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Arkansas Rice Research Studies 1993

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B.R. Wells, editor

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CONTENTS

RICE CULTURE

RICE UTILIZATION

ECONOMICS AND MARKETING

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 1993*, Arkansas Agricultural Experiment Station Research Series 436. 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 the 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

'KAYBONNET': A NEW BLAST-RESISTANT, LONG-GRAIN RICE VARIETY

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

ABSTRACT

The Arkansas Agricultural Experiment Station released a new, blast-resistant, long-grain rice variety, 'Kaybonnet', to seed growers in 1994. Kaybonnet was derived from the cross 'Katy'/'Newbonnet' made in 1986. Kaybonnet's main attributes are blast resistance, greater yield potential than Katy and excellent head rice and total milled rice percentages. Kaybonnet matures three to four days earlier than either Katy or Newbonnet, is moderately susceptible to both sheath blight and straighthead and is moderately resistant to rice peck damage.

INTRODUCTION

Rice blast disease has had a cyclic occurrence in Arkansas for several decades. Most recently, blast epidemics recurred beginning in 1986, mainly causing partial to complete yield loss in the then recently released variety Newbonnet. Varietal resistance is the primary means of rice blast control. In 1989, Katy was released as a blast-resistant long-grain variety with the intention of replacing Newbonnet in areas prone to blast. Under disease-free conditions, most growers have not been able to attain the yields that were achieved with Newbonnet. However, Katy is the only variety with resistance to both blast races IB-49 and IC-17. Consequently, in 1986 the Arkansas rice breeding program set forth objectives to incorporate blast resistance into varieties with higher yield potential.

PROCEDURES

Kaybonnet was derived from the cross Katy/Newbonnet made in 1986 as part of a graduate student project studying the inheritance of rice blast resistance. After crossing, F_1 (first generation after crossing) and F_2 generations were grown in the greenhouse at Stuttgart, Arkansas, during the winter of 1986-87 and tested for reactions to the common blast races found in Arkansas, IB-49 and IC-17. The F_3 generation was grown in the field at Stuttgart in 1987; the F_4 generation was grown in the winter nursery in Lajas, Puerto Rico; and the F_5 generation was grown in the field in 1988. The early experimental designation at Stuttgart was STG88P2-81. Yield testing and expanded disease evaluations (to other blast races, sheath blight and other diseases) of Kaybonnet were begun in 1989. Kaybonnet was tested in the preliminary yield trials in 1989, the Stuttgart Initial Test in 1990, the Arkansas Rice Performance Trials in 1991-1993 and the Uniform Rice Regional Nursery (URRN) in 1991-1993 under the URRN designation RU9101142. During the winter of 1992-1993, 400 panicle rows were grown at the winter nursery in Lajas, Puerto Rico. The panicle rows were rouged for offtypes and bulk harvested to use as seed for the 1993 foundation seed field grown in Stuttgart. One thousand panicle rows, derived from the winter nursery increase, were also grown in 1993, rogued and bulked to produce the 1994 breeder seed. In the yield trials, variety means were separated by the least significant difference (LSD) at the 0.05 probability level.

RESULTS AND DISCUSSION

Kaybonnet has been tested in the Arkansas Rice Performance Trials (ARPT) short-season maturity group rather than in the mid-season maturity group because it is three to four days earlier in maturity than both Katy and Newbonnet. In the URRN, direct comparisons can be made with Katy and Newbonnet because Kaybonnet was evaluated in the same maturity group.

In the ARPT in 1991, Kaybonnet exhibited significantly higher grain yields than 'Millie', 'Lemont' and 'L-203' as well as higher head rice percentages (Table 1). In 1992, the yields of Kaybonnet were significantly lower than those of most of the other check varieties in this group, and in 1993 yields were significantly lower than those for 'Bengal' and 'LaGrue'. However, during 1992 and 1993, Kaybonnet was among the varieties with the highest milling yields. Kaybonnet was approximately three days earlier in maturity than Lemont and similar in plant height to 'Orion' and LaGrue.

Rough rice and milling yields from the 1992-1993 URRN are included in Table 2. In both years for each of the four states, grain yields of Kaybonnet were consistently higher numerically than yields for either of its parents, Katy and Newbonnet. Kaybonnet ranked numerically highest in grain yield of the commercial variety checks for the four-state average. Kaybonnet also exhibited stable, high milling yields when tested across the southern rice growing states. Kaybonnet appears well adapted to the southern U.S. rice growing region.

Kaybonnet's main attribute is resistance to race IB-49 and to the other races commonly found in the southern U.S. (Table 3). It is moderately susceptible to sheath blight, rating similarly to Newbonnet. Kaybonnet is moderately susceptible to straighthead, similar to Katy; thus fields with a history of straighthead injury should be drained and dried 10 to 14 days before panicle initiation.

The recommended nitrogen rate for Kaybonnet is 135 units of N applied as a three-way split (75-30-30). Kaybonnet, like Katy, is moderately susceptible to lodging and moderately resistant to damage from peck. The grain size and dimensions of Kaybonnet are also similar to those of Katy.

SIGNIFICANCE OF FINDINGS

The release of Kaybonnet demonstrates the insight and ability of the Arkansas rice breeding group and its cooperators, through rice producer support, to quickly incorporate the blast resistance of Katy into a new, higher-yielding variety. This group has released Katy and now Kaybonnet, the only two varieties resistant to all rice blast races common to the southern U.S.

Table 1. Agronomic and other data by year for 'Kaybonnet' and varieties of similar maturity from the Arkansas Rice Performance Trials, 1991-1993.

Variety	Yield	Height	Maturity	Kernel wt	Milling yield[y]
	bu/acre	in.	50% HD[z]	mg	%-%
1991					
Orion	167	42	84	16.7	67-72
Mars	167	45	86	18.0	69-72
Kaybonnet	165	44	81	15.5	67-72
Millie	148	41	79	19.5	65-72
Lemont	146	34	85	19.7	62-73
L-203	133	39	73	22.5	51-70
L.S.D.	11	2	1	0.3	2-1
1992					
LaGrue	194	44	84	19.8	62-72
Orion	189	42	84	17.2	64-72
Bengal	188	36	86	21.3	64-74
Lemont	181	36	88	20.1	61-74
Mars	176	47	86	17.9	66-73
Cypress	175	35	86	18.3	66-73
Toro 2	174	43	86	21.0	63-73
Rico	173	43	87	18.4	63-73
Kaybonnet	168	43	85	16.4	66-73
L.S.D.	7	1	1	0.5	2-1
1993					
Bengal	169	37	76	20.7	69-74
LaGrue	168	45	77	18.4	56-71
Lacassine	154	36	78	18.7	60-72
Orion	153	41	77	16.9	61-72
Mars	151	45	78	18.1	65-72
Kaybonnet	149	43	77	15.0	64-71
L.S.D.	7	1	1	0.3	2-1

[z]Number of days from emergence to 50% heading.
[y]Milling yields represent head rice percentage-total milled rice percentage.

Table 2. Grain and milling yields by year for 'Kaybonnet' and varieties of maturity group III from the Uniform Regional Rice Nursery, 1992-1993.

	Grain Yield (bu/acre)					Milling Yields[z]				
Variety	AR	LA	MS	TX	AVE.	AR	LA	MS	TX	AVE.
1992										
Kaybonnet	168	186	173	129	166	64-73	64-71	64-71	59-71	63-71
Lacassine	163	150	172	154	160	59-73	62-71	66-73	54-73	60-72
Gulfmont	161	143	176	143	159	61-73	62-70	66-73	60-73	62-72
Cypress	176	183	161	103	156	64-72	66-71	65-72	56-71	63-71
Katy	159	170	165	115	152	64-71	64-70	67-71	59-70	63-71
Lemont	174	143	159	136	150	62-73	65-72	65-72	59-71	63-72
Newbonnet	157	142	157	82	134	65-73	61-69	67-72	51-70	61-71
LSD	18	15	23	15	20	3-1	2-1	2-1	3-2	3-1
1993										
Kaybonnet	162	193	158	163	169	62-71	61-70	64-69	58-69	61-71
Lacassine	166	165	147	157	159	61-72	58-69	58-72	57-70	59-71
Newbonnet	158	181	122	169	158	62-71	60-68	66-72	58-68	62-70
Cypress	153	188	126	154	155	63-71	66-71	60-71	61-69	63-71
Katy	137	171	154	153	154	61-69	58-67	63-69	58-68	60-68
Gulfmont	150	171	148	145	154	64-72	65-71	55-71	59-71	61-71
Lemont	141	165	101	146	138	61-72	64-71	44-70	56-71	60-71
LSD	15	12	26	21	18	2-1	3-1	4-3	3-1	5-1

[z]Milling yields represent head rice percentage-total milled rice percentage.

Table 3. Reaction of rice varieties to sheath blight, straighthead and blast[z].

	Sheath		Blast Race			
Variety	Blight	Straighthead	IG-1	IH-1	IC-17	IB-49
Cypress	7	4	1	1	6	6
Katy	5	6	1	1	1	2
Lemont	8	4	1	1	6	5
Newbonnet	6	4	1	1	8	8
Kaybonnet	6	5	1	1	1	2

[z]Summary by degree of susceptibility: 1 = least susceptible to 9 = most susceptible.

BREEDING AND EVALUATION FOR IMPROVED RICE VARIETIES

K.A.K. Moldenhauer, K.A. Gravois and F.N. Lee

ABSTRACT

Lines from the sheath blight (*Rhizoctonia solani* Kuhn), recurrent selection breeding program are currently in all stages of the rice variety evaluation program at the Rice Research and Extension Center, Stuttgart, Arkansas. Long-grain rice lines with short stature, less than 40 in. in plant height, and tolerance to sheath blight with a rating less than three on a scale 0 = immune, 9 = maximum disease, have been selected from this program. This demonstrates that recurrent selection is an effective method of producing short-statured, long-grain rice lines with improved levels of sheath blight tolerance.

INTRODUCTION

Much of the work involved in the breeding and development of new rice varieties is, by nature, repetitive. Crosses are made on a yearly basis in an attempt to develop new, improved rice cultivars. The general procedures followed for rice crossing and early generation selection have been reported (Gravois et al., 1992). In addition to the standard crosses completed for the breeding program, there are often separate studies or programs, either of short or long duration, that are conducted to solve specific problems. The recurrent selection program for improved tolerance to sheath blight (*Rhizoctonia solani* Kuhn) is an example of such an ongoing long-term project within the plant breeding program at the Rice Research and Extension Center, Stuttgart, Arkansas. Sheath blight resistance is a quantitative trait controlled by many genes located on different chromosomes (Li et al., 1992). Anticipating this in 1983, a project was started to increase the sheath blight tolerance in long-grain, short-statured, very-short-season rice lines by pyramiding the genes for sheath blight.

PROCEDURES

This is an ongoing project that was started with initial crosses in 1983. This report will include information on the lines grown from this project in 1993. In 1993, approximately 700 second-generation plants from each of 13 of the 23 successful crosses made in 1991 for the fourth cycle of the program were space-planted in the field 10 in. by 12 in. apart and inoculated with the sheath blight organism and evaluated for sheath blight reaction. Parents were selected from the progeny of the 13 crosses to form the fifth cycle in the selection process. Twenty-six crosses were completed in 1993. The plants selected to use as parents were selected on the basis of their tolerant disease reaction (disease scale 0 = no disease, 9 = maximum disease) to the pathogen *Rhizoctonia solani* in inoculated field plots. A rating of five or less is considered an acceptable rating, but a lower rating is the goal. Parents were selected in the field in inoculated plots on the basis of having a tolerant sheath blight rating of one to three while the plants surrounding them were susceptible, rating a six or higher. This method was utilized to reduce the chance that plants selected to be used as parents had escaped infection. Sheath blight development is affected by environmental conditions; therefore, in some cases susceptible plants were unknowingly selected as parents. Selected parent plants were potted and taken to the greenhouse for crossing. Therefore, selected parent plants growing in the warm, humid greenhouse were checked for the progression of sheath blight to eliminate susceptible escapes and to insure that only tolerant plants were used as parents for the next cycle. Plants were kept within families (by cross) and selected plants were crossed between families.

Inoculum was prepared by growing pure cultures of the organism on one part sterile rice grains and three parts rice hull mixtures until thoroughly colonized. At this time the inoculum was allowed to dry slightly and then was spread loosely over the top of each plant when the plants were between the panicle initiation and 1\2-in. internode elongation growth stages.

At maturity panicles were selected from the plants that appeared most tolerant to sheath blight in the parental populations, and the grain was sent to Puerto Rico for generation advance during the winter of 1993-1994. Seed from these plants will continue through the traditional breeding program.

RESULTS AND DISCUSSION

In 1993, lines selected out of the recurrent selection program were in all stages of the breeding program. A comparison of these lines with the check cultivars demonstrates that improvement has been made in the development of long-grain rice lines with short stature and sheath blight tolerance. Four long-grain and two medium-grain lines were grown in the most advanced stage of testing in the Arkansas Rice Performance Trials (ARPT) and Uniform Regional Rice Nursery (URRN). These lines came from cycle 1 of the program and rated no better than average for height and sheath blight tolerance when compared to the checks, 'Mars', 'Lemont', 'Tebonnet' and 'Katy'. In the URRN Katy was 46.5 in. tall and rated 4.3 for sheath blight, similar to the long-grain lines RU9301176 and RU9301164, which were 45.7 and 48.0 in. tall and rated 3.9 and 3.7 for sheath blight, respectively. Consequently, cycle 1 lines showed no improvement over the general breeding population. Note that Katy was released in 1989 and the cycle 1 plants were grown and lines selected in 1986 when the long-grain checks at that time generally rated at best a 5-6.

In the Stuttgart Initial Test (SIT), the next lower stage of testing from the ARPT, the recurrent selection lines comprised 32 of the 124 lines in the test, with 31 long- and one medium-grain types. Sixteen (50%) of the lines in the very-short-season maturity group were from the recurrent selection program. In this maturity group, the mean sheath blight rating and plant height were 4.7 and 37 in., respectively, for the recurrent selection lines and 5.0 and 39.4 in., respectively, for the checks M-201, M-202, 'Orion', 'Alan', 'Adair' and 'Maybelle'. Adair and Katy rated a five for sheath blight, a lower sheath blight rating than that for any of the long-grain commercial cultivars grown in Arkansas at the time the recurrent selection program for sheath blight tolerance was started at Stuttgart. The seven long-grain recurrent selection lines that rated one to three for sheath blight were scattered throughout the maturity groups. They had a mean plant height of 36.6 in. (range 34.3-37.8). The sheath blight ratings of all the checks in the SIT ranged from 'Bengal' at four to 'Lacassine' and 'Cypress' at seven, and they ranged in height from Lacassine at 33.9 in. to Tebonnet at 51.2 in.

In the 1993 Preliminary Yield Test, 98 of the 506 lines evaluated were from the recurrent selection program. Of the 98, only one was a medium-grain line. It was 43.7 in. tall and rated a three for sheath blight. Of the long-grain lines, 32 rated one to three, 53 rated four to five, nine rated six to seven, and two were not rated. The check cultivars (of which nine have been released since the recurrent selection program began) ranged in ratings from four to seven; eight rated from four to five, and seven rated six to seven. The mean rating of the recurrent selection lines was 3.9 compared to the mean of the tolerant check cultivars (Adair, Katy, Mars, 'Millie', 'Nortai' and Orion) at 4.3 and the mean of all check cultivars at 5.4. Twenty-four lines of the original 33 lines in the preliminary test rating one to three were selected and continue to remain in the testing program because they have good agronomic plant type and disease ratings. Of these 24 lines, seven were 39.4 in. or less in height, and nine ranged from 39.8 to 43.3 in. The checks ranged from 35.8 in. for 'Gulfmont' to 36.6 for Lacassine, with sheath blight ratings of six and seven, respectively, to plant heights for Katy at 44.5 in., Millie at 46.9 in. and Tebonnet at 52.4 in. with sheath blight ratings of four, five and five, respectively. Therefore, progress has been made in the selection of long-grain, short-statured lines from the recurrent selection program, which have a higher level of sheath blight tolerance than the current check cultivars.

SIGNIFICANCE OF FINDINGS

The goal of the rice breeding program is to develop maximum-yielding cultivars with good levels of pest (disease and insect) tolerance. This is being accomplished and will result in the reduced need for pesticide applications. The recurrent selection program has produced long-grain rice lines that have shorter stature and improved sheath blight tolerance. Lines developed in the recurrent section program are currently in all phases of the general rice breeding evaluation program at the Rice Research and Extension Center. Compared to the current tolerant check cultivars, these lines offer improved sheath blight tolerance as well as shorter plant height.

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BREEDING AND EVALUATION FOR IMPROVED RICE VARIETIES RICE BIOTECHNOLOGY

K.A.K. Moldenhauer, K.A. Gravois, F.N. Lee, M.M. Blocker and P.C. Rohman

ABSTRACT

Anther culture is being used to reduce the time required to develop improved rice cultivars for Arkansas producers. Doubled haploid plants have been derived from the anther culture program at the Rice Research and Extension Center in Stuttgart, Arkansas. These lines are in different stages of development in the field and greenhouse where they are being evaluated for improved agronomic and disease reaction characteristics. In 1993, 27 of these lines were tested in the preliminary yield trials, and 18 were selected to advance into the Stuttgart Initial Test in 1994.

INTRODUCTION

Anther culture techniques have been used to develop rice (*Oryza sativa* L.) cultivars in China and were utilized in the development of the long-grain rice cultivar Texmont developed by the Texas Agriculture Experiment Station and USDA/ARS. Anther culture can be applied to many of the rice cultivars currently utilized in our breeding program, but the process is still cultivar specific, and the ability to regenerate plants from anther culture is controlled genetically (Chen, 1986). Therefore, some crosses will readily produce plantlets, whereas other crosses that do not have the genes required for regeneration will not produce plantlets. In the Arkansas program, anther culture techniques are currently being utilized to increase blast resistance. F_2 plants were selected from crosses involving 'Katy' or other blast-resistant parents in order to capitalize on the rapid development of anther culture lines to develop new cultivars with increased blast resistance.

PROCEDURES

Anthers were collected from tillers from 1011 selected F_2 spaced plants that were grown in the field in 1993. Generally 10 to 30 F_2 spaced plants were selected from each of the 31 crosses for blast resistance that were utilized for anther culture (Table 1). Usually, two tillers were selected per plant, but as many as three tillers have been selected.

Rice tillers in the boot stage were harvested from the field when the tip of the panicle could be felt within 3 cm of the base of the penultimate leaf. Tillers were wrapped in foil and chilled for four to seven days at 7 C. Chilled panicles, with the flag and second leaf sheath intact, were sterilized in 50% chlorox solution for 30 min and rinsed in sterile deionized water. Anthers were obtained by cutting off the top of the florets (lemma and palea) just above the anthers, and tweezers were used to gently excise the anthers. The anthers were then plated on two calli initiation media, one containing sucrose and the other, maltose. Approximately 50 anthers from each plant were placed on each plate. Plates were sealed with parafilm and incubated in the dark at 27 C for callus formation. Calli became visible in approximately 45 days. Calli were removed from the plates and transferred to calli regeneration media. The regeneration media used for each plate had the same sugar source as the initiation media. The calli were incubated at 27 C on regeneration media under continuous cool-white fluorescent lighting. Development of green spots and roots and albino and green plant regeneration were recorded.

Calli were initiated on N6 Callus Initiation Medium (Chu, 1978) supplemented with 60.0 g/l sugar (sucrose or maltose) and 2,4-dichlorophenoxyacetic acid and adjusted to pH 5.8. Agarose type II was added to make a solid media prior to autoclaving for 25 min at 15 PSI.

Calli regeneration media consisted of medium described by Murashige and Skoog (1962) supplemented with 40.0 g/l sugar (sucrose or maltose), 0.5 mg/l 1-naphthylacetic acid and 1 mg/l kinetin adjusted to pH 5.8 prior to autoclaving. The medium was solidified with 4.0 g/l agarose type II.

Plants that were derived from the 1992-1993 anther culture effort were tested in the pathology greenhouse in the spring of 1993 for rice blast (*Pyricularia gresea*) before being transplanted to the field. Unfortunately, by the time the plants were large enough to transplant into greenhouse pots and become established, they were too old to obtain accurate information on rice blast susceptibility because they were impervious to the fungus. Seedlings derived from seed of these plants are currently being tested in the greenhouse for their rice blast reactions. The anther culture-derived lines that were in the Preliminary Yield Trials in 1993 are also being tested for rice blast reactions.

RESULTS AND DISCUSSION

Table 1 lists preliminary findings on the number of plants per cross that produced calli and were transferred to regeneration media. Some calli were produced from every cross combination plated, but there was considerable variation in the number of plants per cross producing calli. Cross 92858 was the only cross in 1993 in which only 10% of the plants selected had tillers that produced calli for transferring to regeneration media. This is an improvement compared to 1992 when three crosses had a rate of only 10%. Eight of the 1993 crosses produced calli on 75% or more of the plants in which tillers were selected, which was very similar to the 1992 results. Twenty-one of the crosses had calli that produced green spots. Green spots developing on the calli are the first sign of viable calli from which plantlets are produced. Plantlets have been transferred to test tubes from five of these crosses, and at this time we have nine plants surviving in the greenhouse and seven in the growth room in the test tubes that we plan to transfer to the greenhouse in the future. Data are still being collected on these populations. Not all green spots produce plantlets, and the number of green spots produced in 1993 was lower than that in 1992.

There are several possible factors affecting the number of plantlets produced. Included among these are the physiological condition of the donor plant. The environment (i.e. temperatures, light intensity, N fertilization) can be critical in determining the subsequent embryonic responses of the isolated microspores. Rice florets are most sensitive to high temperatures at heading. The next most sensitive stage is nine days before heading, the approximate time of tiller collection. Tolerance to high temperature is variety dependent (Yoshida, 1981). The hot nighttime temperatures experienced in the summer of 1993 could affect the starch accumulation in the anthers before the tillers were gathered and thus affect the ability of the anthers to regenerate plants. We know that the type of starch added to the media can affect the regeneration of plants (Pinson, 1992).

In 1993, 27 anther culture lines were grown in the Preliminary Yield Trials for agronomic evaluation and seed increase. Of 14 lines observed in the field in 1992, six were discarded because of poor agronomic type or blast susceptibility. Eight are currently being retested for rice blast reaction, and the resistant lines will be advanced into the Stuttgart Initial Test in 1994. Eighty-two new anther culture-derived plants were also grown in the field for observation and seed increase in 1993. Seed had been collected from 13 of these lines in time to seed them in the Preliminary Nursery in 1993. Ten of these were selected for advancement based on their agronomic characteristics in the Stuttgart Initial Test in 1992. These lines are also being tested for blast resistance at this time.

SIGNIFICANCE OF FINDINGS

Anther culture is an ongoing part of the rice variety breeding and development project in Arkansas. Anther culture will be utilized for both rice blast and grain quality crosses in 1994. Anther culture lines that are developed will be tested for blast resistance or quality characteristics, increased and entered into the rice breeding program. Populations utilized in the anther culture program are also evaluated in the traditional breeding program.

Regeneration differences that exist among the populations studied in 1993 may be due to environmental conditions as well as genetic response. Utilizing traditional methods along with the anther culture techniques for the selection of lines from populations is important while we evaluate the lines produced from the anther culture procedures to insure that we are not losing valuable material that does not culture.

Lines developed through anther culture have the potential to become varieties in one to two years less time than those that progress through a traditional breeding program because they are homozygous (pure lines) and do not require the several generations of inbreeding to become pure lines. The potential for quickly incorporating blast resistance or desired quality characteristics into rice varieties of the future is increasing with the successful production of the doubled haploid plants emerging from this program. This approach has the potential to develop blast-resistant, high-yielding lines quickly from the 'LaGrue'/Katy crosses made in 1993.

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Table 1. Preliminary data from 1993-1994 anther culture program at Stuttgart, Arkansas.

Cross	Total No. Plants/Cross	No Plants/Cross Producing Calli	No. Plants/Cross Producing Green Spots	No. Green Plantlets/Cross
9123	20	11	1	
9130	20	4		
91658	27	12	4	
91709	8	3		
92205	10	9	1	
92206	10	5	1	
92207	21	7	2	1
92208	10	2		
92209	10	4	2	1
92210	11	11	3	1
92220	8	6		
92228	1	1	1	1
92792	5	3		
92794	10	5	1	1
92803	15	6		
92806	20	15	3	
92814	20	17	5	4
92822	20	15	3	1
92826	15	9	1	
92848	12	2	1	
92852	36	12	4	
92855	35	8	2	
92858	10	1		
92859	21	10	2	
92860	5	1		
92861	21	4	1	
92867	11	7		
92868	30	25	9	1
92869	35	11	4	2
92870	31	24	18	4
92879	30	5		

GENETIC, PHYSIOLOGICAL AND BIOCHEMICAL ENHANCEMENT OF EXOTIC RICE GERMPLASM

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

ABSTRACT

Accessions in the USDA, ARS rice germplasm collection were evaluated for allelopathy to barnyardgrass and ducksalad. Results of a Chi-square test demonstrated that resistance to straighthead in CI 4322 and PI 502796 is controlled by a single recessive gene. Rice cultivars with relatively deeper root systems and lower tillering habit had better relative grain and biomass yields under drought stress conditions than those with shallower roots. Fifty-one Japanese cultivars from four maturity groups were compared to U.S. cultivars. At least one Japanese cultivar in each maturity group was either equal to or greater than the U.S. cultivars for total grain yield and milling yield.

INTRODUCTION

The USDA, ARS rice germplasm working collection contains 16,476 accessions, or varieties, from 99 countries. The collection is the primary source of genetic diversity for rice variety development in the U.S.; however, useful traits or characteristics must be identified before the germplasm can be utilized in variety development programs. More than 300,000 items of data on rice variety plant characteristics have been recorded at Stuttgart, Arkansas, since 1984. Many of the 16,476 accessions have been evaluated for up to 30 characteristics, and data on 17 characteristics have been entered into the Germplasm Resources Information Network (GRIN) so the data can be utilized by scientists involved in variety development research in rice.

Four germplasm evaluation and enhancement projects were emphasized in 1993. These projects were (1) allelopathy (ability of a rice plant to suppress adjacent weed growth and development) in rice to weed species such as ducksalad (*Heteranthera limosa*), barnyardgrass (*Echinochloa crus-galli*) and rice flatsedge (*Cyperus iria*); (2) straighthead, a physiological disease of rice; (3) stress tolerance of rice germplasm to drought, glyphosate (Roundup) and sulphosate (Touchdown); and (4) evaluation of Japanese varieties in the USDA, ARS rice germplasm collection.

PROCEDURE

Investigations of the effect of allelopathy of rice plants on ducksalad and barnyardgrass were conducted on a Crowley silt loam soil at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas. Allelopathy to a natural infestation of ducksalad was evaluated in both a dry-seeded (drill-row) and water-seeded environment. Barnyardgrass seed was applied at a rate of about 3 lb/acre prior to seeding the rice. Two types of measurements for allelopathy were recorded: (1) the radial area of activity, in inches, from the base of the rice plant and (2) the percentage of weed control within the areas of activity.

