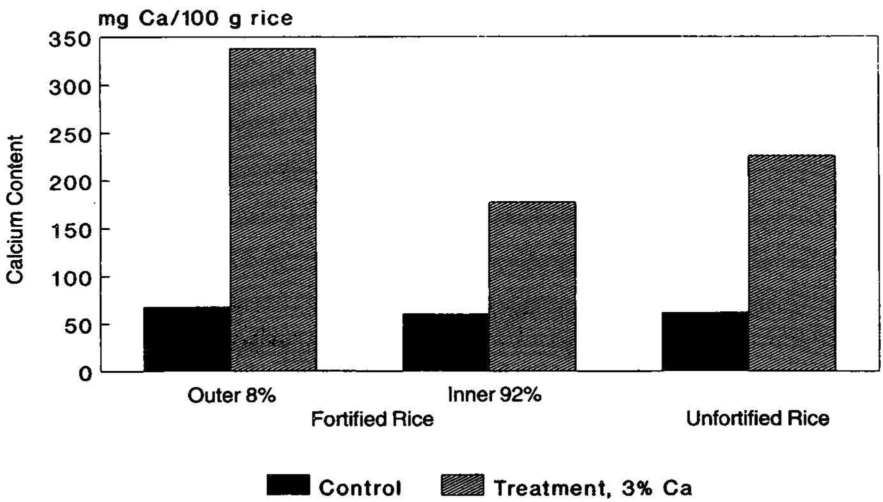

Fig. 2. Distributuion of calcium in unfortified and fortified rice.

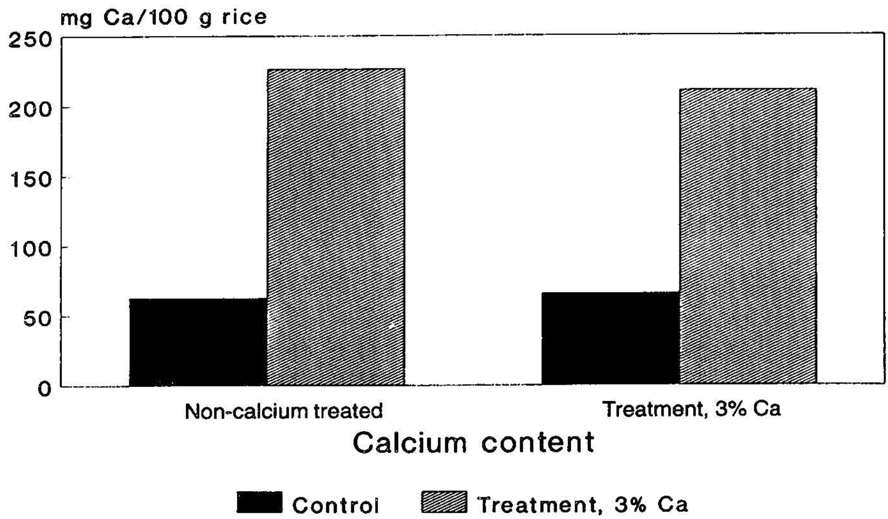

Fig.3. Effect of rinsing of milled rice on calcium retention.