A study on the inheritance of reaction to straighthead was conducted at RREC. Arsenic has been shown to induce straighthead; therefore, following seedbed preparation, arsenic, as MSMA, was surface applied at 4 lb/acre and incorporated into the soil. Twenty parent plants, 20 F_1 plants and 100 F_2 plants from each tolerant x susceptible cross were grown in the field.

A second field experiment was conducted in 1993 at RREC to compare the efficacy of 39 allelopathic rice germplasm accessions and three cultivars without allelopathic activity. The accessions were evaluated by four seeding methods, broadcast versus row spacing and dry versus water seeding. All four tests were hand seeded at a rate of about 2 bu/acre. Aquatic weeds were harvested from the entire plot (2.1 m^2), dried and weighed when the rice reached maturity. Weed dry weights, expressed as percent reduction compared to that in 'Rexmont' plots, were analyzed. The accessions in the test came from the U.S. (4), China (2), India (5), Taiwan (7), Philippines (14), Afghanistan (3), Mali (1), Unknown origin (2) and Japan (1) and the three check cultivars from the U.S.

Three stress-tolerance experiments (drought, glyphosate and sulphosate) were conducted in 1993. Germplasm accessions (384) were evaluated for their reaction to glyphosate (Roundup) and sulphosate (Touchdown). Each accession was treated at three rates, 0.5X, 1.0X and 2.0X (e.g. 0.375, 0.750 and 1.5 lb active ingredient (ai)/acre) of Roundup and Touchdown at three dates: pre-flood, two weeks and three weeks after first flood. A drought-tolerance experiment was conducted with four rice cultivars grown under irrigated and non-irrigated conditions on a Calloway silt loam soil at the University of Arkansas, Pine Bluff, Agricultural Research Center. The cultivars were selected on the basis of root systems as measured by root pulling resistance (RPR) (Ekanayale et al., 1986) plant type and growth habit. The cultivars were 'Dular', a tall, rainfed, upland type cultivar; 'Sufaida Pak', a tall, rainfed, lowland type; and 'Newbonnet' and 'Katy', shorter-strawed U.S. cultivars grown under flood irrigation. Six-row plots, 4.75 m long and rows 20 cm apart, were drill seeded. The irrigated plots were flood irrigated to a depth of 5-10 cm and maintained throughout the growing season. Data were collected for grain yield, yield components and biomass.

Fifty-one Japanese varieties plus five U.S. check cultivars were separated into four maturity groups and evaluated at three locations in 1993. Total yield, milling yield, lodging and days to heading were evaluated for each variety. The varieties were evaluated at RREC; Burkett Farms, located about 3 miles south of Stuttgart, Arkansas; and Dunklin Farms, located near Lodge Corner, Arkansas. Nitrogen was applied as urea in a three-way split at a rate of 50-30-30 at Burkett and Dunklin Farms for each of the four maturity groups. The timing was pre-flood, 1/2- to 3/4-in. internode elongation (IE) and 10 days after IE. Nitrogen was applied in a four-way split for the earliest maturity group (56-70 days) at Stuttgart. The timing was pre-flush (20), preflood (30), 1/2- to 3/4-in. IE (20) and IE + 10 days (20). The nitrogen was applied in a five-way split for the other three maturity groups (>70 days). The timing and amount of nitrogen was pre-flush (15), preflood (30), IE (15), IE + 10 d (15) and IE + 20 d (15).

RESULTS

Of the 5,600 rice germplasm accessions evaluated for allelopathy to barnyardgrass, nine accessions showed an apparent reduction in barnyardgrass growth and development (Table 1). Three of these accessions originated in Pakistan, two were from the Philippines (IRRI), one each from China, Vietnam and Bangladesh, and one was of unknown origin.

Five allelopathic rice germplasm accessions (PI 312777, PI 338046, PI 338065, PI 345920 and PI 373026) and Rexmont (PI 502968), a standard cultivar without allelopathic activity, were evaluated for ducksalad control in four tests, dry-seeded versus water-seeded culture and broadcast versus row spacing in each culture.

In dry-seeded Rexmont, the ducksalad produced 246 g/m^2 dry weight while it produced 447 g/m^2 in water-seeded Rexmont when averaged over row and broadcast plot seeding methods. In dry-seeded rice the five allelopathic rice accessions reduced aquatic weed biomass 77 to 88% in broadcast and 62 to 80% in rows compared to Rexmont. In water-seeded rice the five accessions reduced aquatic weed biomass 61 to 83% in broadcast and 27 to 61% in row planting compared to Rexmont. These data indicate that seeding allelopathic rice in either a broadcast and row pattern, especially broadcast, will improve aquatic weed control.

Seven accessions reduced aquatic weed dry weight by 91 to 98% of the control, Rexmont (Table 2). Of the seven accessions with the greatest allelopathic activity, two each were from India and Taiwan and one each from Afghanistan, China and the U.S.

The genetics of resistance to straighthead is uncertain. Two resistant parents, CI 4322 and PI 502796, and two susceptible parents, PI 160394 and PI 160593, were chosen for genetic analysis. Four possible resistant x susceptible crosses and their reciprocals were made among the four parents selected. The four parents, eight F_1 hybrids and four F_2 progenies of the four resistant x susceptible crosses were tested for reactions to straighthead. The data obtained from the eight F_1 hybrids indicated that resistance to straighthead in CI 4322 and PI 502796 was recessive, and there was no maternal effect on the expression of resistance in the F_1 hybrids. The results of chi-square tests showed that all four resistant x susceptible crosses had a segregation ratio of 1R:3S in the F_2 progenies, demonstrating that resistance to straighthead in CI 4322 and PI 502796 is controlled by a single recessive gene.

Of the 384 rice accessions that were evaluated for tolerance to Roundup and Touchdown, there were seven accessions (PI 319704, PI 348807, PI 350468, PI 399662, PI 414714, PI 414715 and PI 431481) that demonstrated tolerance to both herbicides (Table 3). Three of these accessions originated in Colombia, and four originated in the Philippines (IRRI).

Relative contributions of root systems and other shoot characteristics of rice (*Oryza sativa* L.) to yield and yield components in response to water stress are not well understood. Four rice cultivars (Dular, Sufaida Pak, Newbonnet and Katy) of different origins and plant types were grown under irrigated and non-irrigated conditions. There were significant interactions between cultivars and irrigation treatments in tiller number, fertile panicles, filled grains, grain yield and biomass yield produced per m^2. The interactions in grain yield were attributed mainly to the number of fertile florets and the number of filled grains per unit area. The weight of filled grains (grain filling) was reduced by about

16% due to water stress, but the rate of reduction was similar for all cultivars across irrigation treatments. Rice cultivars with relatively deeper root systems and lower tillering habits had better relative grain and biomass yields under drought stress conditions.

Three tests involving Japanese cultivars of four maturity groups were conducted in 1993, but only the results of the test at RREC will be reported. Also, the U.S. check cultivar will be compared only to the highest-yielding Japanese cultivar in each maturity group. In the earliest maturity group (<70 days), the U.S. cultivar was 'S101' and the highest-yielding Japanese cultivar was 'Amasari'. S101 and Amasari headed 72 days and 64 days after emergence, respectively. There was no significant difference in total grain yield or milling yield (total, head rice and percentage of broken kernels) (Table 4). However, Amasari was significantly taller and had more lodged plants than S101. In group 2 (71-80 days) 'M204' was the U.S. check cultivar, and 'Mutsu Hikari' was the top-yielding Japanese cultivar. M204 headed 76 days after emergence, and Mutsu Hikari headed 73 days after emergence. There was no significant difference between the two varieties in total grain yield, plant height, lodging or milling yield. In group 3 (81-90 days) 'Mars' was the U.S. check cultivar and 'Japan 92.09.31' was the highest-yielding Japanese cultivar. Mars headed 90 days after emergence, and Japan 92-09-31 headed 81 days after emergence. There was no significant difference between the two varieties in total grain yield, plant height, lodging or milling yield. In group 4 (>91 days) the U.S. check cultivar was 'Nortai', and the highest-yielding Japanese cultivar was 'Kotobuki Mochi'. Nortai headed 95 days after emergence, and Kotobuki Mochi headed 98 days after emergence. There was no significant difference in plant height between Nortai and Kotobuki Mochi; however, Kotobuki Mochi was significantly higher in total grain yield, lodging and milling yield.

SIGNIFICANCE OF FINDINGS

Annual losses due to weeds in rice and the expense 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 or sulphosate and, consequently, developing improved cultivars that are tolerant to these herbicides could result in a single application of a herbicide for weed control that becomes non-toxic and environmentally safe when it contacts the soil. Identification of drought-tolerant germplasm would significantly reduce water usage at a time when the water table is declining, especially on the Grand Prairie region of Arkansas. Data from Japanese cultivars identified early-maturing and potentially high-yielding germplasm of Japanese origin that can be utilized in rice variety development in the U.S.

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Table 1. Nine rice accessions that showed apparent allelopathy activity to barnyardgrass by reducing weed growth and development by 10-20% as compared to the check cultivar, 'Mars'.

CI or PI	Name	Country	Grain Type[z]	Days to Flowering[y]	% Weed Reduction
CI 5339	UNMD MGVR-CHINA PR	China	3	90	15
CI 8880	WASE SHIN SHU	Unknown	2	80	10
PI 390193	NANG TAY NHO C	Vietnam	2	65	15
PI 392111	LARI	Pakistan	2	103	20
PI 392196	KANGNI TYPE	Pakistan	5	135	50
PI 399854	KUMAR (ORIO-112)	Philippines	2	107	10
PI 400157	PULUT NANGKA 016	Philippines	2	150	15
PI 403305	DV 121-Bangladesh	Bangladesh	2	96	20
PI 403607	JKW S 18-PAK	Pakistan	2	104	15

[z]Grain type: 2 = medium grain, 3 = long grain and 5 = mixed
[y]Days from emergence to flowering.

Table 2. Germplasm accession, country of origin and percentage control of ducksalad compared to 'Rexmont', a standard cultivar lacking allelopathic control.

CI or PI	Acc. name	Country	% Control
PI 297820	India AC 2489	India	98
PI 389680	MON Z WUAN	China	97
CI 9066	BR41/AKAHO/SBLR	U.S.	95
PI 297816	India AC 1423	India	95
PI 256340	Afghanistan No. 2	Afghanistan	92
PI 338511	YH 1 (Taiwan)	Taiwan	91
PI 294400	TSAI YUAN CHON	Taiwan	91
PI 502968	Rexmont	U.S.	0

Table 3. Seven rice germplasm accessions that demonstrated tolerance to Roundup and Touchdown.

CI or PI	Country	Name	Grain Type[z]	Days to Flowering[y]	Plant Ht (cm)	Lodging[x]
PI 319704	Colombia	ICAIO	3	115	138	2
PI 348807	Philippines	IR 934-529-1	3	96	104	1
PI 350468	Philippines	IR-781-92-1-2-1-2-2	3	103	92	1
PI 399662	Philippines	IR 442-2-58	2	115	126	3
PI 414714	Colombia	Colombia 2	3	105	130	1
PI 414715	Columbia	Colombia 3	3	106	130	2
PI 431481	Philippines	IR RR2-58-2-1-2	3	115	116	2

[z]Grain type: 2 = medium grain, 3 = long grain
[y]Days from emergence to flowering
[x]Lodging: 1 = 0-10%, 2 = 11-20%, and 3 = 21-30% of the plants lodged.

Table 4. Performance of Japanese and U.S. cultivars separated into four maturity groups and grown at Stuttgart, Arkansas.

Maturity Group	Cultivar	Yield (lb/acre)	PLHT	Lodg	DTH	Milling		
						Total	Head	Broken
<70 days	Amasar	6286a[z]	102a	6a		67a	61a	6a
	S101	5838a	86b	1b		67a	62a	5a
71-80 days	M204	6938a	92a	1a		68a	65a	3a
	Matsu Hikari	6593a	96a	1a		67a	61a	6a
81-90 days	Japan 92.09.31	10522a	103a	1a		62a	58a	8a
	Mars	9793a	105a	1a		64a	59a	5a
>91 days	Kotobuki Mochi	7854a	105a	4a		74a	62a	12a
	Nortai	5600b	1-1a	1b		70b	65a	5a

[z]Means in the same column in the same maturity group followed by the same letter are not significantly different at the 0.05 level of probability

EVALUATION OF THE USDA/ARS RICE GERMPLASM COLLECTION FOR TOLERANCE TO ALKALINE SOILS

R.E. Baser, B.R. Wells and R.H. Dilday

ABSTRACT

The USDA/ARS rice (*Oryza sativa*, L.) germplasm collection contains more than 16,000 accessions. Little information is available as to the alkalinity tolerance of these accessions. This knowledge is required if rice varieties tolerant to alkalinity are to be developed with germplasm from this collection. Therefore, we developed a soil-based system utilizing a Calloway silt loam soil adjusted to a pH of 7.6 for evaluating the USDA collection for alkalinity tolerance based on Zn deficiency symptoms. This project is in its second year of funding, and over 8200 of the more than 16000 USDA/ARS accessions have been, or are currently being, screened. Of these, more than 5700 accessions have been evaluated statistically, and 273 of them have demonstrated a potential for tolerating the high pH's found in some soils.

INTRODUCTION

A need for alkalinity-tolerant varieties of rice in the southern United States is becoming increasingly apparent as the soil pH continues to rise from use of irrigation waters containing high levels of calcium bicarbonate. Rice plants are very susceptible to Zn deficiency during the seedling development stage. Zinc availability in the soil is a function of soil pH and decreases rapidly as the pH rises. Previous research (Wells et al., 1973) has shown that the problem, most prevalent on silt loam soils with a pH above 7.3, can be corrected with additions of Zn fertilizers. However, the problem is a reduction in availability, not a lack of Zn in the soil. If accessions can be located that are able to tolerate these alkaline soils, it would both reduce costs to the farmer and improve the environment by limiting the application of a heavy metal (Zn) as a fertilizer. At some time in the future it is likely that water sources may change, after which the soil pH may decrease and

Zn availability increase to a point at which Zn could perhaps become available in excessive amounts for plant uptake, especially on soils with a long history of Zn fertilization. Therefore, the purpose of this study is to develop a soil-based system to screen for alkalinity tolerance and to screen the USDA/ARS germplasm collection and the southern United States rice cultivars varieties for tolerance to alkalinity.

MATERIALS AND METHODS

The alkalinity screening study is conducted with a soil-based system contained in a mobile home that has been renovated for this purpose by adding extra insulation, growth lights and temperature controls. Diurnal temperatures are maintained near optimum for maximum seedling growth (25-33 C day and 18-25 C night). Lighting is supplied by 300-watt quartz lights and supplemented with 8-ft fluorescent lamps. The Calloway silt loam soil is adjusted to a pH of approximately 7.6 by adding finely ground (<100 mesh) calcium carbonate (CaO_3). The CaO_3 is allowed to equilibrate in the soil for approximately 30 days prior to seeding rice in order to allow the pH to stabilize. The amended soil is placed in a 13-in. by 17-in. plastic tray to a depth of approximately 4 in. Twenty-four furrows are made in the soil with the aid of a plexiglass template. Ten seed of each accession are placed in a furrow. After all the furrows in a tray have been seeded, an additional 0.75 in. of soil is placed in the tray and lightly compacted. The soil is drenched with 500 ml of a fungicide (Apron, Gustafson Chemical Co.) solution at a rate of 2 ml of formulated ingredient/gal of deionized water to control seedling disease. An additional 500 ml of deionized water is added the next morning, and the trays are covered with 3.5-ml-thick clear plastic sheeting. The plastic sheeting is used to speed the germination and emergence process. The seed are allowed to germinate and emerge for one week; then the plastic is removed. The seedlings are fertilized with 40 lb N/acre and flooded 10 days after emergence. Zinc deficiency symptoms begin to appear 10 to 21 days after flooding. At 28 days after flooding (DAF), the seedlings are evaluated for Zn deficiency symptoms. The data from the seedling evaluation are entered into a SAS-based computer system that selects tolerant accessions based on the following criteria: 1) 75% of the number of seedlings of an accession must survive to 28 DAF and 2) 75% of those seedlings must not exhibit symptoms of Zn deficiency. Accessions are separated into either tolerant or susceptible groups based on these two criteria. This complete process requires six weeks from seeding to harvest excluding data entry. Two replicates are utilized in the screening process.

RESULTS AND DISCUSSION

The alkalinity screening studies have been underway for approximately one and a half years, during which time 8221 accessions of the USDA/ARS rice germplasm collection have been screened or are currently in the process of being screened (approximately 50% of the entire collection). From those accessions for which the screening process has been completed, data from 5734 have been entered into the computer system for statistical evaluation. Of those 5734 accessions, 273 have been identified as demonstrating a high potential for alkalinity tolerance. Data in Table 1 illustrate a breakdown of the 273 accessions with regard to numbers of accessions with 75/75 and 100/100 [(survival)/(% asymptomatic seedlings)] ratios during either one or both replications of the study. Seven accessions that demonstrated a strong potential for alkalinity tolerance also had good emergence and survival rates.

SIGNIFICANCE OF FINDINGS

The preliminary screening for tolerance to alkaline soils indicates that the USDA/ARS rice germplasm collection appears to contain a relatively small number of lines with very good alkalinity tolerance. Additionally, a relatively large pool of germplasm appears to offer various degrees of tolerance to alkaline soils. These lines offer excellent possibilities for development of varieties with more tolerance to alkalinity than is present in any of our currently grown varieties.

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Table 1. Number of USDA/ARS rice accessions that exhibit tolerance to alkaline soils based on either of two rating systems.

	% Germination			
	< 50		> 50	
	Number of Replications			
Rating System[z]	1[y]	2	1	2
	Number of Accessions			
75/75	86	0	77	5
100/100	65	0	37	2

[z]75/75–Minimum of 75% seedling survival, 75% asymptomatic. 100/100–Minimum of 100% seedling survival, 100% asymptomatic.

[y]Based on either one or two replications.

COMPARISONS BETWEEN A HIGH-YIELDING CHINESE RICE AND U.S. RICE VARIETIES

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

ABSTRACT

Field and greenhouse experiments were conducted to compare the high-yielding Chinese rice variety 'Gui-chao' and U.S. variety 'Lemont'. We compared sucrose metabolism enzymes in the endosperm of Lemont and Gui-chao during the course of grain-filling. We found higher sucrose synthase specific activity from mid-grain filling onward for Gui-chao. It is expected that the greater sucrose synthase activity of Gui-chao confers upon it an ability to fill grain over a longer period than do U.S. varieties. The higher sucrose synthase activity may be partially related to Gui-chao's high yield potential.

INTRODUCTION

The Chinese rice variety Gui-chao has produced high grain yields in several U.S. field experiments. In 1990, 1991 and 1992, Gui-chao outyielded Lemont by 1800 to 3042 lb/acre in field experiments at Suttgart, Arkansas. The physiological characteristics that confer Gui-chao's yielding ability should be examined. Consequently, we conducted field and greenhouse experiments in 1993 to examine why Gui-chao often has yielded considerably more grain than high-yielding U.S. varieties.

PROCEDURES

Lemont and Gui-chao varieties were grown in large (1244-in.^{3}) pots in the greenhouse with plants arranged in a circle around the perimeter of the pots, 30 plants/pot with 60-90 panicles/pot. They were grown under high-light-intensity metal halide lamps plus incident sunlight. The lamps extended the light period to 14 hours/day. The plants were fertilized with a complete mixed soluble fertilizer weekly. The soil in the pots was a Sharkey clay loam.

In the field, Lemont and Gui-chao were drill-seeded with 7-in. spacing in 6-ft X 70-ft plots at the rate of 45 seeds/ft^2 in randomized complete blocks with five replications. Rice was fertilized with 120 lb N/acre and flooded within a day of N application (at the five- to seven-leaf growth stage). At internode elongation and seven days after internode elongation, 30 lb N/acre was applied to the crop. A flood was maintained until seven days after 50% heading on the later-heading Gui-chao. Subsequently, we drained the plots at two weeks after 50% heading. This has been demonstrated to result in no reduction in either rough rice yield or milling quality (Counce et al., 1993).

Panicles were tagged on the date of beginning anthesis in both field and greenhouse experiments. In the greenhouse experiments, the panicles were harvested at five-day intervals beginning five days after onset of anthesis until grain filling was complete. In the field, panicles were harvested at seven-day intervals for determination of enzyme activity and weight increases. Also in the field, panicles were divided into upper and lower halves by counting branches. If there were an odd number of branches, the extra branch was assigned to the upper half of the panicle.

The enzyme extraction consisted of removing the endosperm from the grain within three hours of collection. Subsequently, 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). Enzymes assayed were sucrose synthase, UDP glucose pyrophosphorylase, pyrophosphate phosphofructokinase, NTP-phosphofructokinase, acid and neutral invertases. Enzyme analyses were done within seven hours of collection except for the invertases. In some cases acid and neutral invertase assays were done within 30 hours of collection due to the stability of their activity compared to sucrose synthase (Table 2).

Grain dry matter accumulation was determined for a panicle collection made concurrently with the enzyme assay samples. The dry weight samples were dried at 158 F until weights stabilized. Subsequently, dried rough rice, hulls and hulled grain were weighed.

One meter (3.27 ft) row length of plots was harvested at maturity as well as combine harvested. Grain yields were determined from the combine sample. Yield components and harvest indices were determined from the 1-m row length sample. Harvest index is the decimal fraction of grain to total above-ground dry matter (grain and stubble). Harvest index is a useful measure of how a crop partitions its dry matter yield into grain.

RESULTS AND DISCUSSION

In the greenhouse experiment Gui-chao had heavier individual grains and higher filled grain percentages (filled grain/(filled + unfilled florets)x 100) than Lemont (Table 1). The difference between the two varieties for filled grains per panicle was small. The length of Lemont grains is 9/7 of the length of the Gui-chao grain. Gui-chao grains are approximately 1.5 times thicker than Lemont grains. The grains of Gui-chao filled at a somewhat faster rate than Lemont grains (Fig. 1). From early grain filling onward, sucrose synthase specific activity for Gui-chao was higher in Gui-chao than in Lemont (Fig. 2).

In the field experiment, grain yields did not differ (Table 2). Culms/ ft^2 and panicles/ft^2 were dramatically higher for Gui-chao than for Lemont. Grains per panicle tended toward being higher for Lemont. Individual grain weights were greater for Lemont. Harvest index was also higher for Lemont.

Grain-filling was faster for Lemont than for Gui-chao in the field, and final individual grain weights were heavier for Lemont (data not shown). Sucrose synthase activities during grain filling, however, remained greater for Gui-chao, as was noted in the greenhouse experiment (data not shown). The Lemont plots were at 50% heading in late August, and the Gui-chao plots were at 50% heading about a week later. Grain-filling for Gui-chao was slow, perhaps due to the slightly later beginning and the cooler temperatures during grain-filling. Nevertheless, sucrose synthase activities remained greater for Gui-chao in the field in 1993. We found the higher sucrose synthase activity of Gui-chao to be true for other expressions of sucrose synthase (per grain and per panicle), and the difference held up between other U.S. varieties including the medium-grain rice 'Bengal'.

SIGNIFICANCE OF FINDINGS

The evidence from two separate experiments with Lemont and Gui-chao suggests that one physiological difference between Gui-chao and Lemont is the maintenance of higher endosperm sucrose synthase activity in mid to late grain filling for Gui-chao. The sucrose synthase activity permits Gui-chao to fill grain over a longer period than the U.S. rice varieties. This characteristic could potentially be added to the genetic make-up of Arkansas rice varieties via breeding efforts.

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Table 1. Panicle characteristics of two rice cultivars (mean of 10 randomly selected panicles) grown under similar cultural conditions and environment in a greenhouse at Keiser, Arkansas, in 1993.

Cultivar	Grains/panicle	Individual Grain Weight	Percentage Filled Grain[z]
	no.	mg	%
Gui-chao	82.9 (6.4)[y]	24.7 (0.4)	96.0 (0.8)
Lemont	74.8 (6.4)	23.4 (0.4)	71.9 (2.7)

[z](Filled florets/total (filled + unfilled florets)) x 100.

[y]Values are means and (standard errors of the mean) from 10 panicles randomly sampled at maturity. The standard errors provide a measure of variability within the samples taken.

Table 2. Yield and yield components from a field experiment with 'Gui-chao' and 'Lemont' rice conducted at Keiser, Arkansas in 1993.

Variety	Grain Yield	Culm Density	Panicle Density	Grains per panicle	Individual Grain Weight	Harvest Index[z]
	bu/acre	culms/ft^2	panicles/ft^2	no.	mg/grain	no.
Gui-chao	169(6)[y]	62(3)	57(2)	69(4)	21.4(0.9)	0.441(0.010)
Lemont	171(2)	39(2)	37(2)	79(5)	24.7(0.2)	0.482(0.009)

[z]Harvest index = grain weight/(grain + stubble weight).

[y]Values are means (standard errors of the mean).

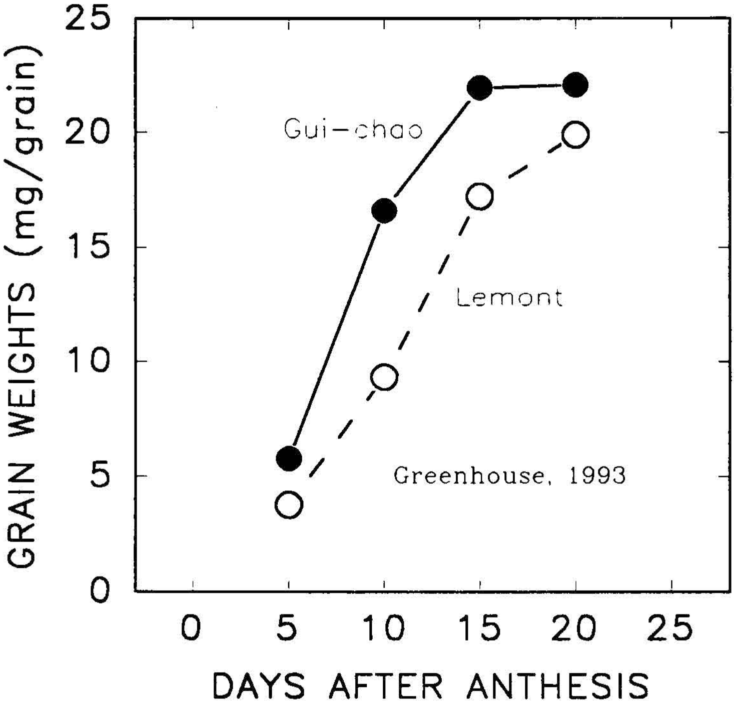


Fig. 1. Grain weight increases during grain filling for 'Lemont' and 'Gui-chao' rice.

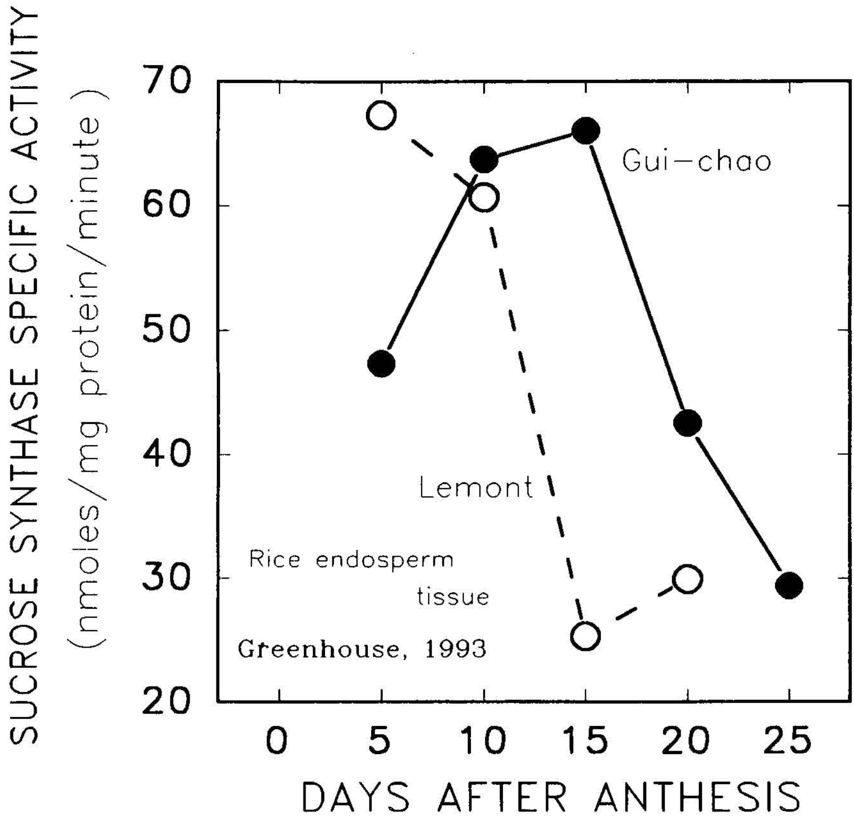


Fig. 2. Sucrose synthase specific activities for 'Lemont' and 'Gui-chao' rice endosperm.

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

J.L. Bernhardt

ABSTRACT

Water and drill seeding were compared to determine if rice water weevils responded differently to methods of seeding rice. Water-seeded rice, in general, had slightly more larvae and had peak numbers earlier than did the drill-seeded rice. Infestation levels were three and two times the treatment threshold in untreated plots of water and drill-seeded rice, respectively. Carbofuran (Furadan) applied 10 days after permanent flood gave control of rice water weevil larvae in treated plots. Statistical analysis indicated that yields were not significantly different in either seeding or treatment method. However, a trend of lower yield was seen in the untreated plots. Water-seeded rice is usually drained to allow for the plants to become well established. Data from this experiment indicate that a delay in application of permanent flood could have an important negative influence on rice water weevil infestation.

INTRODUCTION

Rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) are 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, 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 to develop a root system sufficient in size to receive nutrients when permanently flooded. Water-seeded rice may provide the rice water weevil with submerged, small plants with a less-developed root system. Additionally, water-seeded rice could attract rice water weevils for a longer period of time, as was found by Rolston and Rouse (1964). They found 3.5 and 8.5 times as many weevil larvae in water-seeded plots as in drill-seeded plots four and eight weeks, respectively, after permanent flood in the drill-seeded plots. Weevil numbers and small root systems in water-seeded rice favor early and potentially severe damage to the rice plant that may prove too much to overcome for normal grain yield.

The objective of the study was to compare the infestation levels of rice water weevils in drill- and water-seeded rice 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. The experimental design was a split-plot with seeding method as the main plot and treatment with carbofuran as the subplots. There were four replications. Preplant incorporated fertilizer (180 lb N/acre as urea) plus supplemental fertilizer (30 lb N/acre as urea) two weeks prior to internode elongation and a preflood application of herbicide (Bolero) were used in the water-seeded rice. A three-way split of nitrogen (120-30-30 lb) and a single application of Bolero and Propanil tank mix was applied to the drill-seeded rice. Plots (4.7 x 20 ft) in the water-seeded area were established by broadcasting pre-sprouted 'Lemont' seed in water on 15 May, the same day rice emerged in the drill-seeded plots. After 5 days water was drained. During the next 12 days, the water-seeded plots were flushed twice to keep the soil wet. Permanent flood was applied to all plots on 3 June. Carbofuran (Furadan) at a rate of 20 lb/acre was applied to 'treated' plots on 10 June.

Soil cores (4-in. diameter x 4-in. depth) were first taken from all plots on 17 June and then weekly for four weeks. Soil surrounding the roots was washed into sieves. The sieves were emersed 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.

Prior to harvest the number of panicles/ft^2 was taken in each plot. Eighteen feet of the center four rows of each drill-seeded plot and a comparable area (41.9 ft^2) in the water-seeded plots were harvested with a small plot combine.

RESULTS AND DISCUSSION

Rice Water Weevil Populations

Untreated Plots. Rice water weevil larvae found in the first samples taken in the drill-seeded rice on 17 June were all of very small size (Table 1). In contrast, larvae found in the water-seeded samples ranged from very small to medium size, although the majority were of the very small size. The presence of the small- and medium-sized larvae indicated that adults did oviposit earlier in the water-seeded rice. And even though water was drained from the plots, the soil was kept moist by the flushings, allowing the larvae to survive. Perhaps more eggs would have been deposited in the water-seeded plots if the permanent flood had been applied and maintained earlier after the seed had "pegged-down."

The infestation of rice water weevil larvae peaked earlier in the water-seeded plots and was noticeably greater three weeks after permanent flood than that of the drill-seeded plots, which peaked four weeks after permanent flood (Table 2). Also, the average number of larvae in both seeding methods surpassed the recommended treatment level of 10 larvae/sample three weeks after permanent flood.

The average heading date in each of the seeding methods was slightly later than predicted by the DD50. The drill-seeded rice was four days late, and the water-seeded rice headed two days after the drill-seeded plots. The discrepancy between the actual date and the predicted date was most likely due to a range in emergence of the drill-seeded plots and a very wide range of plant sizes in the water-seeded rice, which made the selection of proper dates difficult.

Treated Plots. The single application of carbofuran at 10 days after permanent flood reduced the level of rice water weevil infestation in plots of both seeding methods (Table 3). The peak level of infestation occurred at about the same time as in untreated plots but was nearly 50% less in the treated plots.

Grain Yields

No significant differences were found in the grain yield between seeding method (mainplots), treated with carbofuran or not (subplots), or for any interaction. The average grain yield per acre for all drill-seeded plots was 6577 lb, and the average for all water-seeded plots was 6391 lb. The average grain yield for treated drill-seeded plots was 6614 lb; the average for untreated drill-seeded plots was 6539 lb. The average grain yield for the treated water-seeded plots was 6529 lb; the average for the untreated water-seeded plots was 6254 lb. The high infestation level of rice water weevil larvae in the untreated plots could have contributed to the trend toward numerically lower grain yields. The number of panicles per square foot averaged 24 in the drill-seeded rice and 26 in the water-seeded rice.

SIGNIFICANCE OF FINDINGS

Rice water weevil adults responded to the different seeding methods by depositing eggs slightly earlier and in slightly higher numbers in water-seeded rice than in drill-seeded rice. A single application of carbofuran 10 days after permanent flood reduced rice water weevil infestation in both seeding methods to levels believed not to lower grain yields significantly.

The level of rice water weevil infestation at the peak density in the untreated plots was nearly three and two times that of the treatment threshold in the water-seeded and drill-seeded rice, respectively. Yet grain yields were not statistically different between treated and untreated, and between type of seeding methods. However, a slight trend was evident. Grain yields of untreated plots were numerically lower than those of treated plots. Perhaps the greater rice water weevil infestation contributed to the numerically lower yields.

The delay in reflooding the water-seeded plots may have had an influence on rice water weevil infestation. That is, water management after the initial water seeding was handled in a manner similar to that for the drill-seeded rice. The only difference was that the water-seeded rice was in the three- to four-leaf stage rather than in the four- to five-leaf stage at time of applying the permanent flood. Perhaps this is a key to successful rice water weevil management after the initial water seeding of rice.

LITERATURE CITED

1. Rolston, L.H., and Phil Rouse. 1964. Effect of common variables in rice production on rice water weevil control. J. Econ. Entomol. 57:395-397.

Table 1. Percentage size distribution of immature rice water weevils from untreated plots of water seeded (WS) and drill seeded (DS) rice, Stuttgart, Arkansas, 1993.

Size or Stage of	Date of Samples									
Rice Water Weevil	6/17		6/24		7/1		7/8		7/14	
Immatures	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS
Very Small	68	100	36	11	3	2	6	2	11	13
Small	30	0	44	47	20	13	17	6	29	0
Medium	2	0	11	27	28	19	7	4	12	13
Large	0	0	8	15	35	40	21	21	36	17
Pupae	0	0	1	0	14	26	7	67	12	57

Table 2. Average number of rice water weevil larvae per five samples taken from untreated plots of two rice seeding methods at Stuttgart, Arkansas, 1993.

	Date of sampling				
Seeding Method	6/17	6/24	7/1	7/8	7/14
Drill Seeded	4.2	17.1	21.0	9.3	1.9
Water Seeded	3.7	29.8	22.4	10.2	5.0

Table 3. Average number of rice water weevil larvae per five samples taken from plots of two rice seeding methods treated with carbofuran at Stuttgart, Arkansas, 1993.

	Date of sampling				
Seeding Method	6/17	6/24	7/1	7/8	7/14
Drill Seeded	0.8	11.3	12.6	6.2	1.3
Water Seeded	0.5	11.7	13.8	8.7	5.6

SCREENING FOR RICE STINK BUG RESISTANCE

J.L. Bernhardt

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 a rice line that is more susceptible to rice stink bug damage than presently grown cultivars. RU8601179 ('Katy') was found to have less damage (pecky rice) than other long-grain rice varieties in the Arkansas Rice Performance Trials (ARPT). Subsequent evaluations of Katy samples from grower fields have verified results obtained from the ARPT comparisons. RU9101142 is an advanced rice line that has Katy and 'Newbonnet' as parents. Evaluations indicate that RU9101142 has resistance to rice stink bug similar to that of Katy.

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 of rice on the panicle 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. Grain fed on by the rice stink bug and discolored by pathogens often may not show any hull discoloration. 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 based on the assessment of the amount of discolored kernels. The overall objective of this part of the total program is to safeguard against the release of more susceptible varieties than exist at the present time. To accomplish the objective, rice grain samples must be 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 on the relative susceptibility of experimental 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) (1988-1993); 2) rice lines from breeding programs of other universities and private seed companies in the ARPT (1988-1992); and 3) rice varieties taken from grower fields in 1991 from nearly all Arkansas counties with rice. Locations of the ARPT were the Rice Research and Extension Center, Stuttgart, Arkansas (RREC, Arkansas County); the Cotton Branch Experiment Station, Marianna, Marianna (CBES, Lee County); a northeastern Arkansas county (Jackson or Clay County; and/or the Southeast Branch Experiment Station, Rohwer, Arkansas (SEBS, Desha County).

For the years 1988 through 1991, 36 rice lines in the ARPT, replicated four times, in three or four locations were evaluated. For the years 1991 and 1992, 63 rice lines in the ARPT, replicated three times, in three locations were evaluated. Named varieties are among entries in the ARPT and are used for comparison with advanced rice lines for the amount of pecky rice.

The uncleaned rough rice was hulled, then the brown rice was passed through an electronic sorting machine that separated discolored kernels from other kernels. The discolored kernels were examined under a dissecting microscope to determine the cause of the discoloration. The categories of discolored kernels were (a) kernels discolored by rice stink bug feeding, (b) kernels infected with kernel smut and (c) all other discolorations. 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 1992, four were released for certified seed production. These lines were RU8601179 (Katy), RU8701105 ('Millie'), RU8701084 ('Alan') and RU8801121 ('Orion'). Each line was released since it was found to have an advantage over other varieties in the same maturity group. The advantage Katy had over other lines was that it has greater resistance to the rice blast disease. In addition, our evaluations also showed that Katy consistently had a lower amount of pecky rice than did any of the other rice cultivars (Table 1).

Since the release of Katy, we have been waiting for seed supplies to reach sufficient volume so that Katy could be evaluated in grower fields throughout Arkansas. In 1992 samples of rice from the 1991 crop were taken from sample warehouses of grower-owned cooperatives and independent buyers of rice. Of the 1586 samples from 32 counties in Arkansas evaluated so far, 165 samples were of Katy. The average amount of pecky rice in samples of Katy in each county was lower, sometimes substantially, than the average amount found in all other long grain rice varieties grown in each county in Arkansas (Fig. 1).

The occurrence of a rice variety with 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. So, advanced rice lines with Katy as one parent have been evaluated to see if the rice stink bug resistance also was transferred. The line RU9101142 (recently released as 'Kaybonnet') comes from a cross between Katy and Newbonnet and was evaluated in the 1992 and 1993 ARPT (Table 1). Kaybonnet had lower amounts of pecky rice than did other long-grain lines in the same maturity group. Apparently Kaybonnet has some resistance to stink bugs.

SIGNIFICANCE OF FINDINGS

The portion of the entomology program for the evaluation of rice lines for resistance to the rice stink bug has been successful. The use of small plot research methods and laboratory equipment was confirmed to give reliable estimates of pecky rice. For example, RU8601179 (Katy) was identified as a resistant line by evaluations of the ARPT, a small plot research method. In addition, the use of the electronic sorting machine gave a rapid, consistent method to separate the pecky rice. The resistance was then confirmed by evaluations of rice samples from grower fields throughout Arkansas. Therefore, advanced lines such as RU9101142 (Kaybonnet) and others in the ARPT can be reliably evaluated for the presence of rice stink bug resistance, and help prevent the release of lines susceptible to severe damage by the rice stink bug.

Table 1. Average percent, by weight, of pecky rice in brown rice samples of rice varieties in the Arkansas Rice Performance Trials.

Maturity Group	Grain	Year - No. Locations					
& Variety	Type	1988-3	1989-4	1990-4	1991-3	1992-3	1993-3
Mid-Season							
Nortai	S	1.45	0.32	1.65	-	-	-
Newbonnet	L	0.88	0.14	0.80	0.79	0.44	1.50
Lemont	L	0.54	0.17	0.64	0.45	0.30	1.14
Katy	L	0.48	0.09	0.40	0.31	0.21	0.98
Short-Season							
Mars	M	0.92	0.17	0.98	0.90	0.60	1.48
Gulfmont	L	0.64	0.19	0.70	-	0.37	-
Orion	M	0.81	0.22	0.96	0.81	0.71	1.98
RU9101142	L	-	-	-	-	0.31	0.92
Very-Short-Season							
L202	L	0.99	0.15	0.87	0.86	0.68	1.56
Tebonnet	L	-	0.17	0.90	0.72	0.39	1.07
Maybelle	L	-	0.19	0.70	0.71	0.32	0.92
Millie	L	0.65	0.18	0.68	0.58	0.36	1.15
Alan	L	1.22	0.27	1.20	0.69	0.56	1.65

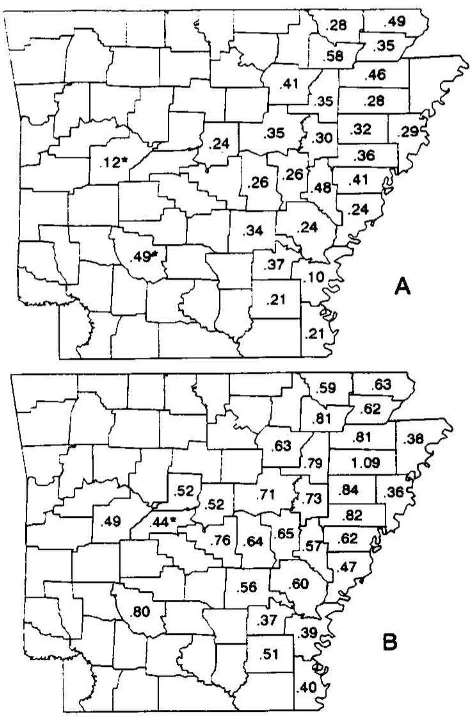


Fig. 1. Average percent, by weight, of pecky rice in brown rice samples taken from counties in Arkansas for (A) Katy and (B) all other long-grain rice varieties in 1991 (* indicates one sample).

WEED MANAGEMENT IN RICE

R.S. Helms, C.B. Guy, H.L. Black and J.A. Grove

ABSTRACT

Experiments were conducted to develop improved weed control technology for grass and broadleaf weeds. Existing herbicide programs controlled barnyardgrass (BYG) and sprangletop. Delayed preemergence (DPRE) reduced-rate applications of Facet controlled BYG but not bearded sprangletop (BST). Reduced-rate tank mixes of Facet + Bolero or Facet + Prowl applied DPRE controlled both BYG and BST. Propanil-resistant BYG was also effectively controlled by reduced-rate DPRE applications of Facet and Facet + Bolero or Facet + Prowl tank-mixes.

INTRODUCTION

Weeds infesting rice reduce grain yields, lower quality and impact harvest efficiency. Barnyardgrass (BYG) and bearded sprangletop (BST) are two major grasses that infest Arkansas rice fields. Season-long competition from these weeds can reduce rice yields as much as 80%. Broadleaf weeds such as hemp sesbania (HS) and northern jointvetch (NJV) reduce rice yields through competitive effects and produce black seeds that reduce rice grade. Control programs for these weeds are available, but continued studies are needed because of 1) changes in state herbicide regulations (2,4-D), 2) changes in industry policies that limit the availability of herbicides and 3) the need to provide a continuous source of control alternatives in an attempt to prevent buildup of weed tolerance to herbicides that could occur from continuous use of a single herbicide. Additionally, conservation tillage systems for rice in Arkansas are increasing. Studies should be addressed to determine if direct-seeded rice herbicide technology is applicable to rice produced in a conservation tillage system.

PROCEDURES

Herbicide treatments were compared in replicated field experiments conducted in 1993 at the Rice Research and Extension Center (RREC). 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 ≥ 80% weed control and ≤ 30% injury to rice from which rice recovered in a reasonable period of time without significant grain yield reduction.

RESULTS AND DISCUSSION

Barnyardgrass and Sprangletop Study

Delayed preemergence (DPRE) applications of Facet at labeled rates (0.38 lb active ingredient (ai)/acre) and reduced rates (0.19 or 0.25 lb ai/acre) provided effective season-long BYG control compared to standard herbicide treatments. 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.

Prowl Timing Study

Prowl (1 or 2 lb ai/acre) applied DPRE at 0, 1, 3 or 5 days after flushing provided effective season-long control of BYG. The application timings after flushing indicate that Prowl can be applied safely to drill-seeded rice after the rice seed has imbibed water for germination. Rice injury from the Prowl treatments was ≤ 10%, and there were no significant rice stand reductions. Broadleaf weeds infested the experimental area at mid-season, indicating that sequential applications of herbicides may be necessary after Prowl applied DPRE.

Propanil-Resistant Barnyardgrass Study

Propanil-resistant barnyardgrass collected in Poinsett County, Arkansas, was over-seeded in the experimental area at RREC. 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. Herbicide treatments that controlled propanil-resistant BYG (≥ 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.

Preflood Broadleaf Weed Control

Facet applied DPRE and early postemergence provided effective control for HS and NJV. Grandstand and Grandstand tank-mixes with propanil or Arrosolo effectively controlled HS and NJV. Londax alone did not effectively control HS or NJV. However, propanil + Londax tank-mixes controlled HS and NJV.

Conservation Tillage Systems in Rice

The experimental area was in soybeans in 1992. The soybeans were harvested, and the experimental area had not been disturbed. Roundup D-Pak (20 oz/acre) was applied approximately four weeks prior to rice seeding for initial burndown. At seeding, Roundup D-Pak (20 oz ai/acre) was applied alone or tank-mixed with Facet (PRE) for BYG control. Herbicide treatments included Facet, Facet tank-mixed with Bolero or Prowl and Bolero applied DPRE. Propanil tank-mixed with Bolero (3 + 3) was considered the standard herbicide treatment. All herbicide treatments provided effective control of BYG. The results demonstrate that the PRE, DPRE or early post herbicide applications in conservation tillage systems in rice can effectively control BYG. Two burndown herbicide applications may be necessary to control the established weeds.

SIGNIFICANCE OF FINDINGS

The reduced rate DPRE applications of Facet and Facet + 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.

The DPRE application of Prowl at 0, 1, 3 or 5 days after flushing indicates that DPRE applications of Prowl are safe on rice as long as the rice has imbibed water for germination. These studies support the expanded DPRE application of Prowl on rice. Grandstand and Grandstand + propanil or Arrosolo provide effective preflood broadleaf weed control.

RICE CULTIVAR RESPONSE TO RICE HERBICIDES AND SIMULATED RICE HERBICIDE DRIFT TO SENSITIVE CROPS

Charles B. Guy, Jr., R.S. Helms and J.D. Beaty

ABSTRACT

Field studies were conducted to evaluate several of the newer rice cultivars to Bolero and Ordram in water-seeded culture and Grandstand and Whip 360 in dry-seeded culture. Studies were also conducted to evaluate cotton response to full and drift rates of the rice herbicides Propanil, Facet, Londax, Grandstand and 2,4-D. Rice response to the new cotton herbicide, Staple, applied at drift rates was also evaluated. Bolero or Ordram did not reduce yields of water-seeded rice varieties 'Bengal' and 'Tebonnet'; however, 'Adair' displayed extreme sensitivity to both Bolero and Ordram, as did 'Millie'. None of the rice cultivars tested showed sensitivity to Grandstand applied between the four-leaf and panicle differentiation development stages. 'Mars', 'Bengal' and 'Orion' showed similar visual injury from Whip 360, but grain yields were not reduced.

Propanil applied preemergence at 4.0 lb active ingredient (ai)/acre and postemergence at 0.4 lb ai/acre to cotton caused severe stand and yield loss, which was worse when Temik was applied in furrow to the cotton at planting. Facet applied to the soil prior to bed knockdown for cotton planting showed less injury than application after cotton planting. Cotton displayed greater sensitivity to Londax drift than in 1992 observations. Cotton was more sensitive to Facet, Grandstand and 2,4-D when treated at early fruiting than at the two-leaf growth stage. Cotton sensitivity to herbicide injury was in the following order: 2,4-D>> Facet > Grandstand. Rice injury from Staple drift was negligible, and yield was not reduced.

INTRODUCTION

In recent years several rice herbicides have been shown to injure some rice varieties more than others. For example, 'L201' is sensitive to molinate (Ordram) and thiobencarb (Bolero). The newer cultivars, 'Millie' and 'Adair', have L201 as a parent and have inherited the sensitivity to these herbicides. Another example of inherited response is the sensitivity of 'Mars' to fenoxaprop (Whip 360). Mars was used as a parent for the new variety 'Bengal', and sensitivity was inherited. Therefore, we can often predict sensitivity to specific herbicides based on genetics. However, as new varieties and herbicides are developed, a screening program such as the one we have recently developed should help determine sensitivity prior to full-scale commercialization of the variety.

Most rice herbicides are aerially applied. Cotton is sometimes planted close to rice, and injury from rice herbicide drift can be a problem. Several rice herbicides have been shown to be extremely toxic to cotton. Our research is designed to identify potential problems and evaluate ways to reduce them.

Therefore, the objectives of these studies are: 1) to screen promising new lines and cultivars for sensitivity to the herbicides commonly used in rice production 2) and to evaluate drift rates of specific herbicides for damage to cotton on rice.

PROCEDURES

Field tests using standard small-plot techniques were conducted at the Southeast Branch Experiment Station (SEBES) near Rohwer, Arkansas, to evaluate the response of certain rice cultivars to selected herbicides. Mars, Bengal, Adair, Millie, 'Alan' and 'Tebonnet' were evaluated for tolerance to Bolero and Ordram at 4.0 and 8.0 lb ai/acre in water-seeded culture. Pin-point flood management was used. 'Katy', 'Lacassine', 'Lemont' and 'Newbonnet' were compared for tolerance to triclopyr (Grandstand) at 0.38 and 0.75 lb ai/acre applied at rice growth stages five-leaf, mid-tiller and late tiller. Mars, Bengal and 'Orion' were compared for tolerance to 0.067 and 0.134 lb ai/acre of Whip 360 applied at five-leaf, mid-tiller and late tiller growth stages. The injury potential of propanil to cotton was evaluated. Propanil (Stam M-4) at 0.04, 0.4 and 4.0 lb ai/acre was applied to aldicarb- (Temik) or disulfoton- (Di-syston) treated cotton (preemergence and postemergence). Quinclorac (Facet) at 0.005, 0.05, 0.25 and 0.5 lb ai/acre was applied to the soil prior to bed knockdown for cotton planting, with or without rainfall. Preemergence application of Facet was also tested. Bensulfuron

(Londax) was applied postemergence to one-leaf and match-head square cotton to determine injury from drift rates of 0.006, 0.06, 0.3 and 0.6 oz ai/acre. Drift rates of 2,4-D (0.001, 0.01 and 0.1 lb ai/acre), Facet (0.0038, 0.038, 0.19 and 0.38 lb ai/acre) and Grandstand (0.0038, 0.038, 0.19 and 0.38 lb ai/acre) were applied at one-leaf and match-head square growth stages, and comparative evaluations were made. Rice response to DPX-PE350 (Staple) was evaluated by applying drift rates of 0.015, 0.030, 0.060, 0.120, 0.24 and 0.48 oz ai/acre at three-leaf, mid-tiller and half-inch internode elongation growth stages.

RESULTS AND DISCUSSION

Response of six rice cultivars to Bolero and Ordram in water-seeded culture.

This is the first year we have evaluated rice tolerance to herbicides commonly used with water-seeding. Rice yields were low due to improper nitrogen management; however, differential response to the herbicides was observed. Figure 1 represents the interaction means for yield as affected by cultivar and herbicide rate. Grain yields of Millie were decreased dramatically from application of either 8 lb ai/acre of Bolero or Ordram. Adair was sensitive to Bolero at 4 lb ai/acre; over 3,400 lb rough rice yield loss was recorded. Mars, Bengal, Alan and Tebonnet did not show a significant yield loss resulting from Bolero application. Adair, Millie, Alan and Mars showed reduced yields as a result of a 2-X rate (8 lb ai/acre) of Ordram, but Bengal and Tebonnet were not affected significantly.

Response of Katy, Lacassine, Lemont and Newbonnet to Grandstand applied at selected growth stages.

Figure 2 represents rough rice yield as affected by timing averaged across for varieties and two rates of Grandstand. When applied at booting, Grandstand reduced yield 3481 lb/acre. In previous tests, rice yield has sometimes been reduced when Grandstand was applied at panicle differentiation plus seven days. These and other data indicate that Grandstand probably is safe to apply between four- to five-leaf and panicle differentiation development stages of the cultivars Alan, Katy, Newbonnet, Lemont, Lacassine, 'Maybelle', Millie, Mars, Orion, 'L202' and Tebonnet.