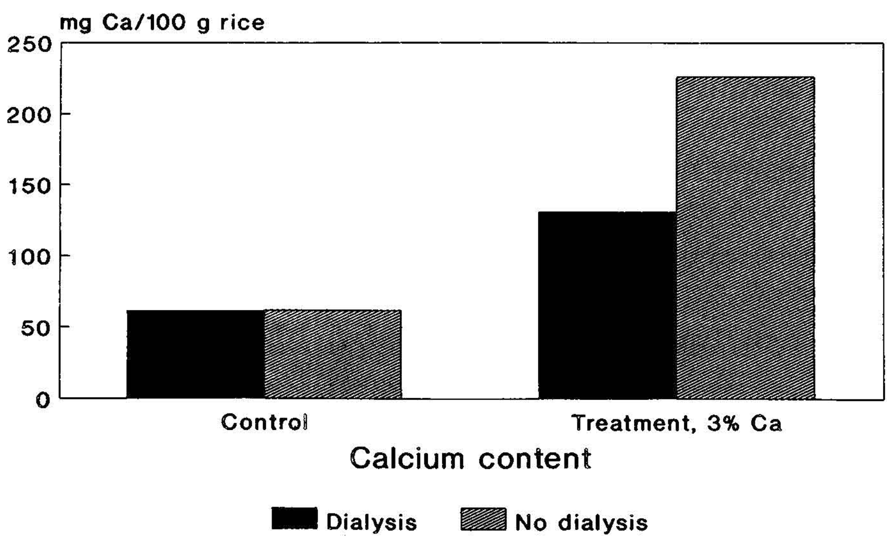

Fig.4. Effect of dialysis on calcium retention of rice flour.

SIMPLE METHOD(S) TO DETERMINE RICE QUALITY AND INVESTIGATIONS OF NOVEL, VALUE-ADDED USES OF RICE BRAN

PART B

VALUE-ADDED USE OF RICE BRAN: PROTEIN CONCENTRATES AND EXTRACTS WITH ANTIOXIDANT ACTIVITY

N.S. Hettiarachchy and R. Gnanasambandam

ABSTRACT

Studies were conducted to investigate value-added uses of rice bran, a milling by-product. Stabilized rice bran had lower protein extractability at all particle sizes (75μ to 150μ) than unstabilized bran. Both unstabilized rice bran protein concentrate (URBPC) and stabilized rice bran protein concentrate (SRBPC) showed maximum nitrogen solubility at pH 8.0 and had appreciable lysine, the first limiting amino acid in cereal proteins when comparing stabilized to unstabilized. SRBPC samples had higher contents of glutamic acid, glycine, arginine and histidine, while URBPC samples had higher contents of serine, alanine, valine, leucine, phenylalanine and lysine. Preliminary investigations have demonstrated the presence of antioxidant activity in the extracts of rice bran. Studies also revealed the possibility of degradable films and edible coatings from rice bran proteins. Protein concentrates and isolates prepared from rice bran can be used for several food and non-food applications, including protein ingredients for various foods, infant formulations, preparation of protein-based biodegradable films and adhesives for the paper board industry.

INTRODUCTION

Rice bran is one of the most under-utilized milling by-products of rough rice. In 1994, about 155 million hundred weight (cwt) of rice was produced in the U.S., resulting in about 12.4 million cwt of bran (Arkansas Agricultural Statistics, 1993). Rice bran is a rich source of proteins with a protein efficiency ratio (PER) of 2.00 to 2.5 compared to the standardized score of 2.5 for casein (Saunders, 1990). Information available on extraction, characterization and properties of protein concentrates from rice bran produced in U.S. is scarce.

Investigations were conducted to explore rice bran, a milling by-product, as a source of protein concentrates. Studies were also conducted on other possible uses of rice bran, including development of natural antioxidant extracts from rice bran and degradable films and edible coatings from rice bran proteins.

MATERIALS AND METHODS

Unstabilized and heat-stabilized rice bran were obtained from Riceland Foods Inc. Stuttgart, Arkansas, and Riviana Food Inc., Abbeville, Louisiana, respectively, packaged in 5-lb polyethylene bags and stored at -5 C. Stabilized rice bran used in the present study is produced by extrusion cooking, a type of retained moisture heating, that involves heating at 125-135 C.

Defatting and Milling

Rice bran samples were dispersed (1:4) in technical-grade hexane (Fisher Scientific, USA), defatted at setting 40 (T-Line lab stirrer, Talboys Engineering Corp., Emerson, New Jersey) for 30 min. and centrifuged (IEC, CRU-5000) at 2500 x g for 10 min. at room temperature. The sediment was extracted once again following the same procedure. Defatted rice bran samples were air dried overnight under a hood then milled once in a Cyclotec mill (Cyclotec 1093 Sample Mill, Tecator AB Box 70, Höganas, Sweden) and sieved through mesh sizes 200 (75μ), 170 (90μ), 140 (106μ), 120 (125μ) and 100 (150μ) (U.S. Standard Testing Sieve, ASTM E-11 Specification) for 3 min. Individual fractions obtained from various mesh screens were packaged in polyethylene bags, labelled and stored at -5 C.