Response of Bengal, Mars and Orion to Whip 360 applied at selected growth stages.

Injury from Whip 360 applied at a rate of 0.067 and 0.134 lb ai/acre at five-leaf, mid-tiller and late-tiller growth stages was slight to moderate. There were no yield reductions resulting from Whip 360 applied at 0.067 and 0.134 lb ai/acre (data not shown). Last year only Bengal showed reduced yield when Whip 360 was applied at 0.067 lb ai/acre to five-leaf rice, and these three cultivars had reduced yield at 0.134 lb ai/acre applied at this growth stage.

Effect of in-furrow insecticide on cotton injury from preemergence and postemergence applications of propanil.

There was a significant interaction among insecticides, method of application and propanil rate. Figure 3 represents cotton yield as affected by in-furrow insecticide, propanil application timing and propanil rate. Propanil applied preemergence at 4.0 lb ai/acre caused a 2570-lb seed cotton/acre decrease when Temik was used in-furrow. This same treatment resulted in a 1797 lb decrease when Di-syston was used in-furrow. These data indicate that propanil does have preemergence activity on cotton. Drift rates of propanil, 0.4 and 0.04 lb ai/acre, applied postemergence reduced yield 2815 and 404 lb/acre, respectively, when Temik was used in-furrow. When Di-syston was used in-furrow, yield was reduced 1969 and 400 lb/acre, respectively, at 0.4 and 0.04 lb ai/acre propanil. Based on this study, Temik-treated cotton was more sensitive to propanil than Di-syston-treated cotton.

Effect of Londax rate on cotton injury and yield.

Figure 4 shows cotton yield as affected by Londax rate averaged across application timing. Londax at 0.6 oz ai/acre is the most common rate used in Arkansas. Injury was more severe this year than in two previous years' research. Londax rates of 0.6, 0.3 and 0.06 oz ai/acre reduced cotton yield in 1993, whereas last year only the full (0.6 oz ai/acre) rate reduced yield. Visual injury was slight yellowing and stunting. The highest amount of visual injury at 0.06 oz ai/acre (1/10x) was only 33% and was not noted in later ratings (data not shown).

Effect of Facet application timing on cotton injury and yield.

Previous tests have indicated that Facet will injure cotton at drift rates. The 1993 test was designed to determine if cotton injury can be avoided from Facet application prior to planting by removing treated soil at bed knockdown and to determine the effect of rainfall after application and prior to bed knockdown. This year we added a set of treatments that received 0.83 in. of rain before bed knockdown. Figure 5 shows cotton yield as affected by Facet application, timing and rate. Cotton yield was not reduced when Facet was applied before bed knockdown, regardless of rainfall or rate. Yield was reduced when Facet was applied preemergence at 0.25 and 0.5 lb ai/acre (half and full rates).

Cotton response to drift rates of 2,4-D, Facet and Grandstand.

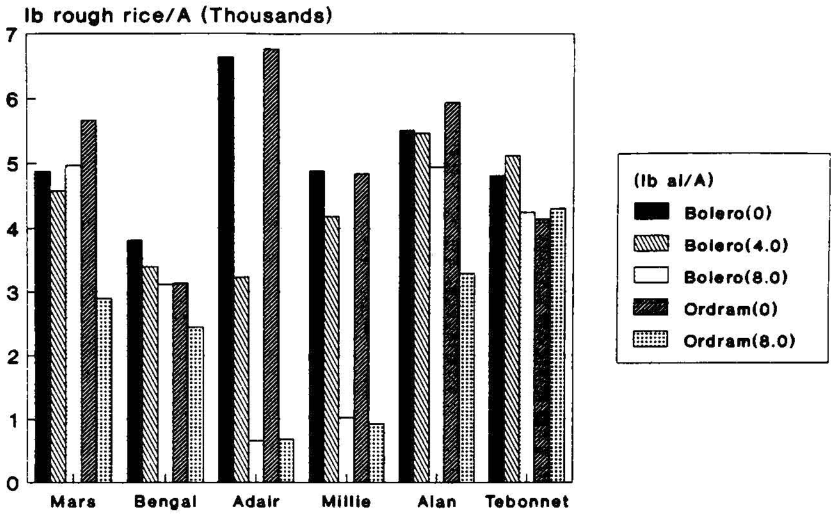
Figure 6 represents seed cotton yield as affected by application timing and herbicide rate. Rates are expressed as a fraction of the full use rate. 2,4-D was much more toxic to cotton as compared to Facet or Grandstand. Cotton was more sensitive to 2,4-D at the 1/100x rate when the application was made at the early fruiting development stage than when applied to two-leaf cotton. Facet reduced cotton yield similarly when applied to two-leaf and early fruiting stages, whereas Grandstand was more toxic to fruiting cotton compared to two-leaf cotton. These data are consistent with previous observations. The order of toxicity was 2,4-D>> Facet > Grandstand.

Rice response to Staple drift.

Staple is a new cotton herbicide being developed for over-the-top use. It may be applied by air when labeled; therefore, drift to nearby rice may be a problem. Staple was applied at 0.48-0.015 oz ai/acre to rice at the three-leaf, mid-tiller and panicle differentiation growth stages. Stunting and upright growth were the only visual symptoms noted. Injury was considered minor, and grain yields were not reduced, irrespective of herbicide rate (data not shown).

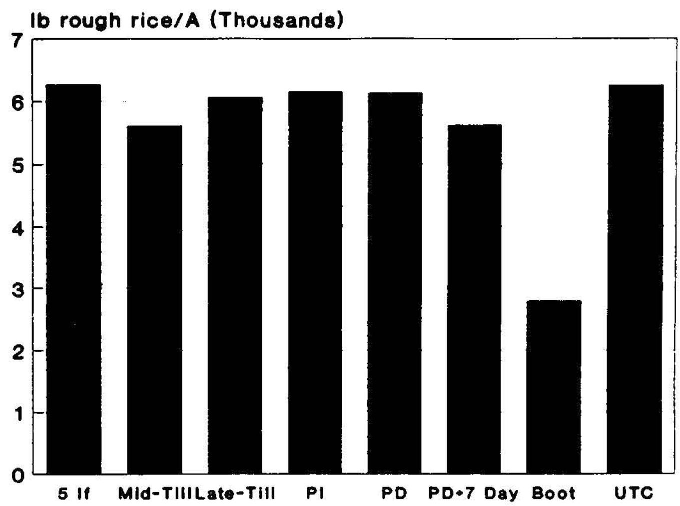
SIGNIFICANCE OF FINDINGS

Adair was found to be sensitive to Bolero and Ordram in water-seeded culture. A statement concerning Adair's sensitivity to Bolero was added to the MP-44 in 1994. Rice tolerance to Grandstand is an issue with producers. Our data indicate that the window for application is from four-leaf to half-inch internode elongation, regardless of variety. Propanil was shown to have preemergence activity on cotton. This has not been documented by other researchers. Additionally, Temik-treated cotton was more sensitive than Di-syston-treated cotton. Facet applied prior to bed knockdown was much safer than that applied preemergence. This information may enable rice producers to apply Facet next to hipped cotton beds with less injury potential to cotton. Rice was tolerant to Staple drift. This fact will be important because Staple may be applied by air.



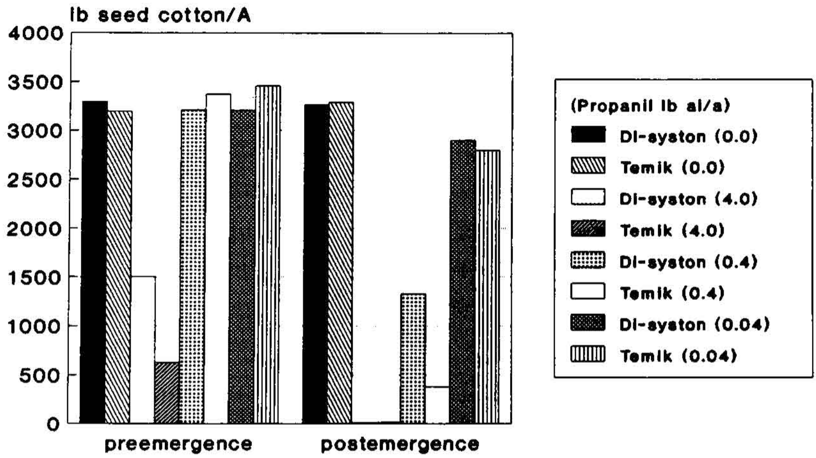
LSD (0.05) = 1394 lb/A

Fig. 1. Effect of Bolero and Ordram applications on grain yields of six cultivars in water-seeded culture.



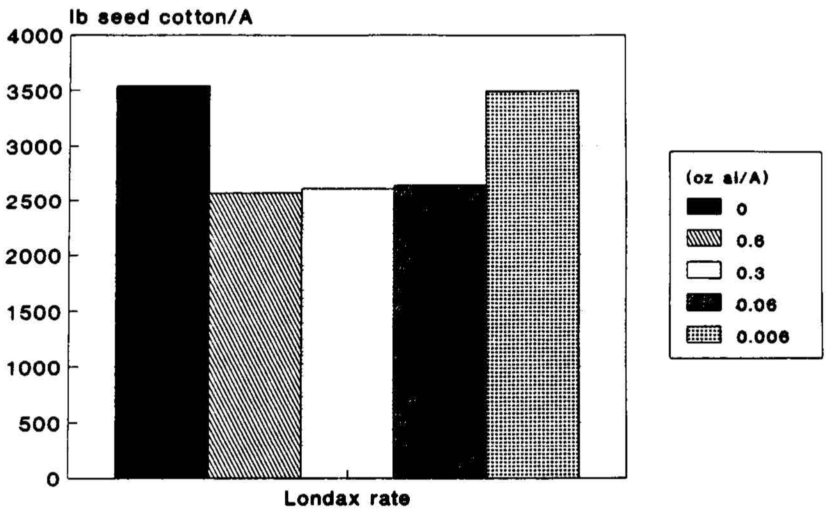
PI = panicle initiation
PD = panicle differentiation
LSD 0.05 = 848

Fig. 2. Effect of plant growth stage of rice on response to Grandstand (Katy, Lacassine, Lemont and Newbonnet combined, 0.38- and 0.75-lb ai/acre rates combined).



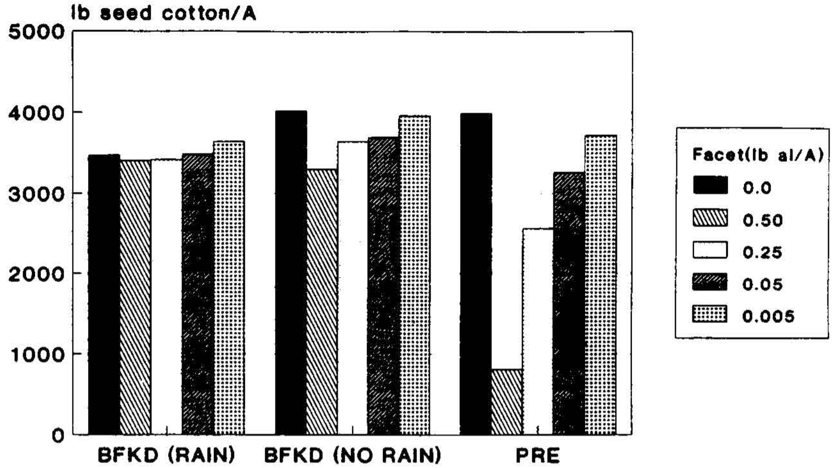
Di-syston 0.75 lb ai/A
Temik 0.5 lb ai/A
LSD 0.05 • 350

Fig. 3. Effect of pre- and postemergence application of propanil (Stam M-4) and two insecticides on cotton yield.



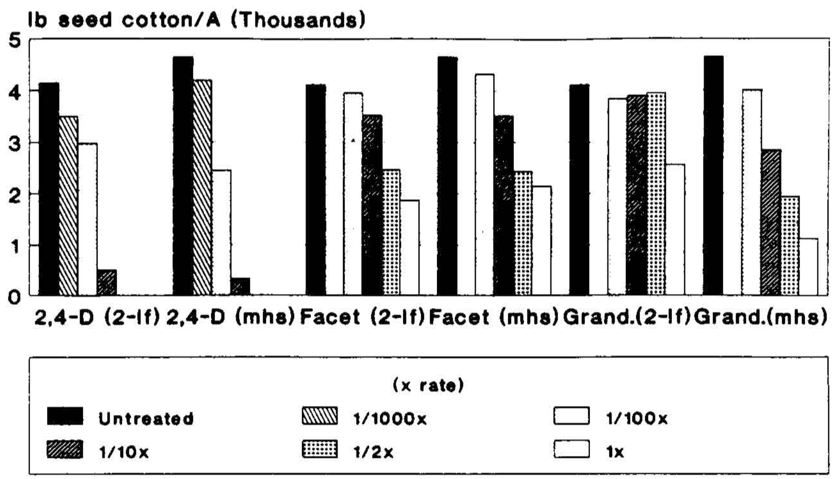
LSD 0.05 • 649

Fig. 4. Effect of bensulfuron (Londax) rate on cotton yield (one-leaf and early fruiting applications combined).



BFKD=before bed knockdown (rain,no rain)
PRE = preemergence
LSD 0.05 = 759

Fig. 5. Effect of Facet application timing and rate on cotton yield.



LSD 0.05 = 395
2lf = two leaves at application
mhs = match-head squares at application

Fig. 6. Effect of 2,4-D, Facet and Grandstand application timing and drift rates on cotton yield.

ENVIRONMENTAL IMPLICATIONS OF PESTICIDES IN RICE PRODUCTION

T.L. Lavy, W.G. Johnson, R.A. Dewell, J.D. Mattice, B.W. Skulman, R.S. Helms, C.B. Guy, Jr. and H.L. Black

ABSTRACT

Studies were conducted to determine the persistence of 2,4-D and Grandstand 1) in paddy-rice soil and water, 2) in dryland-rice soil and 3) on bare ground and to determine the persistence of Furadan and Ordram in paddy-rice soil and water. The studies were conducted at Stuttgart and Rohwer, Arkansas, in 1992 and 1993. Grandstand and 2,4-D applied at the PI stage of rice growth dissipated in paddy water to levels at or below detectability by 28 days after application (DAA), although both herbicides were slightly more persistent in dryland rice soil and on bare ground. Dissipation of Furadan and Ordram from paddy water was rapid. Furadan was not detected in paddy water after 28 DAA. By 21 DAA over 90% of the applied Ordram had dissipated, but detectable levels of residues remained in paddy water through 49 DAA. Furadan and Ordram dissipated rapidly from paddy soil for approximately the first 14 DAA due to solubilization of the granules into the overlying paddy water.

Another study was conducted to monitor tailwaters from several rice-producing fields and determine if significant pesticide concentrations were entering nearby surface waters. Trace level concentrations of 2,4-D and Benlate were detected shortly after application and declined significantly within 7 to 10 DAA.

INTRODUCTION

Arkansas rice growers have relied on man-made pesticides to achieve optimum yields. As a result, the persistence of these chemicals is becoming an increasingly important issue because of the uncertainty of the environmental effects of small amounts remaining in soil and water. Recently pesticide use associated with rice production has aroused the suspicions of regulators and concerned citizens, especially in California. There is no major pool of information from Arkansas that indicates that rice production is harmful to the environment. It is important, however, that the rice industry and other interested parties implement appropriate research to determine if environmental problems are being created by current pesticide use patterns or if there is a likelihood of these problems occurring in the near future.

The overall goal of this research is to monitor the environmental fate of rice pesticides in soil and water in order to estimate their potential to reach groundwater. Specific goals were: 1) to evaluate the persistence of Bolero, 2,4-D and Grandstand in paddy-rice soil and water, dryland-rice soil and on bare ground; 2) to evaluate the persistence of Furadan and Ordram in paddy-rice soil and water; and 3) to monitor tailwaters for pesticide residues and determine which pesticides require further transport and dissipation studies.

PROCEDURES

For objectives 1 and 2, small plot experiments were established at the Rice Research and Extension Center (RREC) in Stuttgart, Arkansas, on a Crowley silt loam and at the Southeast Branch Experiment Station (SEBES) in Rohwer, Arkansas, on a Perry silty clay in 1992 and 1993. Standard cultural practices were followed. Paddy-rice plots were approximately 15 x 15 ft in size with earthen levees surrounding each plot. The dryland rice area was surrounded by a single levee and was flushed once or twice per week to maintain rice growth. The bare ground area was maintained with periodic applications of Roundup and received no supplemental irrigation. The experimental design was a randomized complete block with two replications of each cultural system at each location. Furadan (1 lb/acre) and Ordram (5 lb/acre) were applied in the granular form at the tillering stage of rice growth into the floodwater. Grandstand (0.38 lb/acre) and 2,4-D (1 lb/acre) were applied with a CO_2 backpack sprayer in 10 GPA carrier volume at the PI stage of rice growth. Soil and water samples (from paddy-rice area only) were taken at 0, 1, 7, 14, 21, 28, 35 and 49 d after application (DAA).

Soil samples were extracted with organic solvents and quantified with gas chromatography. Clean-up procedures were performed as needed and included acid-base partitioning and clean-up columns. Water samples were extracted using solid-phase extraction techniques and quantified with co-chromatography. Use of co-chromatography involves either injecting the sample on two separate columns in the same gas chromatograph or analyzing the sample on separate gas chromatographs. When both systems produce the same finding, this confirms the presence of the analytes.

For objective 3, tailwater samples were collected at either weekly or bimonthly intervals from several rice fields in Conway and Faulkner Counties in Arkansas. Two irrigation management systems, one involving continuously recycled water (from ponds) and the other implementing partially recycled water from a creek, were studied. Pesticides monitored were 2,4-D, Ordram, Prowl, Stam, Bolero, Benlate and Methyl Parathion. However, 2,4-D, Stam, Bolero and Benlate were the only pesticides applied to the fields during 1993. Water samples were extracted as mentioned previously and quantified with either gas chromatography or high performance liquid chromatography.

RESULTS AND DISCUSSION

The lower limits of detectability for each pesticide are shown in Table 1. Dissipation of 2,4-D and Grandstand was rapid in paddy water, dryland rice soil and on bare ground with half-lives of 10 days or less (Fig. 1). Trace levels of 2,4-D were detected in soil at the 3- to 6-, 6- to 9- and 9- to 12-in. depths at both locations in all cultural systems (data not shown). Grandstand was slightly more persistent than 2,4-D. Trace levels of Grandstand were detected at 28 DAA in paddy water and at 49 DAA in soil of dryland rice and on bare ground. Trace levels of Grandstand were detected in soil at the 3- to 6-in. depths at both locations; however, Grandstand was not detected below the 6-in. depth. Only trace levels of these chemicals were detected in the soil of paddy-rice culture, probably due to the high water solubilities and low soil adsorption characteristics of these herbicides.

Furadan and Ordram dissipated from paddy water rapidly for approximately 14 DAA, but Ordram was still detected at trace levels at 49 DAA (Fig. 2). Furadan was not detected in paddy water after 28 DAA. Furadan and Ordram dissipation from soil was rapid for the first 7 DAA, probably due to dissolution of the granules into the paddy water. Trace levels of Furadan and Ordram were still detectable in paddy soil through 49 DAA.

For objective 3 (tailwater study), preliminary results indicate that trace levels of 2,4-D and Benlate may be detected in tailwaters for 7 to 10 DAA. Concentrations of both 2,4-D and Benlate decreased significantly between the 1 DAA and the 7 or 10 DAA sampling period (Table 2). Further studies are needed to confirm the presence of these pesticides and to evaluate other pesticides and their significance at trace level concentrations

ACKNOWLEDGMENTS

The authors gratefully acknowledge the research assistance of the personnel at the Rice Research and Extension Center, Stuttgart; the Southeast Branch Experiment Station, Rohwer; and Altheimer Lab personnel Robert Badger, Karen Wiggins, Isaiah Porter, Drew Hodgdon and Jim Ueltschey. The authors would also like to acknowledge the cooperation of Emmett and Joe Torian and Barry Stobaugh for allowing us to take water samples from their rice fields. The financial support of the Rice Research and Promotion Board is also appreciated.

Table 1. Lower limits of detectability and maximum contaminant levels (MCL's) for the pesticides evaluated.

Pesticide	Lower Limit of Detectability		
	Soil	Water	MCL[z]
	ppb		
Furadan	10	5	40
Grandstand	30	1	NA[y]
Ordram	10	1.2	NA
2,4-D	40	1	70
Prowl	--	0.2	NA
Stam	--	0.2	NA
Bolero	--	NA	NA
Benlate	--	0.4	NA
Methyl Parathion	--	0.2	2

[z]MCL = maximum contaminant level. An enforceable, regulatory standard established by the Environmental Protection Agency (EPA) for maximum permissible concentrations of pesticides in water.

[y]Data not available.

Table 2. Trace level pesticide concentrations detected in tailwaters.

Pesticide	Concentration ranges in tailwater			Toxicity Rainbow trout
	1 DAA	7 DAA	10 DAA	LC_{50}[z]
	ppb			
Benlate	15-40	----	2-6	170[y]
2,4-D	100-150	2-5	----	1100[x]

[z]LC_{50} = lethal concentration for 50% of fish population.

[y]Based on 96 hours of exposure.

[x]Based on 48 hours of exposure.

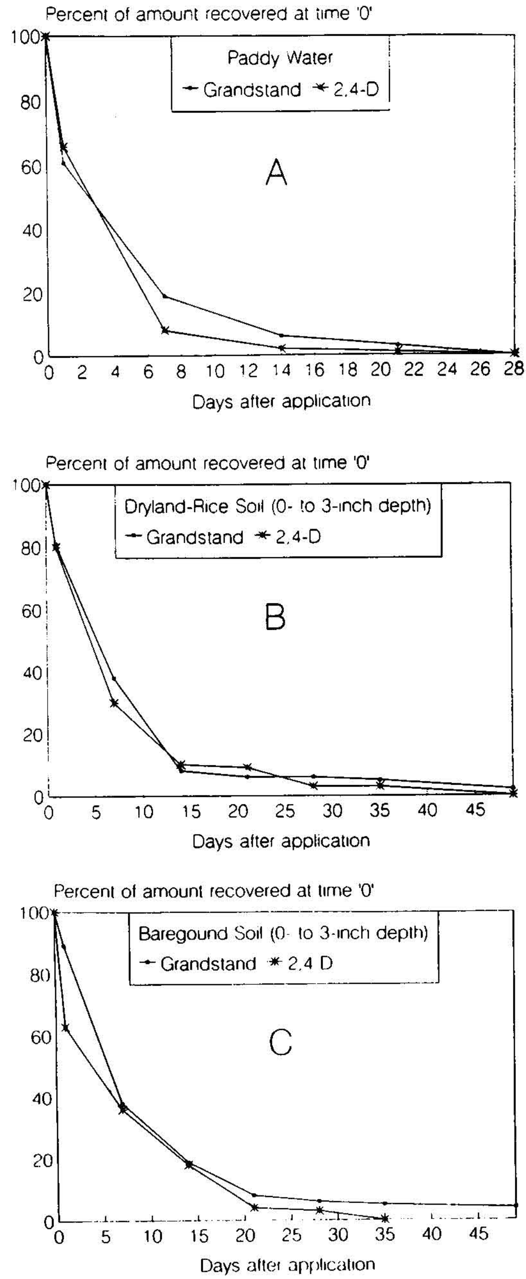
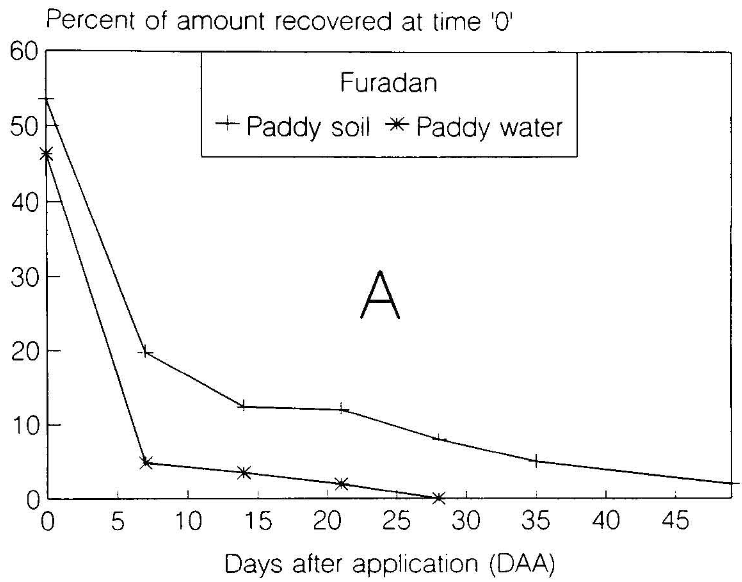


Fig. 1. Relative concentration of 2,4-D and Grandstand residues recovered in paddy water (A), dryland-rice soil (B) and on bare ground (C) at Stuttgart and Rohwer, Arkansas, in 1992 and 1993.



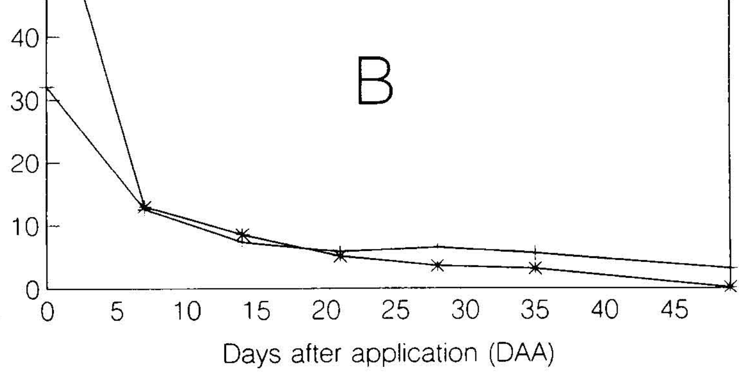


Fig. 2. Relative concentration of Furadan (A) and Ordram (B) residues recovered in paddy water and paddy soil (0- to 3-in. depth) at Stuttgart and Rohwer, Arkansas, in 1992 and 1993.

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

Experiments were conducted in the field and greenhouse to examine the epidemiology of rice blast disease in Arkansas. Replicated field plots were established on two experiment stations and in seven growers' fields with cultivars of major importance to rice production in Arkansas. Disease progress curves were determined for leaf, collar and neck rot infections. In small plots, the incidence of neck rot on a susceptible variety reached 40% while in plots established in growers' fields the incidence of neck rot infection reached 50%. Overall, results suggest there is no clear association of the incidence of leaf and collar infections with the incidence of neck rot infection of susceptible rice cultivars.

INTRODUCTION

Rice blast disease is one of the most serious of all rice diseases in temperate and tropical climates and is capable of causing very significant crop losses in the absence of effective management strategies. The disease has become increasingly important in Arkansas within the past few years on new, high-yielding and susceptible cultivars such as 'Newbonnet'. The pathogen *Magnaporthe grisea* infects leaves, collars, necks and panicles of rice.