Preparation of Protein Concentrates

Alkaline extraction procedures followed by isoelectric precipitation were used to prepare protein concentrates as shown in the flow diagram (Fig. 1).

Nitrogen Solubility

Nitrogen solubility of the protein concentrates was determined using a modification of the procedure of Betschart (1974).

Amino Acid Analyses

Amino acid compositions of unstabilized and stabilized protein concentrates from unsieved fractions were determined using an amino acid analyzer (LKB Biochrom Model 4400, LKB Biochrom Ltd., Science Park, Cambridge, England). Samples were hydrolyzed in 6N HCl at 128 C for 15 hr. A cation-exchange column was used for amino acid separation. A photometer output linked to a recorder (LKB 2220, Recording Integrator) was used to record total retention times for the individual amino acids. The area under each peak was used to quantitate individual amino acids present in the original mixture.

Electrophoresis

Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) of the samples was performed according to Laemmli (1970).

Extraction of Natural Antioxidants

Extracts of stabilized and unstabilized rice bran were prepared in different solvent systems, including water and 60% ethyl alcohol. Other variables of extraction included time and temperature of extraction and heat treatment of rice bran. The extracts obtained were investigated for their antioxidative properties using a Oxidative Stability Instrument (OSI). Film-forming protein soultions were prepared from rice bran by alkaline extraction procedures. A placticizer at different levels was added to the solution ans was heated to various temperatures. Predetermined volumes of film-forming solutions were poured onto plastic plates and dried under conditions of controlled temperature and relative humidity.

Statistical Analyses

A completely randomized design was used. Least square means procedures were used to separate means, and differences reported are considered significant at ($P < 0.05$) (SAS, 1988).

RESULTS AND DISCUSSION

Protein Concentrates

Concentrates prepared from 200-mesh unstabilized rice bran had significantly lower protein content than those prepared from most other fractions (Table 1). Type a and b particles of rice bran as categorized by Pineda (1976) with sizes ranging from 25μ to 120μ might be a major contaminant in 200-mesh fractions. These particles include several non-protein components such as cellulose, hemicellulose, pentosans and lignin. Significant decrease in the protein extracted was observed at particle size <100 mesh ($P < 0.05$). As the particle size increased, the sample became less floury and more water binding.

A significant reduction in percent protein extracted was observed in all fractions of stabilized rice bran when compared to unstabilized rice bran. Protein concentrates from fractions of less than 100 mesh had the lowest protein content (33.5%).

Protein concentrates prepared from unsieved fractions in this study did not show any difference in their protein content from the fractions with highest protein content. The milling yield of the unsieved fraction was about 72%, which was higher than the yield of other particle sizes (Table 1). Hence, studies were continued further to prepare protein concentrates from unsieved fractions of rice bran. Protein contents of unsieved, unstabilized rice bran protein concentrate (URBPC) and stabilized rice bran protein concentrate (SRBPC) were 71.5% and 50.9%, respectively. The protein contents of the URBPC in this study were about 15% higher than those reported for concentrates obtained by alkaline extraction at pH 9.0 (Chen and Houston, 1970; Bera and Mukherjee, 1988; Landers, 1992). In the present study, protein content of the concentrates showed a steady increase as the pH of extraction was increased from 8.0 to 11.0 ($P < 0.05$) (Fig. 2). A significant increase in the protein extractability of stabilized rice bran was observed at pH 11.0 compared to pH 10.0. Protein concentrates prepared at extraction pH 9.5 were compared for their properties.