Much is known about the epidemiology of the disease in tropical regions, and various quantitative procedures utilizing components of the disease process and the effects of environmental conditions on these components have been used to develop crop loss assessment and disease progress models. These models can be used to determine when fungicide applications are economically feasible and most effective. However, since these models are based on tropical varieties infected by tropical strains of the fungus, they may not be suitable for Arkansas conditions.

In comparison, very little quantitative information describes how rice blast develops in Arkansas or how environmental and cultural factors affect disease development on leaves, collars, necks and panicles of Arkansas cultivars. Furthermore, the effects of resistance components in Arkansas cultivars are also unquantified in terms of disease development over time. In 1983, Marchetti described the development of rice blast on rice varieties and breeding lines in studies conducted in Texas and showed that different cultivars exhibited varying levels of resistance to rice blast and that resistance slowed the rate at which epidemics developed (Marchetti, 1983). Bonman et al. (1989) recently showed that resistance to leaf infection is not necessarily related to resistance to neck infection among specific cultivars.

The inter-relationships of the neck blast, leaf spot and collar rot phases of the disease and their cumulative effects on yield must also be clarified. Recent reports have suggested that early infections of leaves and collars provide inoculum for later epidemics on leaves, collars, necks and panicles. Rangaswami and Subramanian (1958) showed that there was a positive correlation between the incidence of leaf infection and neck infections only among the more susceptible varieties while among less susceptible varieties there was no significant correlation. It has been recently suggested that the incidence of neck rot is directly related to yield losses while leaf and collar rot phases have lesser effects on yield reduction (Torres and Teng, 1993).

To better understand this disease in Arkansas, the development of disease on leaves, collars and necks was measured in field plots on experiment stations and in growers' fields to determine the relative rate at which epidemics developed on important cultivars.

PROCEDURES

Eight rice cultivars, 'Adair', 'Alan', 'Cypress', 'Katy', 'Lacassine', Newbonnet, 'Orion' and 'RT7015', were seeded in replicated plots at the Rice Research and Extension Center at Stuttgart, Arkansas, on 24 May 1993 and at the Pine Tree Experiment Station, Colt, Arkansas, on 26 May 1993. Treatments (cultivars) were planted in a randomized complete block design with four replications. Each variety was planted as a split plot for nitrogen level, one half of the plot receiving recommended fertilization and the remaining half receiving 20% above the recommended rates. Each cultivar was planted at a density of 23 seeds/ft^2 in 6 x 16-ft plots. Otherwise, standard agronomic practices were used to grow cultivars to maturity. Yield data were not taken.

Susceptible rice cultivars 'M201', 'M202' and 'Rosemont' were planted on the outer boundaries of each plot to aid in spread of the pathogen to plots. Rosemont was also planted around the entire plot area.

Rice blast was initiated by inoculation of susceptible varieties within plots and by spreading diseased tissue. Diseased Newbonnet tissue was cast over spreader plants surrounding the plot at mid-tillering. Infected seedlings inoculated with races IB49, IC17 and IH1 were transplanted within the spreader plants in each plot at beginning internode elongation. Additionally each cultivar and spreader row was inoculated by spraying spores of races IB49, IC17, IG1 and IH1 at internode elongation.

Four replicated plots (2m X 2m) were established in seven growers' fields grown in Adair, Alan, Lacassine, Mars, Newbonnet, Rosemont and RT7015. The fields were selected on the basis of high early incidence of blast. Although the total area affected by the disease varied from field to field, all plots were placed in the more heavily infected areas.

Disease levels were assessed as the incidence of leaf spot, collar rot and neck blast at weekly intervals after tillering. In the experiment station plots, 10 randomly selected plants were sampled within plots until panicle emergence. After panicle emergence, 50 randomly selected plants from each plot were assessed.

In growers' fields, data were collected from five randomly selected plants within each plot at each interval.

Data collected from all plots at each sample time included number of lesions per leaf, lesion length and width (mm), location of lesions from tip of leaf (cm), age of lesions, collar rot lesions per leaf, collar rot lesion length, rotten neck lesion incidence and lesion length (mm) and rice growth and maturity stages using the Modified Zadok Codes for Rice Maturity (Chin et al., 1991).

Twelve rice cultivars, Adair, Alan, Cypress, Lacassine, LaGrue, Lemont, Katy, Mars, Newbonnet, Orion, Rosemont and RT7015, were planted 18 September 1993 in 3 1/2-in. by 2 7/8-in. pots in the greenhouse experiment at Fayetteville. Two weeks after emergence, ammonium sulfate (0.1 g/pot) was applied at one-week intervals. Cultures of *Pyricularia grisea*, races IB49, IC17 and IB1, were maintained on modified potato dextrose agar (12 g potato dextrose broth, Difco; 2.5 g yeast extract, Difco; 15 g agar, Difco; and 1000 ml deionized water) for 7 to 10 days. Conidia were harvested separately in deionized water and adjusted to 500,000 spores/ml using a hemacytometer. Four replications of each rice cultivar were inoculated with spore suspensions applied with a compressed air applicator. Plants were immediately placed in a dew chamber for 24 hours at 24 C. Plants were rated for disease after 10 days using a scale of 1 (least susceptible) to 9 (most susceptible) (Table 3).

RESULTS AND DISCUSSION

Development of Rice Blast in Experimental Plots at Two Experiment Stations.

At Pine Tree, leaf blast and collar rot phases were not observed during the entire test (Table 1). However, the incidence of rotten neck ranged from 0% rot on Katy to a high of 40% on Newbonnet (Table 1). Because there appeared to be no significant difference in the amount of neck rot between the recommended and the high rate of nitrogen, data for the two treatments were pooled. The rate at which rotten neck symptoms appeared on the eight test varieties is presented in Fig 1. In 1993, neck rot symptoms appeared shortly after anthesis on all varieties except Katy, reaching 40% for Newbonnet by the soft dough stage. Lower levels of infection, ranging from 10% to 20% neck rot, were observed for Lacassine, Alan, Cypress and RT7015 during this same time frame. Less than 10% infection was observed for Adair and Orion, and no lesions were found on Katy.

Leaf spot, collar rot and neck rot were not found on any of the rice varieties grown in plots at the Research and Extension Center at Stuttgart in 1993.

Development of Rice Blast in Growers' Fields

The development of rice blast was also assessed in seven growers' fields chosen on the basis of early incidence of the disease. Plots were established in the more heavily infected areas. In these fields, the highest incidence of leaf blast on the lower leaves ranged from 8% on Lacassine to 79% on Mars (Table 2). The incidence of leaf blast generally declined for the lower three leaves of all varieties during the year while the incidence of leaf blast on the upper three leaves showed periodic increases that were loosely correlated with rainfall episodes (data not shown). The decline in disease incidence on leaves was expected since leaves generally become more resistant to infection with age (Table 3). On the other hand, the total lesion area infected by rice blast on the upper leaves continued to increase over time with some varieties, particularly Mars and Newbonnet. The largest leaf lesions were found on Newbonnet.

The incidence of collar rot in growers' fields ranged from 0% on Alan, Lacassine, Rosemont and RT7015 to a high of 33% on Mars and Newbonnet. The incidence of neck rot ranged from 8.3% for

Lacassine to 50% for Newbonnet. Only Lacassine had less than 25% neck rot at the last sampling date before harvest. Across all varieties, neck rot levels in growers' fields averaged 43% despite fungicide treatments applied by growers in fields of Adair, Alan, Mars, Newbonnet and RT7015.

As in the experimental plots at Pine Tree, symptoms of neck rot appeared shortly after anthesis for all varieties with rapid increases in the incidence of lesions until the milk ripe stage when sampling was terminated (Fig. 2). The increase in incidence with respect to time was very steep for all varieties except Lacassine where less than 10% of the necks were rotted at the last sampling date. The largest neck rot lesions, approximately 17 to 19 mm long, were found on Alan, Lacassine, Mars and Rosemont. Neck rot lesions approximately 10 and 11 mm long were found on Adair and Newbonnet (data not shown).

SIGNIFICANCE OF RESULTS

These results provide additional data on the development of rice blast disease on several major rice cultivars grown in Arkansas. The data were collected in a single year, and additional data must be obtained before significant trends of relationships can be established.

However, the data collected in 1993 suggest that there is no clear association between the incidence of leaf blast, collar rot and neck rot phases. The absence of leaf blast and collar rot in the experimental plots followed by relatively high incidences of neck rot suggest that inoculum from other sources is important to establishing neck rot infections. Since neck rot has been correlated most directly with yield losses, additional data on the susceptibility of neck tissue to infection and the source of inoculum is needed to establish the role of resistance to control this disease.

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ACKNOWLEDGMENTS

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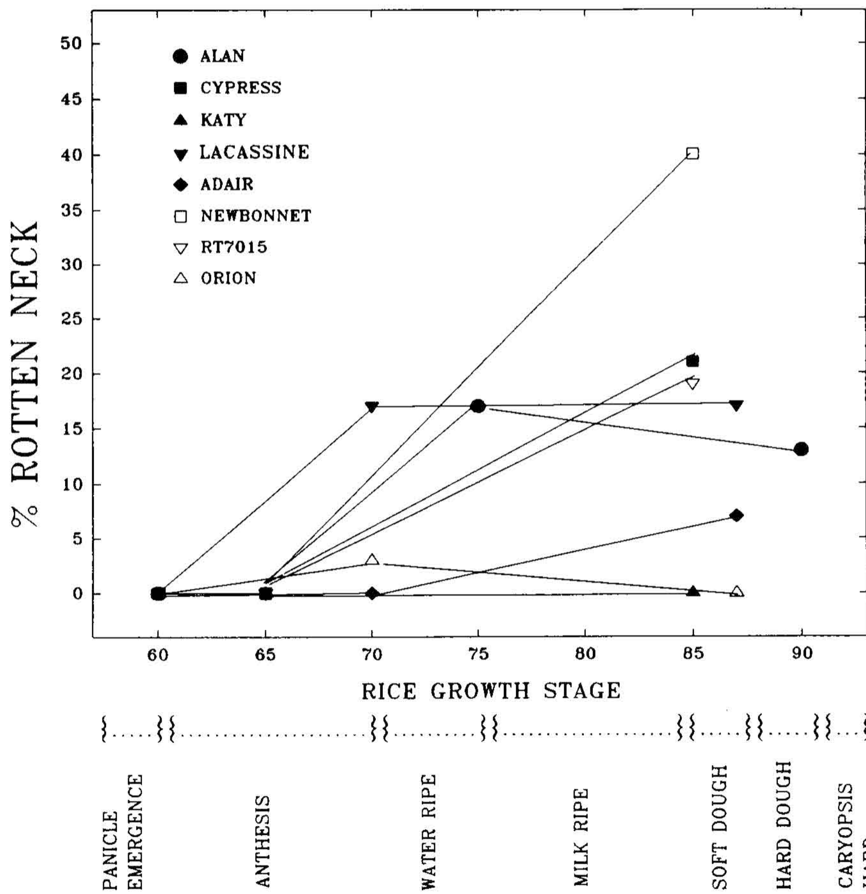

Fig. 1. The incidence of rotten neck on eight rice cultivars grown in small plots over time as plotted against rice growth stages from panicle emergence to hard caryop-sis. (Rice growth state = modified Zadoks decimal code for growth stages of rice.)

Table 1. The incidence of leaf, collar and rotten neck infections on eight rice cultivars grown in small plots in field tests at Pine Tree, Arkansas, in 1993.

Rice cultivars	% leaf blast	% collar rot	% rotten neck
Adair	0	0	8
Alan	0	0	13
Cypress	0	0	21
Katy	0	0	0
Lacassine	0	0	17
Newbonnet	0	0	40
Orion	0	0	4
RT7015	0	0	19

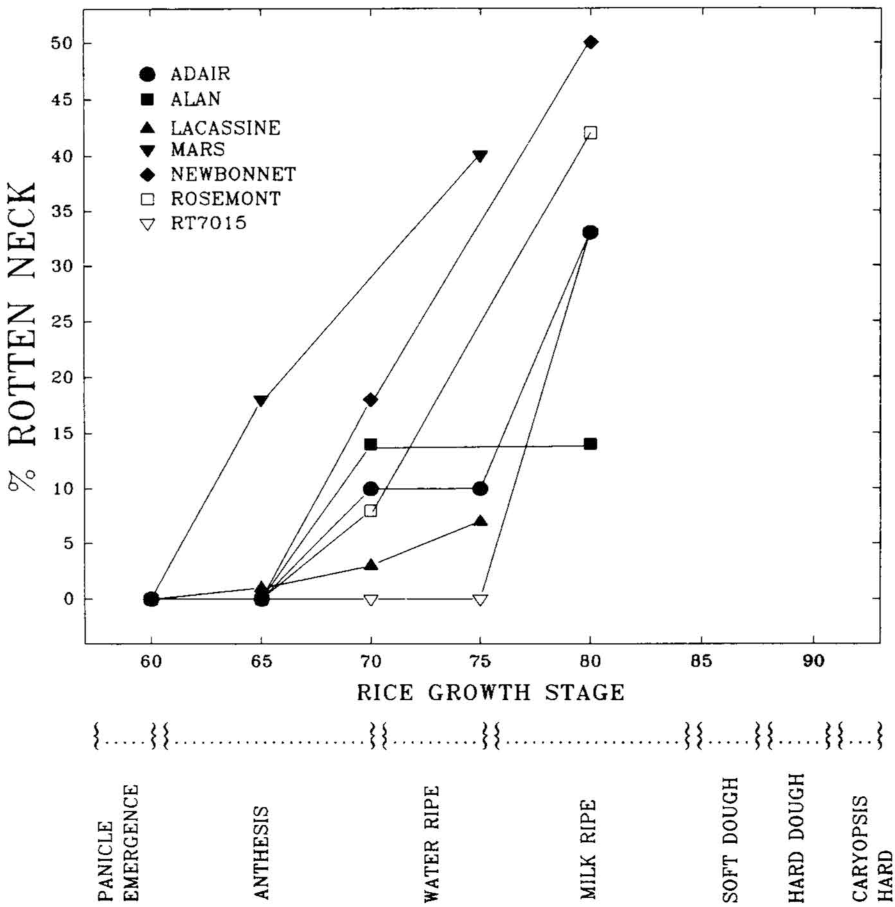

Fig. 2. The incidence of rotten neck on seven rice cultivars in small plots established within grower fields over time as plotted against rice growth stages from panicle emergence to hard caryopsis. (Rice growth state = modified Zadoks decimal code for growth stages of rice.)

Table 2. The incidence of leaf, collar and rotten neck infections on seven rice cultivars in small plots established in growers' fields near Stuttgart, Arkansas, in 1993.

Rice cultivars	% leaf blast	% collar rot	% rotten neck
Adair	74	20	33
Alan	58	0	27
Lacassine	8	0	8
Mars	79	33	33
Newbonnet	21	33	50
Rosemont	27	0	42
RT7015	48	0	33

Table 3. The reaction of the fourth leaf from emergence of 12 rice cultivars to three races of *Magnaporthe grisea* inoculated at 6 and 8 weeks after planting in greenhouse experiments.[z]

	6 weeks			8 weeks		
Rice Cultivars	Race IB49	Race IC17	Race IB1	Race IB49	Race IC17	Race IB1
Adair	8[y]	8	4	4	3	2
Alan	7	4	0	3	0	1
Cypress	8	5	0	4	2	2
Lacassine	5	5	2	4	1	2
LaGrue	8	8	5	7	5	4
Lemont	5	6	0	3	0	1
Katy	1	1	0	0	0	0
Mars	7	3	7	7	2	4
Newbonnet	7	6	0	2	0	0
Orion	6	3	4	6	2	2
Rosemont	8	0	0	6	4	0
RT7015	7	7	0	2	4	1

[z]University of Arkansas, Fayetteville, Arkansas.

[y]Blast ratings using a 1 (least susceptible) to 9 (most susceptible) scale.

EXAMINATION OF RACE DIVERSITY IN RICE BLAST PATHOGEN POPULATIONS

J.C. Correll, F.N. Lee and J.Q. Xia

ABSTRACT

A project was initiated in 1993 to examine race diversity in populations of the rice blast fungus (*Pyricularia grisea*) in Arkansas. Over 800 isolates of the pathogen were recovered from seven rice cultivars, 21 commercial fields and nine counties between 1991 and 1993. Several reference isolates collected over the past 20 years also were examined. The blast isolates from Arkansas could be characterized into eight genetic groups (MGR-DNA fingerprint groups), but only four of the eight groups were identified in the contemporary blast pathogen population. Two races (IC-17 and IB-49) apparently predominate in the pathogen population. The predominance of these two races may be the result of widespread use of the cultivar 'Newbonnet', which is highly susceptible to races IC-17 and IB-49. In addition, examination of specific races over the course of induced rice blast epidemics indicates that fungal genotypes remain stable with regard to DNA fingerprints and race.

INTRODUCTION

Overall, the goal of this project is to determine the extent of race diversity in the rice blast pathogen population in Arkansas. An important aspect of this project is to determine and document the "appearance" of new races attacking previously resistant rice cultivars. This information will provide the basis for screening rice cultivars and breeding lines for resistance to important races of the rice blast pathogen in Arkansas.

In addition to race characterization, several molecular tools, notably DNA fingerprinting, have been used to characterize genetic diversity in *P. grisea* (Levy et al., 1991). By examining a diverse collection of *P. grisea*, Levy et al. (1991) reported a correlation between DNA fingerprint and race, suggesting the diagnostic utility of this technique for race identification. The DNA fingerprinting protocol was developed to assist in the characterization of genetic and virulence diversity in populations of the rice blast fungus in Arkansas.

Race stability, sources of new races and mechanisms by which new races of *P. grisea* attack newly deployed resistance genes in popular rice cultivars are largely unknown (Ou, 1985). Preliminary investigations to examine this phenomenon were conducted by examining "marked" strains during rice blast epidemics.

MATERIALS AND METHODS

Isolates of *P. grisea* were collected from seven cultivars ('Alan', 'L201', 'L202', 'Lemont', 'Mars', 'Millie', 'Newbonnet'), from 21 commercial fields from nine counties in Arkansas (Arkansas, Cross, Jefferson, Lawrence, Lonoke, Monroe, Pulaski, Poinsett and St. Francis).

The isolates were examined for their DNA fingerprints using previously described procedures (Levy et al., 1991; Xia et al., 1993). Selected isolates were characterized for virulence on two sets of differential cultivars (Table 1) (Marchetti et al., 1976).

Field plots were established at Kibler, Arkansas, in 1992 and 1993. Three cultivars, 'M201' and Newbonnet (both susceptible), and either 'Katy' (1992) or Mars (1993), were seeded in a randomized complete block design with three replications. Each replication measured 10 x 10 m. Rice blast epidemics were induced by placing seedlings infected with a representative isolate of each of four different DNA fingerprint groups at the center of each replication. DNA fingerprinting and virulence testing were used to monitor isolate frequencies and race stability over the course of the epidemic. Disease development and disease progression also were recorded.

RESULTS AND DISCUSSION

Although eight genetically distinct DNA fingerprint groups were identified among isolates of *P. grisea* from Arkansas, only four groups were identified in contemporary populations (Fig. 1). These four DNA fingerprint groups, designated A, B, C and D, were distributed throughout the nine counties sampled and were recovered from most of the cultivars.

The majority of the isolates tested were identified as either race IC-17 or IB-49 (Table 2). These two races appear to be the most prevalent in the contemporary population and may be a direct consequence of a large percentage of rice acreage being grown to several cultivars highly susceptible to these two races. Variability in race designations occurs from test to test as a result of phenotypic variation due to variables such as temperature.

Neck blast was severe on M201 and moderate on Newbonnet, particularly near the disease foci (Table 3). The isolates recovered during the course of the epidemics remained stable with respect to their DNA fingerprints and virulence. Thus, no novel races were detected during a single growing season.

SIGNIFICANCE OF FINDINGS

The data collected on DNA fingerprints and race diversity among isolates of *P. grisea* throughout the rice growing region of Arkansas should serve as a starting point to develop a better understanding of this important rice pathogen. In the short term, these data can be used to ensure that newly released cultivars and breeding lines are exposed to a broader genetic spectrum of the pathogen. In the long term, these and future data will be helpful in interpreting and predicting whether or not specific resistance genes may be useful and how long they might last. Furthermore, these data could be used as a foundation to determine if and when new races of *P. grisea* arise from the indigenous population or are introduced from other sources.

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Table 1. Summary of reactions of international pathotypes of *Pyricularia grisea* on two sets of differential rice cultivars.

	International Races[z]								
Cultivar	IB-1	IB-33	IB-45	IB-49	IB-54	IC-17	IE-1	IG-1	IH-1
Arkansas differentials[y]									
M-201	S[x]	S	S	S	R	S	S	S	S
Starbonnet	S	S	S	S	S	S	S	S	R
Tebonnet	S	S	S	S	R	S	S	R	R
Newbonnet	S	S	R	S	R	S	S	R	R
Lemont	R	S	R	S	R	S	S	R	R
Zenith	S	S	S	S	S	R	R	R	R
Mars	S	S	I	S	R	R	R	R	R
Katy	R	S	R	R	R	R	R	R	R
International differentials[y]									
Raminad Str.3	R	R	R	R	R	R	R	R	R
Zenith	S	S	S	S	S	R	R	R	R
NP125	S	R	R	R	R	S	R	R	R
Usen	S	S	S	R	R	R	R	R	R
Dular	S	S	R	S	S	S	S	R	R
Kanto 51	S	S	R	S	R	S	S	R	R
Sha Tiao Tsao	S	S	S	S	S	S	S	S	R
Caloro	S	S	S	S	R	S	S	S	S

[z]Pathotype designations on international differentials (Ou, 1985).

[y]Disease reactions on the Arkansas and International differentials are a composite summary from pathogenicity tests conducted at Stuttgart, Arkansas, or Beaumont, Texas.

[x]R = resistant reaction (disease rating 0-3); S = susceptible reaction (disease rating 4); I = intermediate reaction.

Table 2. Virulence tests on two sets of rice differential cultivars.

		Pathotype identification[z]				
	MGR586 Fingerprint	International differentials			Arkansas differentials	
Isolates	Group	Test1	Test2	Test3	Test1	Test2
75A49[y]	B	IG-1	IG-1	IG-1	IG-1	IG-1
85A7[y]	D	IC-17	IC-17	IC-17	IC-17	IC-17
49-D[y]	E	IB-49	IB-49	IB-49	IB-49	IB-49
75A10[y]	G	IH-1	IH-1	IH-1	IH-1	IH-1
LO1-4	A1	IB-17	IB-1	IB-1	IB-1	NT
LO3-16	A2	IB-1	NT[x]	NT	IB-49	IB-49
BM1-7	A1	IB-1	IB-1	IB-1	IB-49	IB-49
BM3-13	A2	IB-1	IC-17	IC-17	IB-49	IB-49
LO5-9	A1	NT	IC-17	IB-1	IB-49	NT
LO1-10	B1	IC-17	IC-17	IC-17	IC-17	IC-17
LO5-7	B2	IC-17	IC-17	IC-17	IC-17	IC-17
BM4-27	B2	IC-17	IC-17	IE-1	IC-17	NT
BM4-17	B2	IC-17	IC-17	IE-1	IC-17	IC-17
LO3-8	B1	NT	NT	NT	IC-17	NT
LO2-27	C1	IB-1	IE-1	IE-1	IB-49	IB-49
LO4-8	C1	IE-1	IE-1	IG-1	IC-17	IC-17
BM1-24	C1	IC-17	IE-1	IB-49	IC-17	NT
BM5-27	C2	IB-49	IB-49	IE-1	IB-49	IB-49
LO3-14	C1	NT	NT	NT	IB-49	NT
LO1-24	D3	IC-17	IC-17	IC-17	IC-17	IC-17
LO3-4	D2	IC-17	IC-17	IC-17	IC-17	IC-17
BM4-10	D3	IC-17	IC-17	IC-17	IC-17	IC-17
BM5-11	D1	IC-17	IC-17	IC-17	IC-17	NT
BM5-30	D1	NT	NT	NT	IC-17	IC-17

[z]A disease rating scale of 0-9 for leaf blast disease was used. A reaction of 0-3 was considered a resistant reaction and 4 a susceptible reaction. Tests on international differential cultivars were conducted at Beaumont, Texas, and on Arkansas differential cultivars at Stuttgart, Arkansas.

[y]Previously collected reference isolate from Arkansas.

[x]NT = not tested.

Table 3. Rice blast disease severity at Kibler, Arkansas, during 1992 and 1993.

		Percent neck blast					
	Sample	M201		Newbonnet		Katy/Mars[z]	
Year	location	Mean	Range	Mean	Range	Mean	Range
1992	Location 1[y]	61.6	59.9-63.5	12.4	12.1-13.1	0.0	0.0-0.0
	Location 2[x]	4.3	1.8- 9.0	2.3	1.3- 5.3	0.0	0.0-0.0
1993	Location 1	24.3	13.7-42.7	3.6	3.3- 4.2	0.0	0.0-0.0
	Location 2	6.2	3.8-11.1	1.3	1.1- 2.0	0.0	0.0-0.0

[z]The cultivar Katy was used in 1992 and Mars in 1993.

[y]Location one was at the inoculum focal point. Approximately 1 m^2 was sampled per replication. The three replications consisted of approximately 1200 tillers per cultivar.

[x]Location two was from around the perimeter of the plot, approximately 3 m from the inoculum focal point. Eight 1-m^2 samples were taken per replication. The three replications consisted of approximately 10,000 tillers per cultivar.

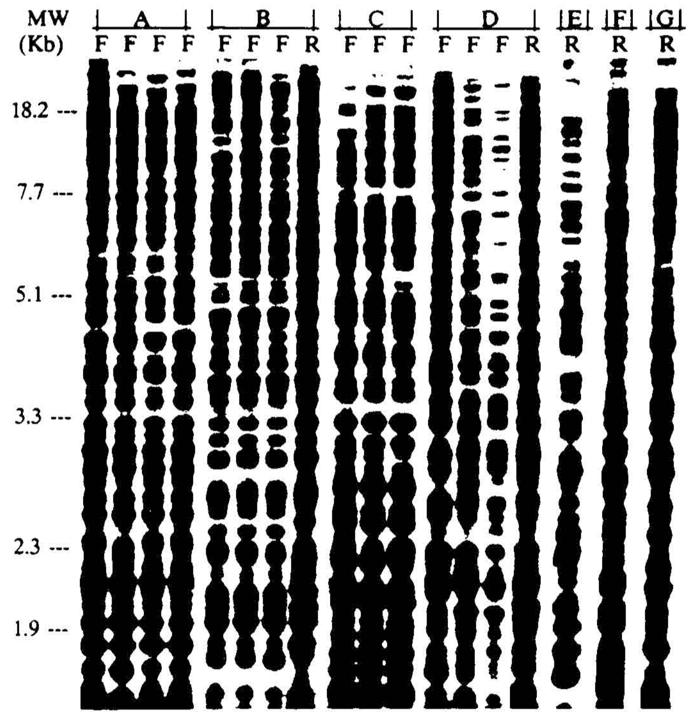

Fig. 1. Composite Southern blot (MGR-DNA fingerprinting) showing seven groups in *Pyricularia grisea* population from Arkansas. DNA of the isolates from each of seven fingerprint groups was digested with EcoR1 and hybridized with MGR-DNA probe labeled with an ECL DNA detection kit. The seven groups are designated A to G. Isolates within a group had >80% shared fragments, and isolates between groups had <60% shared fragments. F = field isolates; R = reference isolates.