Nitrogen Solubility

Nitrogen solubility of URBPC and SRBPC is presented in Fig. 3. Over the pH range that was used in this study (2.00 - 12.00), both samples showed the lowest solubility at pH 4.0. Below and above this pH, the samples showed a gradual increase in solubility. At pH 2.0 the samples had about 30 to 40% solubility. Maximum solubility for both the samples was observed at pH 8.0, beyond which there was not much benefit. In the present investigation, although SRBPC samples showed much lower extractability, the nitrogen solubility of the protein concentrates was similar to that of URBPC.

Amino Acid Content

Out of the 13 amino acids determined, the content levels of 10 were significantly different between the stabilized and unstabilized bran (Table 2). Both types of samples had a relatively high content of lysine, the first limiting amino acid in cereal proteins. No significant differences were found in threonine, tyrosine and aspartic acid contents of the two types of samples. SRBPC samples had higher contents of glutamic acid, glycine, arginine and histidine; URBPC samples had higher contents of serine, alanine, valine, leucine, phenylalanine and lysine. The amino acid value for rice bran protein concentrate was reported to be 80, while casein had a value of 85 (FAO/WHO, 1973). The amino acid content and distribution of protein concentrates as reported in this study were similar to the reported data for rice bran protein concentrates prepared at pH 9.0 (Bera and Mukherjee, 1988). However, the amount of protein extracted was about 20% more in the present study.

Electrophoresis

Electrophoresis of both types of protein concentrate samples revealed the presence of several components and differences in their distribution pattern. SRBPC was distinctly different from URBPC, as is evident from the absence of several components in the molecular weight (MW) range 45 kDa to 97 kDa. Protein denaturation during the stabilization process might be an important factor in the absence of several of these components.

Natural Antioxidants from Rice Bran

Extracts prepared from rice bran were tested for antioxidant activity using oil stability index OSI. Extracts of rice bran in ethyl alcohol showed increased antioxidant effect compared to the control (Fig. 4) as indicated by a larger induction periods in those samples. The effect was also found to increase with increase in the concentration of alcohol. Extracts from 60% ethyl alcohol (30MINST1) showed the longest induction period of 10.10 hr. compared to the control (no extract) (7.55 hr).

Degradable Films and Coatings from Rice Bran Proteins

Investigations also revealed an exciting possibility of producing degradable films and edible coating material from rice bran proteins. Films produced had thicknesses ranging from 0.2 to 0.4 mm.

SIGNIFICANCE OF FINDINGS

Significant differences exist in the protein concentrates prepared from unstabilized and stabilized rice bran. Although the stabilization process inactivates lipases and extends keeping quality of rice bran, it results in an irreversible effect on quantitative as well as qualitative protein recovery, as evidenced in this study by a decreased protein extractability and differences in amino acid content and electrophoretic pattern. A pH of 9.5, as used in this study, might be considered moderate and yet useful to prepare a rice bran concentrate with 70% protein content.

Rice bran is also a good source of natural antioxidant. Further studies are justified and may result in the development of food-grade antioxidants from rice bran for several food uses. Studies also revealed the possibility of rice bran proteins as a source of edible films and coatings. Further studies are necessary to investigate the optimum conditions of film preparation, evaluation of mechanical and barrier properties of films produced and use of the protein films as coating material and packaging wrap.

ACKNOWLEDGMENTS

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Table 1. Milling recovery[z] and the protein content of the unstabilized and stabilized rice bran protein concentrates

	Unstabilized		Stabilized	
Mesh size	Recovery, %	Protein, %	Recovery, %	Protein,%
Unsieved	72.4	71.5 a[y]	72.2	50.9 a
200	40.1	63.3 b	40.2	50.7 a
170	3.7	68.0 a	4.9	47.3 b
140	3.7	70.7 a	4.9	43.7 b
120	4.9	70.9 a	7.7	43.1 b
100	7.9	67.7 a	4.7	38.9 c
< 100	11.6	58.4 c	10.5	33.5 c

[z]Milling recovery calculated based on weight of the defatted material.
[y]Mean values in the same column with different superscripts are significantly different ($P < 0.05$).

Table 2. Amino acid composition of unstabilized and stabilized rice bran protein concentrates[z]

Amino acid[y]	URBPC	SRBPC
Asp	10.57 a[x]	11.50 a
Thr	3.86 a	3.471 a
Ser	4.58 a	3.47 b
Glu	11.91 a	26.62 b
Gly	6.89 a	9.40 b
Ala	7.86 a	6.44 b
Val	7.72 a	5.27 b
Leu	9.52 a	6.00 b
Tyr	3.86 a	3.11 a
Phe	5.89 a	2.47 b
His	4.96 a	8.80 b
Lys	7.08 a	6.27 b
Arg	13.65 a	16.20 b

[z]Amino acid mg/100 mg of protein.
[y]Mean of three replications.
[x]Mean values in the same row with different superscripts are significantly different ($P < 0.05$).

Defatted rice bran sample + distilled deionized water (1:4 to 1:6)
pH adjusted to 9.5 stirred 30 min. (room temperature)

↓

Centrifuged 10,000 X g for 30 min. (room temperature)

↓

Decant, pH of the supernatant adjusted to 4.5,
centrifuged 10,000 X g for 30 min.(room temperature)

↓

Precipitate washed (pH 4.5),
suspended in distilled deionized water (pH 7.0)

↓

Freeze dried and stored at -5°C

Fig. 1. Flow diagram of preparation of protein concentrates.

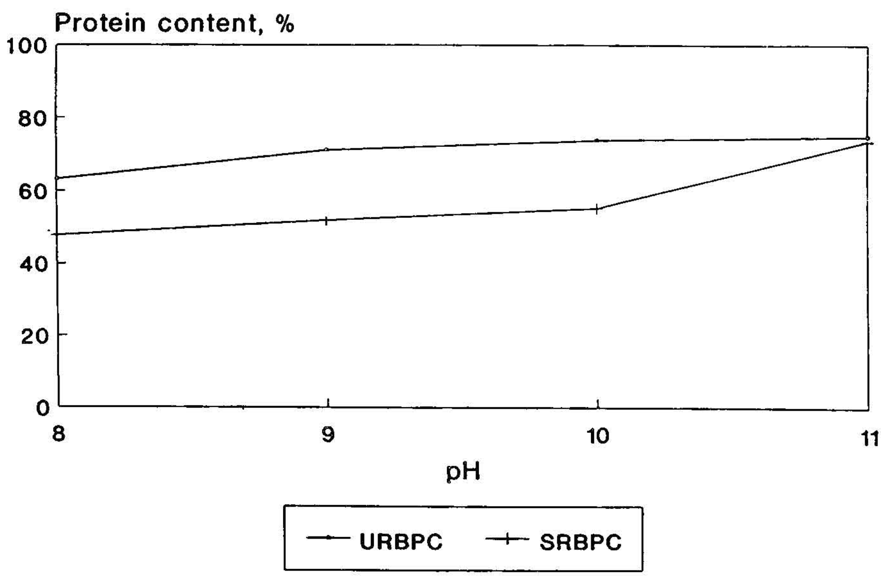

Fig. 2. Protein content of concentrates as affected by pH of extraction.