KERNEL SMUT RESEARCH IN ARKANSAS

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ABSTRACT

Kernel smut of rice reemerged as a major disease problem in Arkansas in 1993, causing widespread yield and quality losses on early-maturing fields of 'Alan', 'Newbonnet' and 'RT7015' rice. This underscores the need for continued research on this complex and difficult-to-manage disease. Research on development of an improved, "more natural" inoculation technique than the boot injection method for screening for smut-resistant rice germplasm continued by emphasizing fundamental studies on the genetics and infection process of the kernel smut fungus. Pathogenicity of single teliospore isolates of the fungus was confirmed, and pathogenicity of single allantoid secondary sporidial isolates was demonstrated. This implies formation of a stable dikaryon in culture with production of solopathogenic, dikaryotic secondary sporidia. Single primary sporidial isolates were nonpathogenic unless mixed in specific combinations with other single primary sporidial isolates. Two putative mating strains of opposite mating types were determined and will be used to study the mating type genetics of the kernel smut fungus. Several preliminary "more natural" inoculation methods were attempted under greenhouse conditions but were unsuccessful.

INTRODUCTION

Kernel smut of rice was very severe on early-maturing rice cultivars in Arkansas in 1993, causing significant yield losses in some fields and resulting in low-quality grain delivered to the mills. Mills were generally unable to parboil any of the early-harvested rice and resorted to preferential buying of later-maturing rice and avoiding certain cultivars altogether.

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 is believed that *T. barclayana* infects the open rice flower 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 and residue and in the soil (Whitney and Frederiksen, 1975). These spores 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 plant host (Fischer, 1953). This phenomenon is not clearly understood for the kernel smut fungus.

Kernel smut is more severe on rice that has received heavy rates of nitrogen fertilizer (Templeton et al., 1960) and may be favored by light, rainy weather (Whitney and Frederiksen, 1975). Rice cultivars vary greatly in susceptibility to kernel smut, and this is the basis for resistant cultivars, the only practical means of control at the present time. 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). 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 this disease (Whitney and Frederiksen, 1975). Using this method, it has been clearly demonstrated that cultivars resistant in the field are not resistant when injected with kernel smut inoculum in the boot. This supports the suggestion that field resistance is related to floret morphology or duration of flowering and does not have a strong physiological basis. This method has shown that very few germplasm sources are resistant to kernel smut using the boot injection technique, and a more natural inoculation procedure to screen germplasm might improve discovery of "field" resistant germplasm.

Unfortunately, the actual infection process of the fungus has never been clearly demonstrated. 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, 1973b). Indirect evidence clearly suggests 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.

After considerable work with the boot injection method, it was decided to attempt development of a more natural inoculation procedure. To do this, a fundamental 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. To prevent any possibility of aerial contamination that would confuse results, most of the research is being conducted at Fayetteville, Arkansas, approximately 200 miles from the rice-producing region of Arkansas.

PROCEDURES

Since the kernel smut fungus may change through repeated culturing or when isolates may 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 with a population of individuals. With this in mind, single teliospores of the kernel smut fungus 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 very technically 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. Finally, 12 individual allantoid secondary sporidia were isolated from a single teliospore culture (4T3) growing in an Emerson broth layer on water agar. Again, purity of the individual allantoid sporidium was checked microscopically, and each sporidium was individually cultured and stored as before.

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' from California was selected for further experimentation. 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 two to three 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 (two layers) to remove clumps, and mycelium and the filtered suspension was standardized to 1 x 10^6 sporidia/ml.

For testing of pathogenicity of single isolates and various isolate combinations, the boot injection method was used as it is currently the most reliable method to determine pathogenicity of kernel smut fungal isolates. Most tests were conducted under greenhouse conditions in Fayetteville, although some inoculations were also made under field conditions at Stuttgart, Arkansas, for supplemental information. Inoculum was prepared and concentrated as previously described.

For study of inoculation methods and the infection process, only inoculum of isolate 4T3 was used. Methods tested included the brush method of Whitney (Whitney, 1989) in which a droplet of sporidial suspension is placed directly inside the pollinated but still young rice flower with a fine camel hair artist's brush. Secondly, a sporidial suspension was atomized onto flowering panicles of M202 using a compressed air canister and paint atomizer attachment. Finally, a sporidial suspension was poured into a misting humidifier, and mist containing sporidia was circulated in a misting tent over flowering panicles of M202. The boot injection method was used as a pathogenic control for comparison purposes. All inoculated plants except those inoculated by misting humidifier were subjected to either 72 hours of mist in a misting tent following inoculation or simply ambient greenhouse conditions to determine if high relative humidity following inoculation would improve inoculation success.

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.

RESULTS AND DISCUSSION

Summary results of pathogenicity tests of single teliospore cultures of the kernel smut fungus are shown in Table 1. Clearly, an individual teliospore has the genes required for pathogenicity. Inoculation with some isolates results in up to 100% smutted grains per panicle while others have not proven pathogenic as yet. This diversity of results remains to be explained; however, the boot injection technique is still quite variable, and some (or all) of the nonpathogenic isolates may actually be pathogenic. In at least two cases, putative nonpathogenic isolates were pathogenic in later tests.

Results of pathogenicity tests on a limited number of single primary sporidial isolates from the same teliospore are shown in Table 2. These isolates were mixed in all possible combinations and injected into the "boots" of rice plants in both the greenhouse and field in 1993. Results were very consistent at both locations. Results suggest two mating types within these six isolates, one represented by isolate 18 and the other represented by isolates 3, 11, 27, 43 and 50. Only combinations of the two different mating types resulted in kernel smut. This needs to be repeated; however, if true, it would indicate that an individual teliospore possesses two alleles for mating type at a single locus. This would be similar to the karnal bunt fungus, *Tilletia indica* (Duran and Cromarty, 1977). Further tests will be made in which the balance of the 51 primary sporidial isolates from this same teliospore will be combined with isolate 18 and isolate 43. Individual combinations will then be inoculated on rice to determine pathogenicity. It is possible that the fungus has a more complex mating type system than the bipolar type mentioned above, and these combinations should help determine its exact composition. Regardless, even if the individual teliospore has only two mating type alleles at one locus, it is likely that the fungal population in Arkansas and elsewhere contains additional mating type alleles. Once the mating type genetics of the individual are understood, the mating strains can be used to test the population. 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 breaking down of resistant cultivars over time.

Results of the pathogenicity tests for single allantoid sporidial cultures are presented in Table 3. Most of the cultures were pathogenic even though they were not combined with other single sporidial cultures. Allantoid sporidia of these pathogenic cultures and of the parent culture 4T3 appeared to be mostly binucleate when observed microscopically. This did not appear to be the case for the nonpathogenic cultures; however, more detailed observation and retesting are needed to verify this information. If true, this suggests that 4T3 is a stable dikaryon in culture and would be valuable in subsequent genetic research. While suggested in the literature, this phenomenon has not been clearly demonstrated for the kernel smut fungus (Singh and Pavgi, 1973a; Whitney and Frederiksen, 1975). If this occurs in nature, it means that only a single dikaryotic airborne sporidium is necessary for infection of a rice flower. This would bypass the necessity for two compatible sporidia to cross within the flower or on the surface of the plant and would result in increased success of infection in the field.

Results of different inoculation methods for kernel smut in the greenhouse are presented in Table 4. All methods were unsuccessful except the boot inoculation technique already being used. Attempts were hampered by lack of equipment and space for these studies, and more work is needed to determine what conditions are needed for reliable floret infection of rice by the kernel smut fungus. Repeated attempts to observe sporidia of the kernel smut fungus within and on the rice flowers were not wholly successful. Methods for observation of the infection process will require more research.

SIGNIFICANCE OF RESULTS

Progress in understanding the genetics of the kernel smut fungus was made with determination of two potential tester strains of opposite mating type from an individual teliospore. This is the first step in assessing the mating type genetics of the individual teliospore and, later, the kernel smut population in the state. When determined, this information will be used to assess the potential of the fungus to develop pathogenic races that can overcome our current "field" resistant cultivars. Progress remains slow on understanding the infection process and developing a more natural inoculation method, primarily due to lack of adequate greenhouse space to continually produce mature rice plants. Modifications to the misting system method have been made, and additional attempts at mist inoculation will be conducted in the spring and summer of 1994.

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Table 1. Pathogenicity of single teliospore cultures of the kernel smut fungus.[z]

Isolate	Pathogenic	SI[y]	Isolate	Pathogenic	SI	Isolate	Pathogenic	SI
1T1	+	3	3T4	+	7	8T1	+	122
1T3	-	0	4T1	-	0	8T2	-	0
1T5	+	105	4T2	-	0	8T3	-	0
2T1	-	0	4T3	+	141	8T4	+	113
2T2	-	0	4T4	-	0	8T5	-	0
2T3	+	10	6T1	+	15	9T2	+	103
2T4	-	0	6T3	+	16	9T3	+	18
2T6	-	0	7T2	+	6	9T5	+	97
3T3	+	4	7T4	+	9			

[z]Results are derived from combination of all greenhouse and field inoculations in 1992-93.
[y]SI = smut index = No. of smutted kernels x [no. of smutted panicles/no. of panicles assayed] - 1993 data (Lee et al., 1992)

Table 2. Pathogenicity of single primary sporidial isolate combinations from one teliospore (1993 greenhouse and field inoculation results).

Isolate	3	SI[z]	11	SI	18	SI	27	SI	43	SI	50	SI
3	-	0	-	0	+	36	-	0	-	0	-	0
11			-	0	+	23	-	0	-	0	-	0
18					-	0	+	40	+	34	+	9
27							-	0	-	0	-	0
43									-	0	-	0
50											-	0

[z]SI = smut index = No. of smutted kernels x [no. of smutted panicles/no. of panicles assayed] (Lee et al., 1992)

Table 3. Pathogenicity of single allantoid secondary sporidial isolates[z] of the kernel smut fungus (Greenhouse results from 1993).

Isolate	Tests	Pathogenic	SI[y]	Isolate	Tests	Pathogenic	SI
A1	7	-	0	A7	7	+	22
A2	7	+	85	A8	6	-	0
A3	7	+	66	A9	6	+	65
A4	7	+	41	A10	6	+	81
A5	6	+	52	A11	6	+	73
A6	7	-	0	A12	6	+	62

[z]Sporidia originally isolated from pathogenic single teliospore culture 4T3.
[y]SI = smut index = No. of smutted kernels x [no. of smutted panicles/no. of panicles assayed] (Lee et al., 1992).

Table 4. Results of different inoculation methods[z] for kernel smut under greenhouse conditions.

Method	Mist Chamber	Panicles Treated	Panicles Smutted
Brush inoculation	Yes	38	0
Brush inoculation	No	22	0
Atomizer	Yes	67	0
Atomizer	No	48	0
Mist inoculation	Yes	86	0
Boot injection	Yes	24	23
Boot injection	No	18	18

[z]All methods employed 1 x 10^6 sporidia/ml suspension from pathogenic culture 4T3. Cultivar was M202. Mist chamber was operated 72 hours, when employed.

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

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

ABSTRACT

A long-term field experiment was established in 1993 at the Pine Tree Experiment Station, Colt, Arkansas, to determine the effect of reduced tillage on sheath and stem diseases of rice. Cultivars 'Katy' and 'Lacassine' were seeded on conventional, stale-seedbed and no-till seedbeds in large, permanent plots with separate water systems. Primary inoculum levels of *Rhizoctonia solani* (sheath blight), *Sclerotium oryzae* (stem rot) and other rice-field fungi were low and uniform in seedbed soil samples prior to planting. Final sheath blight incidence (percent infected tillers) was 3, 26 and 24% for Lacassine and 0.5, 6 and 3% for Katy on conventional, stale-seedbed and no-till treatments, respectively. Vertical development of sheath blight was limited in most plots. Other diseases were noted but were minor in incidence, although stem rot was detectable in most plots. The Lacassine x no-till treatment had a significantly lower plot yield than the Lacassine conventional or stale-seedbed treatments but was thought to be due to stand establishment problems, rather than stem and sheath diseases.

INTRODUCTION

Prevalence of and damage from rice diseases change over time in response to changes in rice production practices by growers. For example, sheath blight was considered a minor curiosity until farmers adopted modern cultivars, denser stands, shorter crop rotations and increased nitrogen rates. These practices substantially increase the severity of many rice diseases including blast, sheath blight, stem rot, kernel smut and, probably, black sheath rot, all of which are now epidemic 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 seedbed preparation 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, and rice (or soybeans) is planted into the undisturbed seedbed with minimum-tillage planting equipment. In isolated instances, growers are experimenting with "no-till" rice in which the crop is planted directly into the previous crop residue with no tillage. Previous studies have been conducted in Louisiana and Arkansas (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, 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). On the other hand, diseases such as take-all of wheat have actually declined in certain areas where reduced tillage has been adopted (Brooks and Dawson, 1968). In California, recent evidence on stem rot 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 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 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.

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, reduced (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 features rice in 1993, 1995 and 1997 and site 2 in 1994, 1996 and 1998. Hutchison soybeans will be drill planted on the plots in non-rice years.

Prior to seeding, twenty 3-in.-dia. x 2-in.-thick soil cores 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 (Lee, 1980) to estimate number of sclerotia of *Rhizoctonia solani* AG1-IA (the sheath blight fungus). A smaller sieve (150-um 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.

Due to the late development and funding of the project, tillage treatments for 1993 were not made until mid-winter (February 1993). In subsequent years, tillage for conventional seedbeds will involve fall and spring operations and only fall tillage for stale seedbed preparation. Glyphosate was applied approximately seven days prior to seeding rice to kill existing vegetation on stale-seedbed and no-till plots. Conventional tillage plots were tilled as needed to prepare an optimum seedbed.

Seeding was done on 24 April 1993 using a minimum-tillage drill with 7-in. row spacings. Due to adverse soil conditions and equipment problems, no-till plots were replanted in early May. After emergence, permanent levees were installed, and all plots were watered and managed separately to prevent exchange of soil- or water-borne inoculum between plots.

Plots were monitored periodically for disease development throughout the growing season. Final disease incidence and severity data were estimated at grain maturity from randomly collected tillers (150) from each plot. Grain was combine harvested and weighed and yield adjusted to 12% moisture for analysis. Precautions were taken during harvest to retain rice residue within respective plots in order to prevent cross contamination of plots.

RESULTS AND DISCUSSION

Primary inoculum levels were considered low in all plots (Table 1). This represents an ideal situation in which to study population changes over time, since increases can be more easily measured when starting from a low initial value. The fungal pathogens *R. solani* (sheath blight) and *Sclerotium oryzae* (stem rot) were detected in most plots as was the minor pathogen *Rhizoctonia oryzae-sativae* (aggregate sheath spot) and the fungal epiphyte *Sclerotium hydrophilum*. *G. graminis graminis* (black sheath rot) and *R. oryzae* (bordered sheath spot) were not detected, and other assay methods may have to be developed for these fungi.

Final disease incidence and severity levels are listed in Table 2. Sheath blight was the only significant disease present in 1993, although stem rot was also present at low levels in most plots. Sheath blight incidence was significantly higher on both Katy and Lacassine in the stale-seedbed and no-till plots as compared to the conventional tillage plots (Table 2). Nevertheless, there was no measurable effect on plot yield, and, in fact, the stale seedbed plots tended to have higher yields than conventional plots for both cultivars, although not significantly so (Table 3). Only the Lacassine no-till treatment had a significantly lower yield than the other combinations within this cultivar (Table 3). Difficulty in stand establishment resulted in unevenness of the stand of this treatment and an overall lower stand density, especially in two replications. It is believed that these stand problems were responsible for the significant reduction in yield. Although the incidence levels of sheath blight in the Lacassine stale-seedbed and no-till plots were certainly high enough to result in yield loss under some circumstances, the vertical development of the disease on infected tillers remained fairly low (Table 2). These observations demonstrate the dual components of sheath blight severity--a combination of incidence and early vertical development is necessary for this disease to measurably affect rice yields (Ahn et al., 1986). Because the majority of rice yield is determined by the upper leaves, sheath blight has less effect if confined to lower levels of the plant. Stand density was close to optimum in the conventional and stale-seedbed plots and was slightly below optimum in the no-till plots. Nitrogen fertilizer was applied only at recommended rates and times. These management factors probably contributed to less vertical development of the disease since overly thick stands and excessive nitrogen use result in increased sheath blight intensity.

SIGNIFICANCE OF FINDINGS

These results are from a single year, so any interpretation should be viewed with caution. Reliable information on changes in monocyclic pathogen populations or disease levels cannot be generated in less than three crop cycles. In this experiment, that would represent five years. Nevertheless, the information collected during the first rice season suggests that sheath blight may increase under reduced tillage practices within the same rotation scheme. Because the initial levels of *R. solani* sclerotia were equivalent regardless of seedbed type, the data appear to suggest that the soybean residue in the stale-seedbed and no-till plots played a significant role in the increased incidence of sheath blight noted at season end. It has been suggested that this role may be more as an energy source for *R. solani* than as primary inoculum. Regardless, the significant increase of *R. solani* in the reduced tillage plots is cause for concern, especially since the stale-seedbed approach is now favored by so many producers. On the other hand, germination and stand establishment were slightly better on the stale seedbed plots in this test than the conventional plots and much better than the no-till plots. Part of this may have been due to roughness of the no-till plots and equipment problems and to the wet, cold conditions in April. The stale-seedbed was firmer and better drained than the conventional. These results are also significant since they represent the first designed and replicated experiment with appropriate controls to study the long-term effect of reduced tillage practices on rice diseases.

ACKNOWLEDGMENTS

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Table 1. Primary inoculum levels of various rice fungi detected in soil samples from reduced tillage experiment field plots.

		Viable Sclerotia/kg Dry Soil (Mean)				Total Sclerotia/kg Dry Soil (Mean)			
Cultivar	Tillage Trt.	RS[z]	SO	ROS	SH	RS	SO	ROS	SH
Katy	Conventional	1	23	3	7	1	49	2	11
Katy	Stale-Seedbed	ND	13	1	2	ND	29	1	8
Katy	No-Till	1	26	7	18	1	51	13	26
Lacassine	Conventional	ND	9	ND	4	ND	21	1	6
Lacassine	Stale-Seedbed	2	17	5	11	3	34	7	15
Lacassine	No-Till	1	15	4	14	1	35	6	20

[z]RS = *Rhizoctonia solani*; SO = *Sclerotium oryzae*; ROS = *Rhizoctonia oryzae-sativae*; SH = *Sclerotium hydrophilum*; ND = not detected. *G. graminis graminis* was not detected in soil samples.

Table 2. Final disease incidence and severity data for various rice diseases detected in reduced tillage experiment, 1993.

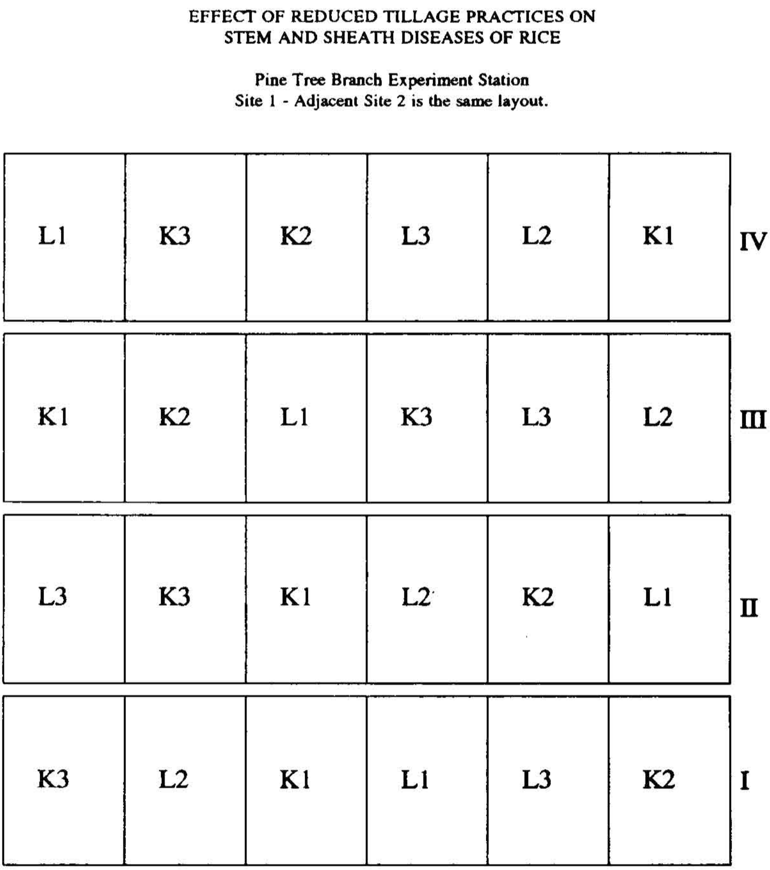
		Final Disease Rating % Infected Tillers							
Cultivar	Tillage Trt.	SHB[z]	SHB-RLH	SR	BSHR	NB	NBLS	BS	LS
Katy	Conventional	.5 a	.23	.3	0	0	2	2	1
Katy	Stale-Seedbed	6 b	.29	2	0	0	12	13	4
Katy	No-Till	3 b	.23	.8	0	0	.8	25	0
Lacassine	Conventional	3 x	.36	.5	.3	0	0	47	0
Lacassine	Stale-Seedbed	26 y	.36	2	1	1	0	45	.7
Lacassine	No-Till	24 y	.33	.5	.7	0	28	58	0

[z]SHB = sheath blight. SHB-RLH = Relative Lesion Height of Sheath Blight Symptoms on infected tillers (estimates disease severity); 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. 1993 plot yield data for reduced tillage experiment.

Cultivar	Tillage Treatment	Yield (bu/acre 12% moisture)
Katy	Conventional	148 a[z]
Katy	Stale-Seedbed	158 a
Katy	No-Till	159 a
Lacassine	Conventional	176 x
Lacassine	Stale-Seedbed	180 x
Lacassine	No-Till	160 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 $P = 0.05$.



L = Rice cultivar Lacassine
K = Rice cultivar Katy
1 = Conventional Tillage
2 = Stale-Seedbed Tillage
3 = No-Till

SITE 1 = Rice in 1993, 1995, 1997
SITE 2 = Rice in 1994, 1996, 1998
Hutchison soybeans drilled in plots on each site in non-rice years.

Fig. 1. Layout of long-term reduced tillage experiment.

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

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ABSTRACT

A comprehensive rice disease monitoring project was initiated in 1993 to determine the identity, distribution and severity of rice diseases in Arkansas. Replicated monitoring plots (six locations, 20 cultivars) and a systematic grower field survey (80 fields, 14 counties, 16 cultivars) were utilized in the study. A total of 17 diseases/disorders were recorded on rice in the state. Sheath blight, stem rot and kernel smut caused widespread damage and were noted at greater than 20% positive stops in 66, 41 and 21%, respectively, of fields surveyed near grain maturity. Blast was sporadic and less damaging in 1993, probably because of the hot, dry weather. Kernel smut was especially damaging to early-maturing fields of 'Alan', 'Newbonnet' and 'RT7015'. An apparently new disease was discovered on the newly released medium-grain cultivar, 'Bengal'. Symptoms include a large, dark brown lesion on the flag leaf sheath and blanking of the panicle. A fungus, tentatively identified as *Fusarium proliferatum*, was found associated with affected tissue and is being tested to determine if it is the cause. In addition, it was observed that plants attacked by both sheath blight and stem rot were more seriously damaged than those attacked by either disease alone.

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/mlos, fungi, bacteria, nematodes and physiological imbalances (Ou, 1985). Since that time, various 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 and seedling blight, and, possibly, black sheath rot) all caused by fungi and one major physiological disorder (straighthead) (Webster and Gunnell, 1992). 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 yet-unknown cause that have been recently noted.

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

Monitoring of plant diseases is a time-consuming, yet valuable, service that plant pathologists must perform 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 done yearly and be long-term and systematic in design to be of value. If monitoring is done properly, the information generated is valuable in establishing or modifying research priorities and helping 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 increased importance of an existing minor disease. 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, a 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 seeded in six grower fields in southwestern, east central and northeastern Arkansas and on the Pine Tree Experiment Station, Colt, Arkansas (Tables 1 and 2, Fig. 1). Grower fields were selected by the cooperating Cooperative Extension Service (CES) agent based on grower cooperation, disease history, cultural practices and previous observations. Cultivars were seeded in seven row x 16 ft plots and replicated two times in a randomized complete block design. Semidwarf cultivars (eight) were planted in semidwarf cultivar fields and standard (non-semidwarf) cultivars (12) in fields with a standard-type cultivar. 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 for diseases beginning at internode elongation for the earliest cultivars, 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.

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. Approximately 80 fields in major rice-producing counties (Fig. 1) were assessed for rice disease identity and incidence. These included 10 rice verification fields (Table 3). 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. A 1-m-long section of tillers was 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

A total of 11 common fungal diseases were observed in the monitoring plots, depending on location and cultivar (Tables 1 and 2). In addition, the poorly understood conditions of purple leaf spot on medium-grain cultivars and floret blight on 'Alan' were observed (Table 2). Straighthead was noted on 'Jasmine 85' at one location and an apparently new disease on 'Bengal' was observed at all locations (Table 2).

Of the major diseases, sheath blight was most common, being observed at all but one survey location in Lafayette County (Tables 1 and 2). Incidence was highest at the Pine Tree, Lonoke County and Lawrence County (site 1) sites (Tables 1 and 2).

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 82% of tiller height on 'RT7015' with all other semidwarf cultivars ranging between 42 and 74% (Table 1). On the standard cultivars, maximum symptom height was 79% of tiller height on Maybelle with all other cultivars ranging downward from 72% (Table 2). 'Mars', 'Millie' and Jasmine 85 had symptom heights below 50% of tiller height (Table 2).

Heavy stem rot was noted at only the Pine Tree location with all cultivars showing susceptibility (Tables 1 and 2). Jasmine 85 and Bengal had the lowest disease index values (Table 2). All others had an average value of 3 or above, indicating that at least the outer surface of the culm was attacked. Ratings at this value or above have been correlated with economic yield losses in California (R.K. Webster, personal communication).

Significant neck blast was noted only at the Pine Tree, Clark County and Lawrence County (site 1) sites (Tables 1 and 2). 'L203', 'Rosemont' and 'RT7015' were most heavily damaged. Neck blast was not observed on Katy, Mars, 'Orion', 'Dellmont', 'Lemont' and Jasmine 85 at any site, and all other cultivars had minor damage (Tables 1 and 2).

Kernel smut was observed at all sites except Lafayette County (Tables 1 and 2). It was most severe at Lawrence County site 1 (Table 1). Rosemont, RT7015, L202, L203, Alan, Adair, Jackson, Newbonnet, Jasmine 85, LaGrue, Maybelle and Millie had significant levels of smutted panicles at several sites (Tables 1 and 2). Cypress had 6% smutted panicles, and Rosemont and RT7015 had 100% infected panicles at the Lawrence County site 1 (Table 1). Smut was rarely observed on Lacassine, Dellmont, Lemont, Bengal and Orion and was not observed on Katy or Mars in these tests (Tables 1 and 2).

Black sheath rot was noted at Lawrence County site 1, most severely affecting Rosemont, Lacassine, L202, Lemont and RT7015, although it was common on the other semidwarf cultivars (Table 1).

Lodging associated with stem rot was observed on L202, Alan, Adair, Katy, Mars and Orion at the Pine Tree location. A high incidence of sheath blight was also noted in most of these lodged plots (Tables 1 and 2).

A potentially new disease was noted on Bengal in all monitoring plots (Table 2). Symptoms included a large brown lesion on the flag leaf sheath of some plants and total or partial blanking and discoloration of the panicle. A fungus, tentatively identified as *Fusarium proliferatum*, was consistently isolated from affected tissue, and research is underway to determine whether it is the pathogen and what steps might be taken to control it.

Systematic Grower Field Survey

A total of 80 grower fields in 14 counties, including 10 rice verification fields, were surveyed for rice diseases (Tables 3 and 4). There were 16 different rice cultivars encountered and 17 diseases or maladies recorded (Tables 3 and 4). Sheath blight was very common, noted in 90% of the fields surveyed (Table 3). It was found at greater than 20% of stops in 66% of the fields (Table 4). Maximum vertical development in any field noted was 100% of tiller height (rating 9 - Ahn et al., 1986), meaning that the panicle was infected. However, this was uncommon, and symptom height was more usually between 30 and 65% (ratings 5-7 - Ahn et al., 1986) of tiller height at grain maturity (Table 3).

Stem rot was also widespread in 1993, being observed in 90% of the fields (Table 3), with greater than 20% positive stops in 41% of the fields (Table 4). Maximum severity of 5 (1 = healthy; 5 = culm infected and premature tiller death) was noted on most cultivars although the average severity was less (Table 3). In several fields, a combination of sheath blight and stem rot was observed, causing lodging and blanking of the lower part of the panicle in certain areas of the fields. The combination of these two diseases appeared more damaging than either disease alone.

Neck blast was sporadic and relatively minor compared to previous years (Table 3). Only 8% of the fields had neck blast at more than 20% of the stops (Table 4).

Kernel smut was widespread and severe in 1993. It was noted in 73% of fields and above 20% positive stops in 21% of the fields (Tables 3 and 4). Heavy damage was noted primarily on early-maturing fields of Alan, Newbonnet and RT7015 (Table 3). Heavily damaged fields were obviously heavily fertilized.

Black sheath rot was noted in 71% of the fields but was usually of minor significance (Table 3). In only 18% of the fields was the disease noted at greater than 20% positive stops (Table 4). Damage was observed in only two instances, a field of first-year rice where no other diseases were noted and a field planted to rice for the first time since 1981, again where other diseases were rarely observed.

Scab (caused by *Fusarium graminearum*, same as head scab of wheat) and a blight of developing florets (especially on Alan) were observed repeatedly (Table 3). The floret blight may be caused by the scab fungus, but this is still unclear. Regardless, scab is of increasing concern as wheat is being more commonly rotated with rice in Arkansas.

Finally, the new disease on Bengal, which was first noted in the disease monitoring plots, was observed in the two Bengal fields of the survey and various other cultivars located near Bengal plots or fields. Additional cultivars in which this disease appeared included Orion, Mars, LaGrue, Adair, Lacassine and Maybelle. Incidence was very minor on these cultivars, and infected Bengal plants were almost always nearby. Additional Bengal fields (three) were inspected in three different counties, and the disease was always present but varied greatly in incidence. In the most heavily diseased field, approximately 4% of the panicles were blanked or partially blanked as determined by random sampling of square meter areas across the field. The number of diseased panicles appeared to be greater in areas of higher soil fertility.

SIGNIFICANCE OF RESULTS

Data gathered demonstrate the broad spectrum of rice diseases present in the state and their varying intensity as influenced by cultivar, location and management practices. Clearly, improved control of these diseases from year to year will involve both additional research and education of growers in regard to the influence of cultural practices on disease severity. The systematic nature of this disease monitoring project will permit accumulation of comparative data from year to year and should help researchers prioritize research needs and approaches. The value of this research is to provide data on cultivar response to diseases under grower conditions to supplement 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. Discovery of the new disease on Bengal has allowed research to be conducted this winter to address the potential problem before this new cultivar is widely grown in 1994. Hopefully, the exact cause of the disease can be determined and control recommendations made before the 1994 planting season. Finally, stem rot, sheath blight and kernel smut caused major damage to the Arkansas rice crop in 1993, reducing both yield and grain quality. Whether the impact of diseases on the overall lower yields and quality of the

1993 Arkansas rice crop was as great as or greater than the adverse weather during part of the growing season is debatable, but the poor rice crop is most likely the result of both factors.

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● **Monitoring Plots in Grower Fields (8 semidwarf cultivars and 12 standard type cultivars).**

■ **Grower field surveys (80 fields total) of different rice cultivars grown under different management systems. Included were 10 rice verification fields.**

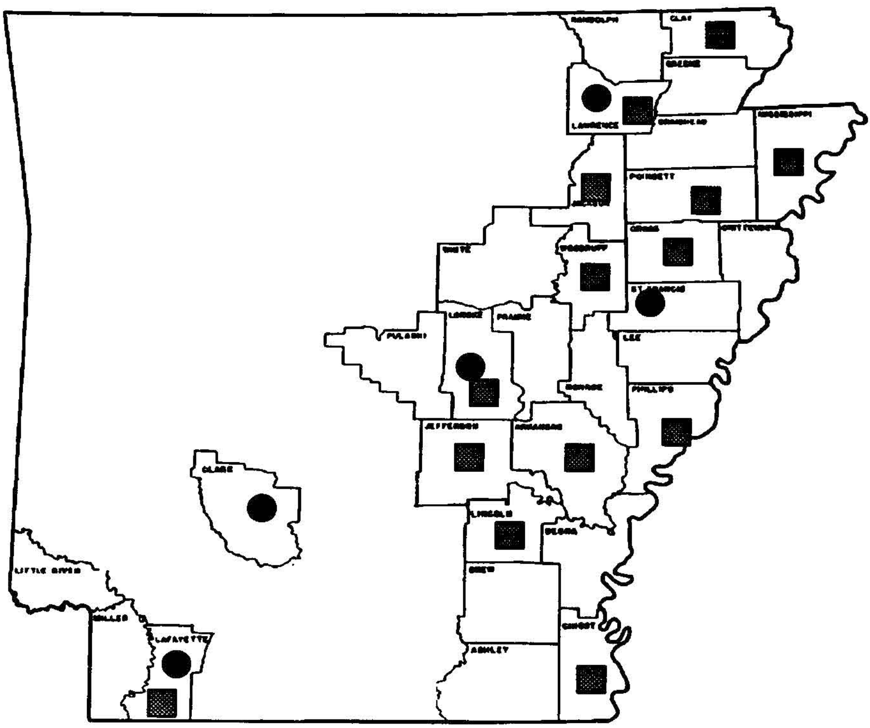

Fig. 1. Rice disease monitoring locations in Arkansas for 1993.

Table 1. Summary of 1993 disease data for semidwarf cultivar monitoring plots.

County (Site)	Test Variety	SHBI^z	RLH	SR-DI	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	STHD	LODG	FB
Clark	Cypress	16	0.71	1	2	0	0	0	0	0	2	0	0	0	0	0	0		0
Clark	Dellmont	8	0.68	1	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Clark	L202	4	0.6	1	6	0	12	0	0	0	0	0	0	0	0	0	0		0
Clark	L203	2	0.52	1	50	0	10	0	6	0	2	0	0	0	0	0	0		0
Clark	Lacassine	10	0.65	1	2	0	0	0	0	0	0	0	0	0	0	0	0		0
Clark	Lemont	12	0.64	1	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Clark	Rosemont	14	0.73	1	16	0	14	0	0	0	4	0	0	0	0	0	0		0
Clark	RT7015	6	0.82	1	4	0	16	0	0	0	2	0	0	0	0	0	0		4
Lafayette	Cypress	0	0	1	0	0	0	0	100	0	0	2	0	0	0	0	0		0
Lafayette	Dellmont	0	0	1	0	0	0	0	100	0	0	2	0	0	0	0	0		0
Lafayette	L202	0	0	1	0	0	0	0	100	2	0	0	0	0	0	0	0		0
Lafayette	L203	0	0	1	0	0	0	0	100	0	0	2	0	0	0	0	0		0
Lafayette	Lacassine	0	0	1	0	0	0	0	100	0	0	0	0	0	0	0	0		0
Lafayette	Lemont	0	0	1	0	0	0	0	100	0	0	2	0	0	0	0	0		0
Lafayette	Rosemont	0	0	1	0	0	0	0	100	6	0	2	0	0	0	0	0		0
Lafayette	RT7015	0	0	1	0	0	0	0	100	2	0	2	0	0	0	0	0		0
Lawrence site 1	Cypress	54	0.53	1.04	2	0	6	38	0	0	2	0	0	100	0	0	0		0
Lawrence site 1	Dellmont	82	0.66	1.04	0	0	2	28	0	0	0	0	0	100	0	0	0		0
Lawrence site 1	L202	12	0.42	1.08	4	0	52	58	0	0	2	0	0	100	0	0	0		0
Lawrence site 1	L203	2	0.55	1	18	0	26	22	0	0	2	0	0	100	0	0	0		0
Lawrence site 1	Lacassine	32	0.46	1.04	0	0	2	68	0	0	0	0	0	100	0	0	0		0
Lawrence site 1	Lemont	22	0.57	1.08	0	0	2	54	0	0	0	0	0	100	0	0	0		0
Lawrence site 1	Rosemont	74	0.65	1.04	2	0	100	100	0	0	6	0	0	100	0	0	0		0
Lawrence site 1	RT7015	14	0.68	1.04	6	0	100	50	0	0	6	0	0	100	0	0	0		0
Pine Tree	Cypress	68	0.54	3.6	2	0	0	0	0	0	0	0	0	0	0	0	0		0
Pine Tree	Dellmont	38	0.66	3.2	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Pine Tree	L202	56	0.57	3.3	12	0	0	0	0	0	0	0	0	0	0	0	0	yes	0
Pine Tree	L203	28	0.54	2.7	60	0	2	2	0	0	2	0	0	0	0	0	0		0
Pine Tree	Lacassine	42	0.64	3.8	6	0	0	2	0	0	0	0	0	0	0	2	0		0
Pine Tree	Lemont	48	0.69	3.1	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Pine Tree	Rosemont	84	0.74	4.2	42	0	16	6	0	0	2	0	0	0	0	0	0		0
Pine Tree	RT7015	44	0.61	3.4	28	0	2	0	0	0	2	0	0	0	0	0	0		0

^{z}Column heading codes represent: SHBI=sheath blight incidence (%infected tillers); RLH =average symptom height to tiller height ratio for sheath blight on infected tillers (estimate of disease severity); SR-DI=stem rot disease index (1=healthy, 5=inside of culm infected and premature tiller death); Data on the following is given as percent infected tillers - NB=neck blast; LB=leaf blast; KS=kernel smut (%infected panicles); BSHR=black sheath rot; BS=brown spot; NBLS=narrow brown leaf spot; SCAB=head scab (*Fusarium graminearum*); BSS=bordered sheath spot; AgSS=aggregate sheath spot; LS=leaf smut; PLS=purple leaf spot of medium grains-cause unknown; FSHR=unidentified disease first observed on Bengal; STHD=straighthead; LODG=lodging observed; FB=floret blight as observed on Alan - cause unknown but may be related to scab.

Table 2. Summary of 1993 disease data for standard (non-semidwarf) cultivar monitoring plots.

County (Site))	Test Variety	SHBI	RLH	SR-DI	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	STHD	LODG	FB
Clark	Adair	4	0.6	1	4	0	18	0	6	6	4	0	0	0	0	0	0		0
Clark	Alan	2	0.55	1	2	0	22	0	28	0	6	0	0	0	0	0	0		12
Clark	Bengal	8	0.63	1	2	0	0	0	0	0	0	0	0	0	12	2	0		0
Clark	Jackson	6	0.72	1	0	0	18	0	24	0	2	0	0	0	0	0	0		0
Clark	Jasmine 85	4	0.48	1	0	0	14	0	16	24	0	0	0	0	0	0	0		0
Clark	Katy	2	0.57	1	0	0	0	0	0	100	0	0	0	0	0	0	0		0
Clark	Lagrue	4	0.66	1	2	0	12	0	12	38	2	0	0	0	0	0	0		0
Clark	Mars	2	0.44	1	0	0	0	0	0	0	2	0	0	0	56	0	0		0
Clark	Maybelle	24	0.74	1	6	0	8	0	8	4	8	0	0	0	0	0	0		0
Clark	Millie	2	0.47	1	0	0	2	0	0	0	0	0	0	0	0	0	0		0
Clark	Newbonnet	6	0.53	1	4	0	8	0	2	68	2	0	0	0	0	0	0		2
Clark	Orion	4	0.53	1	0	0	2	0	0	0	2	0	0	0	90	0	0		0
Lawrence site 2	Adair	2	0.32	1	0	0	2	0	44	26	0	0	0	0	0	0	0		0
Lawrence site 2	Alan	8	0.35	1	2	0	4	0	56	24	0	0	0	0	0	0	0		4
Lawrence site 2	Bengal	6	0.41	1	0	0	2	0	0	0	0	0	0	0	24	2	0		0
Lawrence site 2	Jasmine 85	2	0.23	1	0	0	0	0	8	0	0	0	0	0	0	0	0		0
Lawrence site 2	Katy	4	0.43	1	0	0	0	0	32	100	0	0	0	0	0	0	0		0
Lawrence site 2	Lagrue	4	0.44	1	2	0	2	0	22	36	2	0	0	0	0	0	0		0
Lawrence site 2	Mars	4	0.26	1	0	0	0	0	0	0	0	0	0	0	100	0	0		0
Lawrence site 2	Maybelle	16	0.65	1	2	0	2	0	16	100	2	0	0	0	0	0	0		0
Lawrence site 2	Millie	2	0.42	1	0	0	2	0	24	12	0	0	0	0	0	0	0		0
Lawrence site 2	Newbonnet	2	0.33	1	2	0	2	0	36	100	0	0	0	0	0	0	0		0
Lawrence site 2	Orion	4	0.35	1	0	0	0	0	0	0	0	0	0	0	100	0	0		0
Lonoke	Adair	74	0.51	1	0	0	22	0	0	10	2	0	0	0	0	2	0		2
Lonoke	Alan	66	0.55	1	0	0	28	0	2	6	0	0	2	0	0	0	0		0
Lonoke	Bengal	76	0.41	1	0	0	2	0	0	2	0	0	2	0	0	4	0		0
Lonoke	Jackson	86	0.62	1	0	0	10	0	2	14	2	0	0	0	0	0	0		0
Lonoke	Jasmine 85	72	0.48	1	0	0	0	0	0	0	0	0	0	0	0	0	16		0
Lonoke	Katy	70	0.52	1	0	0	0	0	0	100	0	0	0	0	0	0	0		0
Lonoke	Lagrue	60	0.67	1	0	0	8	0	2	16	0	0	0	0	0	2	0		0
Lonoke	Mars	52	0.3	1	0	0	0	0	0	2	0	0	0	0	0	2	0		0
Lonoke	Maybelle	100	0.79	1	0	0	12	0	2	100	2	0	0	0	0	2	0		2
Lonoke	Millie	50	0.32	1	0	0	12	0	0	0	0	0	0	0	0	0	0		0
Lonoke	Newbonnet	56	0.48	1	0	0	16	0	0	100	0	0	0	0	0	0	0		0
Lonoke	Orion	50	0.32	1	0	0	0	0	0	2	0	0	0	0	0	2	0		0

continued

Table 2. Continued

County(Site)	Test Variety	SHBI	RLH	SR-DI	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	STHD	LODG	FB
Pine Tree	Adair	26	0.44	4.1	2	0	0	2	0	10	2	0	0	0	0	2	0	yes	0
Pine Tree	Alan	44	0.58	3.8	2	0	4	2	0	6	2	0	0	0	0	0	0	yes	2
Pine Tree	Bengal	34	0.42	2.6	4	0	0	0	0	0	0	0	0	0	0	4	0		0
Pine Tree	Jackson	36	0.46	4.2	2	0	8	2	0	0	0	0	0	0	0	0	0		0
Pine Tree	Jasmine 85	22	0.41	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Pine Tree	Katy	64	0.56	3.4	0	0	0	6	0	100	0	0	0	0	0	0	0	yes	0
Pine Tree	Lagrue	46	0.54	3.6	6	0	2	2	0	12	2	0	0	0	0	2	0		0
Pine Tree	Mars	44	0.28	3.6	0	0	0	2	0	2	2	0	0	0	100	0	0	yes	0
Pine Tree	Maybelle	90	0.68	4.3	8	0	6	0	0	24	2	0	0	0	0	0	0		0
Pine Tree	Millie	28	0.48	3.5	2	0	0	0	0	0	0	0	0	0	0	0	0		0
Pine Tree	Newbonnet	32	0.51	3.5	16	0	2	4	0	100	2	0	0	0	0	0	0		0
Pine Tree	Orion	32	0.35	3.8	0	0	0	2	0	2	2	0	0	0	100	0	0	yes	0

[z]Column heading codes represent: SHBI=sheath blight incidence (%infected tillers); RLH=average symptom height to tiller height ratio for sheath blight on infected tillers (estimate of disease severity); SR-DI=stem rot disease index (1=healthy, 5=inside of culm infected and premature tiller death); Data for the following is given as percent infected tillers - NB=neck blast; LB=leaf blast; KS=kernel smut (%infected panicles); BSHR=black sheath rot; BS=brown spot; NBLS=narrow brown leaf spot; SCAB=head scab (*Fusarium graminearum*); BSS=bordered sheath spot; AgSS=aggregate sheath spot; LS=leaf smut; PLS=purple leaf spot of medium grains-cause unknown; FSHR=unidentified disease first observed on Bengal; STHD=straighthead; LODG=lodging observed; FB=floret blight as observed on Alan - cause unknown but may be related to scab.

Table 3. Summary of 1993 disease data from grower field survey (sorted by cultivar).

County	Variety	SHBI	SHBSEV	SR	SRSEV	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	DTS	STBN	FB
Clay	Alan	6	5	4	3	4	0	6	2	32	2	0	0	0	4	0	0	0	0	12
Cross	Alan	42	7	24	5	4	0	52	4	100	0	0	0	0	30	0	0	0	0	100
Cross	Alan	62	7	12	3	4	0	100	0	0	0	0	0	0	100	0	0	0	0	36
Jackson[y]	Alan	36	7	44	5	6	0	40	16	4	2	0	0	0	0	0	0	0	0	56
Lafayette	Alan	10	7	36	5	0	0	2	0	8	0	0	6	0	20	0	0	0	0	0
Lawrence	Alan	30	5	12	3	0	0	10	0	0	30	6	0	48	0	0	0	0	0	0
Lonoke	Alan	70	5	6	3	0	0	12	2	0	0	0	0	4	2	0	0	0	0	0
Lonoke	Alan	36	7	2	3	4	0	32	4	36	0	0	0	0	52	0	0	0	0	58
Mississippi[y]	Alan	4	5	100	5	4	0	30	0	36	0	0	0	0	6	0	0	0	0	36
Mississippi	Alan	40	7	56	5	32	0	30	2	6	4	0	0	0	100	0	0	0	0	100
Mississippi	Alan	22	7	82	5	18	0	100	8	14	2	0	0	0	6	0	0	0	0	100
Woodruff	Alan	10	7	8	5	4	0	46	6	2	0	0	0	6	4	0	0	0	0	100
Woodruff	Alan	68	7	32	5	16	0	100	6	24	6	8	0	4	0	0	0	0	0	0
Cross	Bengal	56	7	4	3	12	0	0	2	4	0	0	0	0	0	0	16	0	0	0
Cross	Bengal	32	7	0	1	6	0	0	2	0	0	0	0	0	0	0	4	0	0	0
Chicot	Cypress	78	9	46	5	4	0	2	2	12	0	2	0	0	0	0	0	0	0	0
Chicot	Cypress	46	7	14	5	2	0	2	12	0	0	0	2	2	2	0	0	0	0	0
Monroe	Della	20	5	32	5	10	0	2	0	12	46	0	0	4	0	0	0	0	0	0
Arkansas	Dellmont	16	5	8	3	0	0	2	0	6	48	0	24	100	8	0	0	0	0	0
Monroe	Dellmont	52	7	58	5	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
Poinsett[y]	Jackson	22	7	62	5	0	0	12	0	4	0	2	0	0	10	0	0	0	0	0
Arkansas	Katy	44	9	0	1	0	0	0	4	0	54	0	0	0	0	0	0	0	0	0
Arkansas	Katy	74	7	32	5	0	0	4	10	4	100	6	0	0	100	0	0	0	0	0
Arkansas	Katy	30	5	16	5	0	0	2	12	4	100	12	0	6	2	0	0	0	0	0
Jefferson[y]	Katy	56	5	12	3	0	0	2	22	18	100	2	0	0	62	0	0	0	0	0
Lafayette	Katy	2	5	6	3	0	0	0	0	28	26	2	8	2	0	0	0	0	4	0
Lawrence	Katy	32	7	12	3	0	0	2	30	0	100	2	0	4	0	0	0	0	0	0
Lawrence	Katy	12	5	0	0	0	0	0	36	0	100	2	0	0	0	0	0	0	0	0
Lonoke	Katy	28	5	48	3	0	0	2	4	0	52	2	0	12	0	0	0	0	0	0
Lonoke	Katy	52	7	6	5	0	0	2	32	0	100	16	0	52	100	0	0	0	0	0
Lonoke	Katy	22	7	28	5	0	0	2	16	0	100	6	0	0	82	0	0	0	0	0
Woodruff[y]	Katy	12	3	6	3	0	0	0	2	0	100	0	0	0	0	0	0	0	0	0
Woodruff[y]	Katy	32	7	22	3	0	0	2	4	10	100	0	0	0	28	0	0	0	0	0
Woodruff	Katy	32	7	8	3	0	0	10	4	22	100	0	0	0	0	0	0	0	0	0
Woodruff	Katy	66	7	14	3	0	0	4	12	10	100	0	0	0	0	0	0	0	0	0
Woodruff	Katy	52	7	2	3	0	0	2	12	4	100	0	0	0	2	0	0	0	0	0

continued

Table 3. Continued.

County	Variety	SHBI	SHBSEV	SR	SRSEV	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	DTS	STBN	FB
Lonoke	Koshi-hikari	2	3	24	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Lonoke	Koshi-hikari	0	0	36	5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Arkansas	Lacassine	52	7	58	5	2	0	4	0	2	100	0	2	46	100	0	0	0	0	0
Arkansas	Lacassine	26	7	68	5	10	0	4	2	2	4	0	2	10	26	0	0	0	0	0
Chicot	Lacassine	38	7	6	3	6	0	0	28	0	0	0	4	0	2	0	0	0	0	0
Clay	Lacassine	28	7	2	3	20	0	0	18	12	0	2	0	0	6	0	0	0	0	0
Clay	Lacassine	72	7	10	3	4	0	0	8	0	0	0	0	0	10	0	0	0	0	0
Cross	Lacassine	76	7	8	3	2	0	2	10	6	0	0	0	0	0	0	0	0	0	0
Cross	Lacassine	12	5	4	3	2	0	0	4	2	0	0	0	2	2	0	0	0	0	0
Cross	Lacassine	0	0	0	1	4	0	0	100	2	0	0	0	0	0	0	4	0	0	0
Lafayette	Lacassine	0	0	2	3	0	0	0	0	52	0	0	4	0	0	0	0	0	0	0
Lincoln[y]	Lacassine	24	7	34	3	4	0	2	24	4	0	0	0	0	16	0	0	0	0	0
Mississippi	Lacassine	28	9	66	5	2	0	10	22	4	0	2	0	4	0	0	0	0	0	0
Mississippi	Lacassine	18	7	0	1	0	0	6	2	8	0	0	2	8	0	0	0	0	0	0
Phillips[y]	Lacassine	28	7	50	5	0	0	2	30	22	0	0	0	0	2	0	0	0	0	0
Chicot	Lemont	46	7	44	5	2	0	0	28	34	0	0	0	0	0	0	0	0	0	0
Chicot	Lemont	64	7	78	5	0	0	0	32	10	0	0	0	0	24	0	0	0	0	0
Lafayette	Lemont	0	0	12	4	0	0	0	0	8	0	0	4	0	0	0	0	0	0	0
Lafayette	Lemont	0	0	32	3	0	0	4	0	0	0	0	6	2	0	0	0	0	0	0
Lafayette	Lemont	0	0	12	3	0	0	0	0	8	0	0	18	0	0	0	0	0	0	0
Lawrence	Lemont	22	7	6	5	0	0	2	96	2	4	0	0	2	0	0	0	0	0	0
Lawrence	Lemont	56	7	12	3	0	0	2	8	0	0	0	0	4	0	0	0	0	0	0
Lawrence	Lemont	62	7	74	5	0	0	0	10	0	0	0	0	12	0	0	0	0	0	0
Lawrence	Lemont	26	7	16	3	0	0	2	24	0	2	0	4	80	0	0	0	0	0	0
Lawrence	Mars	10	5	2	3	0	0	0	12	0	0	6	0	4	0	26	0	0	0	0
Lonoke	Mars	16	5	32	5	0	0	0	0	0	0	10	0	4	0	100	0	0	0	0
Clay	Maybelle	36	9	0	1	20	20	2	0	22	2	0	8	0	0	0	0	0	0	0
Lafayette	Maybelle	0	0	6	5	2	0	22	0	6	0	0	2	0	8	0	0	0	0	0
Chicot	Millie	24	7	4	3	8	0	6	2	16	2	2	0	0	2	0	0	0	0	0
Lonoke	Millie	100	7	4	3	2	0	2	4	0	0	0	0	2	0	0	0	0	0	0
Lonoke	Millie	100	7	2	3	10	0	4	4	2	2	0	0	0	0	0	0	0	0	0
Chicot	Newbonnet	8	3	4	3	2	0	100	0	38	10	6	0	0	24	0	0	0	0	0
Chicot	Newbonnet	6	5	16	3	22	0	8	0	0	100	2	0	0	2	0	0	0	0	0
Clay	Newbonnet	84	5	92	3	84	0	100	2	0	100	8	0	8	16	0	0	0	0	0
Lafayette	Newbonnet	0	0	4	2	4	0	2	0	12	22	0	4	16	0	0	0	0	0	0
Lawrence	Newbonnet	76	7	84	5	14	0	16	18	0	100	0	0	2	0	0	0	0	0	0

continued

Table 3. Continued.