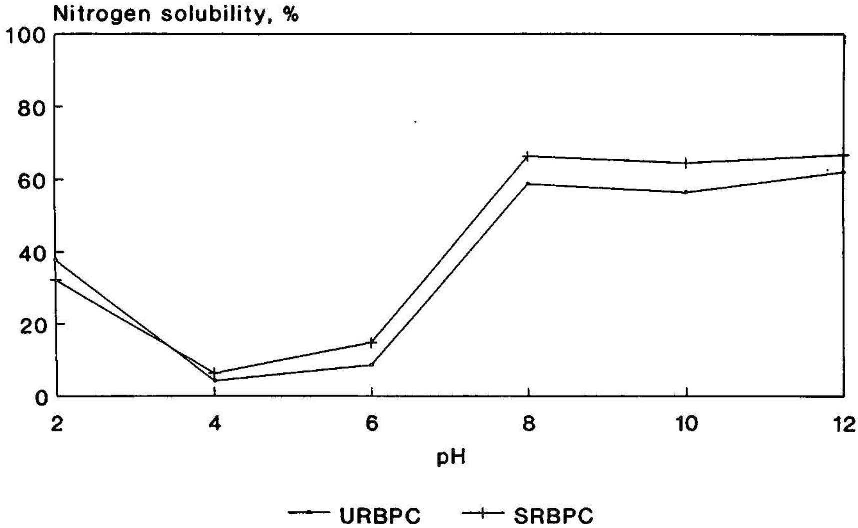

Fig. 3. Nitrogen solubility profile of protein concentrates.

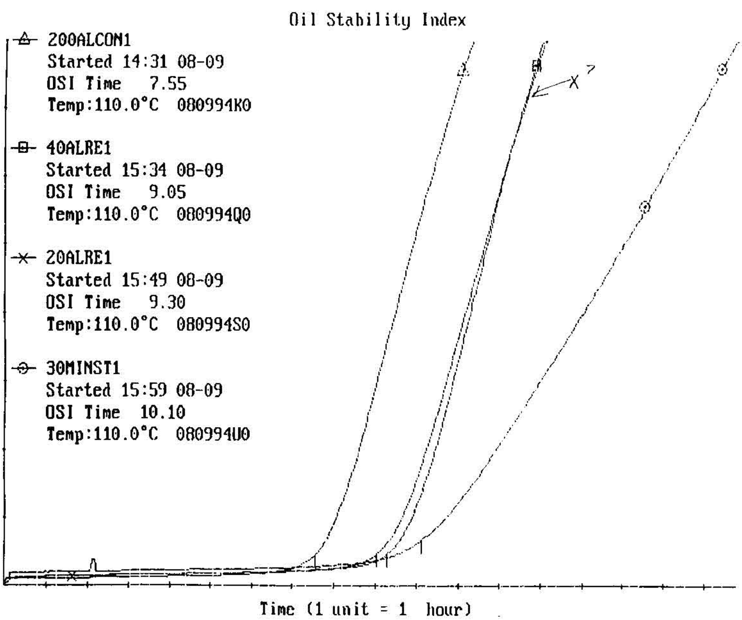

Fig. 4. Rice bran extracts with antioxidant activity: 200ALCON1 = Control, 20ALRE1, 40ALRE1 and 30MINST1 are rice bran extracts of 20%, 40% and 60% ethyl alcohol, repectively. OSI Time expressed in hours.

RESOURCE ALLOCATION AND AGRICULTURAL POLICY SIMULATION MODEL: PROJECT UPDATE

Bobby Coats

ABSTRACT

The goal of the Resource Allocation and Agricultural Policy Simulation Model (RAAPSIM) project is to develop a user-friendly, menu-driven, fully integrated, PC-based modelling system with library options for alternative submodels. This will allow individual states to conduct relatively straightforward analyses on a wide range of farm firm, area and statewide questions concerning the impact of various policy initiatives as the need arises. The policy initiatives that RAAPSIM will be capable of analyzing include local, regional and national policies, including environmental regulations that could result in regional resource constraints.

This project will provide each state's rice industry with a means of modeling typical firm, area and statewide impacts of proposed public policy initiatives and other industry-driven economic scenarios from resource allocation, economic cost and financial perspectives. The area-specific capabilities of the modelling system resulting from this project are particularly important as a given initiative may have significantly different consequences between areas and among the typical farm organizational structures within each area.

INTRODUCTION

A major advantage of RAAPSIM is that once the program, submodels and databases have been established, each sponsoring state will have in-house access to the package through their Land Grant University. Consequently, industry requests concerning the impact of various policy scenarios can be addressed through state Land Grant Universities.

RAAPSIM should not be viewed as a "one shot" project but rather as a long-term self-evolving system capable of providing timely information to the industry and support to Land Grant research and graduate education programs. After establishment of the programs and databases, funding levels required to keep the integrated model package current should be minimal compared to initial expenditures.

I am coordinating the development of farm firm policy analysis software by a multistate research team of Land Grant Scientists. Rice states participating in the project include Arkansas, California, Louisiana, Mississippi and Texas. Also, scientists from Ohio State University and the University of Wisconsin are participating in the development of the farm firm financial policy analysis simulation model. The scientists participating in the project have a diversity of economic specialization expertise. Areas of specialization include the following: (1) management, (2) production economics, (3) finance, (4) marketing, (5) policy, (6) risk, (7) statistics, (8) econometrics and (9) resource use and development.

This is a four-year project. In its final version, this project will provide each state's rice industry with a means of modeling typical firm, area and statewide impacts of proposed public policy initiatives and other industry-driven economic scenarios from resource allocation, economic cost and financial perspectives.

OBJECTIVES

Currently, the primary objective of the project is to evaluated public policy alternatives in the 1995 farm bill debate.

PROCEDURES

The Resource Allocation and Agricultural Policy Simulation Model (RAAPSIM) will consist of two separate, but linked, models. The first model (multiperiod resource allocation simulator) will determine optimal farm structure for each typical farm organization within each area based primarily on agronomic technology that is reflected in production costs and a combination of market and non-market activities that are reflected in commodity prices and returns for crops within the area, hours suitable for fieldwork and the policy initiative being evaluated. The second model (multiperiod financial simulator) will estimate farm firm financial performance based on data generated by the first model. Together, these two models will allow a detailed analysis of typical firm, area and statewide impacts emanating from proposed changes in agricultural policy, environmental regulation and other concerns of interest to the industry. It is important to note that the RAAPSIM package will utilize a "ground up" analytical approach: impacts on each typical farm firm within each region will be estimated then aggregated by the percentage of the resource base controlled by each of these firms. There is considerable flexibility in the number of representative farms RAAPSIM can handle, reflecting the "submodel" manner in which the data will be assimilated.

Publications emanating from the use of RAAPSIM fall into four clearly defined areas: industry-wide adjustment assessments developed at the request of the representatives of the U.S. Rice Producers' Group by the Land Grant research team; area and state adjustment studies implemented at the request of the industry within a state for use by that state's rice industry; regional analyses implemented by members of the Land Grant research team working cooperatively; and state analyses conducted by individual members of the Land Grant research team that may be published in support of their research and graduate teaching programs. Initial results obtained from RAAPSIM will be reviewed within each cooperating state, and an industry assessment will be prepared by the Land Grant research team for the industry. Distribution of the RAAPSIM package to Land Grant agricultural economists identified by the industry within each cooperating state will preclude unauthorized industry assessments.

RESULTS AND DISCUSSION

The first year's progress of the project has been impacted by the death of Dr. Art Heagler, LSU Professor. In addition, project monies from some states have been available for only a few months, limiting software development.

Providing data and information needed for the 1995 farm bill debate requires policy options that are politically, socially, financially and economically viable and analyzing these options to determine the consequences of their inclusion in farm bill legislation.

Version 1 of the farm firm financial policy simulator is currently being evaluated. The objective is to start evaluating farm firm policy alternatives for rice producers the first week in April 1995. Risk modeling capabilities will be programmed into the model while these test runs are being made to maximize the use of time. Version 1 of the model will allow for financial projections for up to five years; the final model will allow for ten years.

Version 1 of the resource allocation policy model is still being programmed. An evaluation run on data from southwestern Louisiana should be made in the near future. Preliminary data from each of the rice producing states have been collected and are in the process of being compiled.

Alternatives currently being evaluated with the financial policy model include farm-level impact of annual rice program cuts of $150 million, $200 million and $250 million. The analysis will provide the rice producers with information for each of these three alternative levels of annual outlay reductions as to which method of cutting rice program outlays would best maintain production and profitability and would be least disruptive to the rice producers.

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