County	Variety	SHBI	SHBSEV	SR	SRSEV	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	DTS	STBN	FB
Lawrence	Newbonnet	32	7	24	5	10	0	12	4	0	100	0	0	24	0	0	0	10	0	0
Mississippi	Newbonnet	32	5	22	5	10	0	48	2	22	100	2	50	12	0	0	0	0	0	0
Mississippi	Newbonnet	4	7	0	1	2	0	2	44	12	100	0	38	6	12	0	0	0	0	100
Woodruff[y]	Newbonnet	8	3	10	3	2	0	52	2	0	100	0	4	0	2	0	0	0	0	0
Woodruff	Newbonnet	32	5	6	5	12	0	26	2	2	100	4	0	0	0	0	0	0	0	0
Arkansas[y]	Orion	6	5	8	5	0	0	2	20	6	2	46	10	0	0	100	0	0	0	0
Clay	Orion	4	5	6	5	2	0	2	2	0	0	12	2	0	0	46	0	0	0	0
Cross	Orion	12	5	8	5	0	0	0	0	0	0	0	0	0	0	32	2	0	0	0
Clay	RT7015	56	9	32	5	54	54	62	6	24	2	2	0	4	12	0	0	0	0	0
Mississippi	RT7015	16	5	52	5	2	6	100	6	4	2	2	0	0	0	0	0	0	0	0

[z]Column heading codes represent: SHBI=sheath blight incidence (%positive stops); SHBSEV=maximum sheath blight symptom height observed - visual rating of 1=waterline region to 9 = panicle infected; SR=stem rot (%positive stops); SRSEV=maximum severity rating of stem rot observed (1=healthy, 5=inside of culm infected and premature tiller death); Data for the following is given as percent positive stops - NB=neck blast; LB=leaf blast; KS=kernel smut; BSHR=black sheath rot; BS=brown spot; NBLS=narrow brown leaf spot; SCAB=head scab (*Fusarium graminearum*); BSS=bordered sheath spot; AgSS=aggregate sheath spot; LS=leaf smut; PLS=purple leaf spot of medium grains-cause unknown; FSHR=unidentified disease first observed on Bengal; DTS=dead tiller syndrome; STBN=stackburn; FB=floret blight as observed on Alan-cause unknown but may be related to scab.

[y]Rice verification field - N. Slaton, Coordinator.

Table 4. Overall summary of 1993 rice disease data from grower field survey (mean % positive stops by cultivar).

Cultivar	Fields	SHB	SR	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	DTS	STBN	FB
Alan	13	34	32	7	0	43	4	20	4	1	0	5	25	0	0	0	0	46
Bengal	2	44	2	9	0	0	2	2	0	0	0	0	0	0	10	0	0	0
Cypress	2	62	30	3	0	2	7	6	0	1	1	1	1	0	0	0	0	0
Dellmont	2	34	33	0	0	1	0	4	25	0	12	50	4	0	0	0	0	0
Katy	15	36	14	0	0	2	13	7	89	3	1	5	25	0	0	0	<1	0
Koshi-hikari	2	1	30	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Lacassine	13	31	24	4	0	2	19	9	8	0	1	5	13	0	0	0	0	0
Lemont	9	31	32	0	0	1	22	7	1	0	4	11	3	0	0	0	0	0
Mars	2	13	17	0	0	0	6	0	0	8	0	4	0	63	0	0	0	0
Maybelle	2	18	3	11	10	12	0	14	1	0	5	0	4	0	0	0	0	0
Millie	3	75	3	7	0	4	3	6	1	1	0	1	1	0	0	0	0	0
Newbonnet	10	28	26	16	0	37	7	9	83	2	16	7	6	0	0	1	0	10
Orion	3	7	7	1	0	1	7	2	1	19	4	0	0	59	1	0	0	0
RT7015	2	36	42	28	30	81	6	14	2	2	0	2	6	0	0	0	0	0
TOTAL	80																	

Overall mean (percentage of positive stops) for each disease[z]

SHB	SR	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	DTS	STBN	FB
32	21	6	3	13	7	7	15	3	3	6	6	9	1	<1	<1	4

Percentage of fields with greater than 20% positive stops for each disease at or near grain maturity[z]

SHB	SR	NB	LB	KS	BSHR	BS	NBLS	SCAB	BSS	AgSS	LS	PLS	FSHR	DTS	STBN	FB
66	41	8	3	21	19	18	35	1	4	8	18	6	0	0	0	11

[z]All data are percentage of positive stops in the field. SHB=sheath blight; SR=stem rot; NB=neck blast; LB=leaf blast; KS=kernel smut; BSHR=black sheath rot; BS=brown spot; NBLS=narrow brown leaf spot; SCAB=head scab (*Fusarium graminearum*); BSS=bordered sheath spot; AgSS=aggregate sheath spot; LS=leaf smut; PLS=purple leaf spot of medium grains-cause unknown; FSHR=unidentified disease first observed on Bengal; DTS=dead tiller syndrome; STBN=stackburn; FB=floret blight as observed on Alan-cause unknown but may be related to scab.

DISEASE RESISTANCE IN THE NEW RICE CULTIVAR 'KAYBONNET'

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ABSTRACT

Disease testing was conducted in cooperation with the University of Arkansas cultivar development program to incorporate blast resistance of the 'Katy' cultivar into high-yielding, agronomically acceptable cultivars to be used in Arkansas rice production areas. Disease testing was conducted in inoculated greenhouse and field nurseries manipulated to favor disease development and in un-inoculated field plots, primarily grower fields, using standard agronomic practices for rice production. One breeding line, RU9101142, which was recently released to rice growers as the 'Kaybonnet' cultivar, has both blast resistance and excellent agronomic potential. In greenhouse tests, Kaybonnet was resistant to all blast races tested except IB-33, a race currently not found in Arkansas rice production areas. Kaybonnet was blast resistant in all field tests conducted to date. Kaybonnet is considered to be moderately susceptible to sheath blight and kernel smut. In test observations to date, Kaybonnet does not appear to be unusually susceptible to any of the many diseases found in Arkansas.

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 and the incorporation of new sources of resistance are continuous endeavors serving as one cornerstone for good cultivar development programs. A considerable effort is expended by the rice disease research program to define existing resistance levels and to locate and incorporate new sources of resistance into agronomically acceptable cultivars as defined in the University of Arkansas project *Identification* *and Utilization of Varietal Resistance for Control of Rice Diseases in Arkansas*, funded by grower check-off monies administered by the Rice Research and Promotion Board. To achieve these objectives, University of Arkansas rice cultivar development program entries are continually evaluated in tests designed to provide information on breeding lines and to define disease resistance and liabilities of new varieties prior to release for rice production in Arkansas.

Diseases frequently become limiting factors in Arkansas rice production. For example, the high-yielding and very adaptable 'Newbonnet' cultivar was released to growers in 1983 as being blast resistant to the then-predominant blast races. Two minor blast races, IB-49 and IC-17, quickly became predominant in Newbonnet and have caused substantial yield losses since 1985. Intense greenhouse screening quickly located resistance to IB-49 and IC-17 in the University of Arkansas breeding program germplasm pool soon after the Newbonnet blast vulnerability became evident. An intense breeding and disease screening effort led to release of the blast resistant 'Katy' cultivar in 1989. As is often the case when pest resistance is rushed into a cultivar at the expense of other features, Katy proved not to possess quite as high yield or adaptability characteristics as Newbonnet and other modern cultivars. The blast resistance in Katy, however, has endured. Results presented here reflect the concerted effort to incorporate this resistance into cultivars better suited for Arkansas production areas.

MATERIALS AND METHODS

Data were collected from several sources. In addition to the considerable testing within the Arkansas program, data were obtained from advanced and promising breeding line evaluations conducted by researchers in other states. It is not unusual for these data to vary with location due to environmental differences and research procedures. The tests were conducted by the professional and qualified support staff necessary to provide quality disease evaluations, and, consequently, ratings within a source location are consistent.

Two types of disease nurseries were established. In the first, greenhouse or field plots (usually on a University of Arkansas experiment station) were established under conditions highly favorable for disease. Cultural practices, such as row spacing, fertility requirements, flood conditions, etc., were manipulated to predispose the plant to infection. Plots were artificially inoculated at the most opportune growth stage to insure an adequate level of infective propagules to cause disease. In the second nursery type, un-inoculated observation nurseries were established in grower fields to evaluate disease reactions under current production practices. This is usually done annually at three or more locations throughout Arkansas rice production areas.

Disease evaluations were made by comparing performance with standard check cultivars using data obtained from either direct or indirect assays or from visual estimates of disease progress and severity. The visual disease ratings were made on a standard scale of 0-9. A rating of zero indicates complete disease immunity. A rating of one to three indicates resistance where little loss occurs and, in the case of rice blast lesions, growth of the lesions is considerably restricted. Conversely, a nine rating indicates maximum disease susceptibility, which typically results in complete plant death and/or yield loss. Depending upon the disease in question, a disease rating of four to five is usually indicative of acceptable disease resistance under general field conditions slightly favoring the pathogen. Numerical ratings are sometimes converted to letter symbols where 0-3 = R (resistant), 3-4 = MR (moderately resistant), 5-6 = MS (moderately susceptible), 7 = S (susceptible), and 8-9 = VS (very susceptible).

One breeding line in the Arkansas program, RU9101142, was recently released to rice growers as the 'Kaybonnet' cultivar. Kaybonnet was tested as a developing experimental line in greenhouse seedling blast tests. These trials are the primary means of screening large numbers of breeding lines for susceptibility to common regional blast races. These tests are quite variable, and the blast races tend to overwhelm any field resistance present in the entry. However, under controlled conditions the tests provide an accurate definition of the fungus-cultivar genetics and, if properly conducted, provide a rough estimate of field performance. Seedling plants near the three- to five-leaf growth stage were sprayed with approximately 5 X 10^5 spores of different *Pyricularia oryzae* races. Plants were immediately placed into a humidity chamber for 24 hours and then moved to greenhouse benches. When susceptible reference plants showed well-developed lesions (usually about seven days), leaf lesion characteristics were used to provide a visual estimation of varietal reaction to the different blast races. Blast field nurseries were established to evaluate blast susceptibility under field conditions. These usually were artificially inoculated nurseries growing under conditions favoring blast infection. The inoculated field nurseries and un-inoculated plots in grower production fields were used to estimate field performance using both leaf lesion characteristics and panicle infection characteristics.

Evaluations for reaction to sheath blight (*Rhizoctonia solani*) were made in field nurseries only. In tests on University of Arkansas experiment stations, plots were artificially inoculated when plants reached the beginning internode elongation growth stage. The mixture that was used to inoculate the plots was one part rice grain - three parts rice hulls mixture well colonized with rice pathogenic strains of *Rhizoctonia solani* that had been further expanded by adding moist sterile rice hulls in a one to twenty ratio followed by an additional 24 hours incubation. Sheath blight severity and vertical progress on the plants was estimated visually using the 0-9 rating scale when the plants were physiologically mature. Un-inoculated plots in grower observation tests were evaluated using the same technique.

For determination of field reaction to rice kernel smut, rice panicles from plots in grower fields having a smut (causal organism *Tilletia barclayana*) history were collected when mature and wrapped in nylon mesh; the hulls were cleared in a 0.27 M KOH solution and rinsed in tap water, and the number of smutted kernels was determined by examining rice kernels over a light box. A smut index, indicating the mean number of smutted kernels per ten panicles, was calculated to compare smut susceptibility relative to other entries in the test. In addition, hulls were cleared in grain sub-samples from different agronomic tests and the number of smutted grain per 100 g rough rice found when examined over the light box was used as a relative susceptibility comparison.

Evaluations for other diseases were made by visual examination of all test plots located on University of Arkansas experiment stations and in grower fields. Plots were inspected, but specific data were not recorded for most diseases unless an unusual level of susceptibility was evident or the disease pressure was abnormally severe.

RESULTS AND DISCUSSION

Greenhouse seedling tests indicate that Kaybonnet is resistant to all blast races tested with the exception of race IB-33 (Table 1). Race IB-33 is not commonly found in Arkansas rice production fields and had not been detected in any of the blasted field samples prior to 1993. Although 1993 samples are still being processed, blast isolates pathogenic to Katy and Kaybonnet have been isolated from six samples representing four different counties.

The significance of Kaybonnet being very susceptible to IB-33 is unknown at this time, but it does suggest a potential disease liability. However, the production history of Katy, a parent that is also susceptible to IB-33, is encouraging. Since the release to growers in 1989, a limited number of blasted samples have been found in Katy fields and processed for race identification. All *P. oryzae* isolates from these samples were identified as being known races to which Katy is resistant, and none caused blast in subsequent inoculations to Katy. Seed from some susceptible samples were grown out and determined to be some cultivar or strain other than Katy. To date, Kaybonnet has exhibited good field tolerance in all field tests (Table 2) but has not been challenged with race IB-33. The one possible exception could be a very late planted seedling blast test located adjacent to a heavily blasted 'Alan' field in Lonoke county. Blast isolates pathogenic to Katy and Kaybonnet were isolated from M201 and other cultivars in that test, but Katy or Kaybonnet plots did not exhibit blast symptoms. There will be considerable selection pressure for minor races such as IB-33 if Kaybonnet is planted to a large percentage of the state rice acreage. Kaybonnet has several desirable agronomic characteristics and will be selected by growers over Katy and some popular blast-susceptible cultivars. Thus, early field plantings of Kaybonnet need to be very carefully monitored to avert a situation similar to that which occurred with the Newbonnet cultivar.

Kaybonnet is rated six for sheath blight reaction compared to a rating of five for Katy (Table 3). In production fields, cultivars with these ratings are considered as being moderately susceptible. Some losses will occur under normal disease situations, but fungicide applications may not be deemed necessary except under adverse conditions.

In the past, kernel smut susceptibility has been determined in new cultivars by judging field performance three or four years following release to growers. Although an acceptable inoculation technique is unavailable, we have developed adequate evaluation techniques to compare cultivar susceptibility to rice kernel smut using samples from naturally infected field plots. Data collected to date can be used assign a smut rating of five for Kaybonnet prior to release to growers (Table 4). For comparison, Newbonnet has proved to be kernel smut susceptible and is being assigned a seven rating. These ratings are somewhat tentative until a larger data base and more rating experience can be acquired.

Data are limited on some important diseases such as stem rot which has been increasing over the past three to four years. In a single test Kaybonnet showed more stem rot damage than did Katy (Table 5). Kaybonnet has good tolerance to minor diseases such as leaf smut, brown spot and narrow brown leaf spot. Panicle blight, a term referring to the light-weight panicles resulting from premature maturation from some unknown cause, appears to have been increasing in the Katy cultivar during 1992 and 1993. Ratings from a single test in Louisiana suggest the problem may be less likely to occur with Kaybonnet than with Katy. *Fusarium graminearum* is consistently associated with the random individual floret blanking observed for some time in certain cultivars in the state. Three years of data from grower observation fields indicate that Kaybonnet is not badly affected by blanking and as such is rated four in comparison to a rating of three for the Katy cultivar and a seven for the more susceptible Alan cultivar.

Disease ratings reported here are only estimates based on a limited number of tests with a restricted amount of seed. More accurate ratings can be established after three or four years of production history. Grower production practices are constantly changing, and, as a result, Kaybonnet will be exposed to an entire gambit of situations that may alter current estimates of disease susceptibility.

Table 1. Summary leaf blast reactions in 'Kaybonnet' and reference cultivars when inoculated with *Pyricularia oryzae* races.

	International Blast Race[z]									
Cultivar	IB-1	IB-33	IB-45	IB 49	IB-54	IC-17	ID-13	IE-1	IG-1	IH-1
Katy	1	8	3	2	0	0	0	2	1	0
Newbonnet	5	8	1	8	0	8	1	8	1	0
Cypress	4	6	3	7	0	7	0	5	3	0
LaGrue	6	8	7	8	6	8	6	8	7	6
Kaybonnet	3	8	0	2	1	0	0	1	0	0

[z]Composite leaf blast ratings on the 0-9 disease scale from greenhouse tests conducted by Dr. M. A. Marchetti, USDA, Beaumont, Texas and at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Ratings indicate relative susceptibility under conditions favorable for seedling blast.

Table 2. Summary composite leaf and panicle blast ratings in inoculated field nurseries and non-inoculated grower plots of 'Kaybonnet' and reference cultivars.

	Blast Field Data Source[z]						
	Arkansas		Texas	Louisiana	Mississippi		
	Grower	Field	Field	Field	Field	Overall Rating	
Cultivar	Plots	Nursery	Nursery	Nursery	Nursery	Numerical	Symbol[y]
Katy	2	2	1	2	2	2	R
Newbonnet	7	7	8	6	8	7-8	VS
Cypress	7	7	6	4	8	7	S
LaGrue	6	7	7	8	7	7	S
Kaybonnet	3	3	2	3	3	3	R

[x]Composite leaf and rotten neck blast ratings on the 0-9 disease scale from field nursery tests at the indicated locations. Ratings indicate relative susceptibility under favorable blast conditions.

[y]Conversion of the 0-9 disease scale to symbols. R (resistant) = 0-3, MR (moderately resistant) = 3-4, MS (moderately susceptible) = 5-6, S (susceptible) = 7, and VS (very susceptible) = 8-9. Varieties labeled MS may be damaged and those labeled S or VS may be severely damaged under conditions favorable for blast development.

Table 3. Summary sheath blight ratings for 'Kaybonnet' and reference cultivars in inoculated field nurseries and non-inoculated grower plots.

	Sheath Blight Data Source[z]						
	Arkansas		Texas	Louisiana	Mississippi	Overall Rating	
Cultivar	Grower	Nursery	Nursery	Nursery	Nursery	Numerical	Symbol
Katy	5	5	6	6	3	5	MS
Newbonnet	5	6-7	7	6	5	6-7	S
Cypress	7	7	6	6-7	5	7	S
LaGrue	6	7	6	7	4	6-7	S
Kaybonnet	6	5-6	7	5-6	3	6	MS

[z]Composite sheath blight lesion height evaluations on the 0-9 disease rating scale from the indicated source. Ratings indicate relative susceptibility under favorable sheath blight conditions. Conversion of the 0-9 disease scale to symbols: R (resistant - lesions on or below lower 20 % of total plant height) = 0-3, MR (moderately resistant - lesions below 40 % of height) = 3-4, MS (moderately susceptible - 50-60 % of height) = 5-6, S (susceptible - a few infected flag leaf sheaths) = 7, and VS (very susceptible - lesions on flag leaf sheath and above with plant death) 8-9.

Table 4. Kernel smut comparison data for 'Kaybonnet' and reference cultivars.

	Cross County Grower Tests					1993 ARPT[x]				
	1991	1992	1992	1993	1993	JKSN	RREC	SEBE	Overall[v] Rating	
Cultivar	Vis.[z]	Index[y]	Index	Index	Index	Count[w]	Count	Count	Numerical	Symbol
Katy	4	-	-	-	-	0	0	2	1	R
Newbonnet	6	4	-	-	-	3	1	17	7	S
Cypress	5	12	3	21	-	1	1	5	5	MS
LaGrue	5	13	48	48	50	2	2	9	7-8	S
Kaybonnet	4	10	6	26	17	1	1	1	5	MS

[z]Visual field smut evaluation on the 0-9 disease scale. This is an inadequate severity estimate for this disease.
[y]Smut index indicating the mean number of smutted kernels per 10 panicles.
[x]Arkansas Performance Test with locations in Jackson county (JKSN), on the Rice Research and Extension Center (RREC) and the Southeast Branch Experiment Station (SEBE).
[w]Mean number of smutted kernels found in 100 grams (about 1/4 lb) of rough rice.
[v]The summary system is not well established and ratings are tentative.

Table 5. Ratings for other diseases in 'Kaybonnet' and reference varieties.

	Disease					
Cultivar	Stem[z] Rot	Leaf[y] Smut	Brown Spot	Narrow Brown Leaf spot	Panicle[x] Blight	Blank Florets[w] (Scab)
Katy	2	3	2	3	6	3
Newbonnet	5	3	2	4	7	5
Cypress	0	3	3	4	6	4
Lagrue	6	2	3	1	8	4
Kaybonnet	4	3	3	4	2	4

[z]Visual ratings on the 0-9 disease scale from a 1991 Arkansas grower test location. Inadequate severity estimate for this disease.

[y]Ratings for leaf smut, brown spot and narrow brown leaf spot summarized on the 0-9 disease scale from 1991-1993 disease evaluations provided by Dr. Don Groth, LSU Rice Experiment Station, Crowley, Louisiana.

[x]Highest visual panicle blight (cause unknown) rating in a 1993 two replication test located at Pine Island, Louisiana. Severity estimate of damage on the 0-9 disease scale is not well established.

[w]Grain blanking (possible causal agent *Fusarium graminearum*) rated on the 0-9 disease scale. Summary 1991-1993 visual ratings from grower observation tests. Alan which rated 7 is the most susceptible commercial cultivar.

ROW SPACING EFFECT ON MOISTURE EVAPORATION AND VERTICAL SHEATH BLIGHT PROGRESS IN SELECTED RICE CULTIVARS

Fleet N. Lee

ABSTRACT

Sixteen-foot paired non-inoculated and *Rhizoctonia solani*, Kuhn, inoculated plots of the cultivars 'Adair', 'Cypress', 'Jackson' and 'LaGrue' were seeded on 16-ft-long plots with 7-in., 10-in. and four 7-in. rows bordered by 10-in. (10-7-7-7-7-10) row spacings. Mean daily water evaporation (MDWE) from white porous atmometers placed within the canopy of inoculated plots was 5.1 ml in Cypress, 5.5 ml in Adair and 6.0 ml in LaGrue over all row spacings. Over all cultivars, the MDWE was 5.0 ml in the 7-in., 5.4 ml in the 10-7-7-7-7-10-in. and 6.3 ml in the 10-in. row spacings. Mean yield and visual sheath blight ratings were not statistically different for row spacing. A significant cultivar x row spacing interaction occurred with the visual sheath blight ratings. Data from this one year test are inconclusive but suggest that planting rice in somewhat wider row spacing does not reduce yield losses from sheath blight.

INTRODUCTION

The "Yield Loss Assessment and Environmental Factors Affecting Severity of Sheath Blight of Rice" project funded by the Arkansas Rice Research and Promotion Board has the ultimate objective of defining those disease parameters that influence sheath blight (causal agent *Rhizoctonia solani* Kuhn) severity and developing a sufficiently large data base to predict the final impact of sheath blight on rice yield. The results will be used for evaluating advanced breeding lines during cultivar development and establishing loss thresholds in established cultivars. Losses can be partitioned into those due to the environment, the pathogen, the rice genotype and various agronomic practices.

Grain yield loss is correlated with the vertical progress of sheath blight on the rice plant. Most of the loss occurs when the disease disrupts normal functions of the top two leaves of the plant during the early stages of grain filling. Environmental variables such as temperature, relative humidity and free water (dew period and rainfall); pathogen variables such as source (biotype), quantity and quality of infecting propagules; cultivar characteristics such as inherent susceptibility, plant canopy characteristics and tillering ability; and various agronomic practices such as row spacing, plant population and distribution, nitrogen fertility levels and timing, etc. interact to provide a sum total effect on the upward growth rate of the fungal pathogen on the rice plant.

Grower and consultant claims about the value of various agronomic practices such as row spacings and/or the orientation of rows relative to wind and sunlight frequently are expounded in popular publications and agricultural advertisements without sufficient substantiating research data. Existing research data on the subject are limited. These tests were conducted to better define sheath blight progress in representative cultivars at different row spacings.

MATERIALS AND METHODS

Four replications of paired inoculated and non-inoculated six row by 16 ft plots of Cypress, LaGrue, Jackson and Adair cultivars were established using 7-in., 10-in. and four 7-in. rows bordered by 10-in. (10-7-7-7-7-10) row spacings. The number of tillers per row ft was determined in each cultivar prior to permanent flood. One quart of *Rhizoctonia solani* inoculum grown on a rice grain - rice hull mixture was spread between the center two rows of inoculated plots at the beginning internode elongation growth stage. The number of diseased tillers per row foot was determined at internode elongation. A visual sheath blight severity estimate at grain maturity was made using the 0 = none to 9 = maximum vertical progress and yield loss rating system. An area 30 in. by 14 ft was harvested using a small combine for rough rice (adjusted to 12% moisture) yield comparisons. Thus, the harvested area included four rows in the 7-in. and three rows in the 10-in. spacing.

Standardized white porous spherical atmometers 2 in. in diameter with a 0.12-in. wall and 1.8-in. neck were mounted at a height of approximately 8 to 9 in. on metal rods for use in this experiment. All atmometers within a particular cultivar were positioned at the same height such that moisture losses would represent evaporation potential near the sheath of the second leaf above the flood water of adjacent plants. Atmometer height was repositioned to keep it within the plant canopy throughout the growing season. An additional three atmometers were placed outside the canopy at approximately 36 in. above the water surface throughout the test. Moisture that evaporated from the surface of the water-filled atmometers was replaced via a continuous water column established through a plastic tube connecting the atmometer neck with a 500 ml (approximately 1/2 quart) flask serving as a reservoir. Water loss was replenished in each reservoir on three- or four-day intervals. Soon after plots were inoculated, the atmometers were placed within one of the two center rows for each spacing in the Adair, Cypress and LaGrue cultivars.

RESULTS AND DISCUSSION

Atmometers of various kinds have been used for many years in theoretical studies and have practical application. For example, evaporation from open pans of water and wet paper have been used over time in scheduling irrigations. More recently atmometers were used to measure evaporation potential in different grape pruning systems. Differences in water evaporation indicate dissimilar environmental conditions. The use of atmometers makes possible a comparison of evaporation conditions over different environments over time. In this case, test comparisons were made between different cultivars planted on different row spacings. Atmometers have been proposed as a possible tool for use in predicting sheath blight severity (David Laird, Personal Communication).

Potential sources of error were detected that may reflect erratic atmometer performance. At the start of the test, the rate of water evaporation from certain atmometers appeared to be abnormally low compared with others in similar environments. The defective units were replaced. Road dust collected on atmometers outside the canopy. Alga grew on the surface of atmometers within the plant canopy. To reduce the effect of these problems, a copper solution was added to the water and the surface of the atmometers was washed with this solution each time that water was replenished in the reservoirs.

Throughout the period in which measurements were recorded, water evaporation from atmometers outside the canopy generally corresponded with changes in evaporation within the canopy. When measured over all row spacings, evaporation was greatest in LaGrue, which had a mean daily water evaporation (MDWE) for the monitoring period of approximately 6.0 ml/atmometer and the least in Cypress with a MDWE of 5.1 ml (Fig. 1). The MDWE for Adair over all row spacings was 5.5 ml. Averaged across cultivars, evaporation was least for the 7-in. row spacing with a MDWE of approximately 5.0 ml/atmometer

(Fig. 2). The MDWE was approximately 5.4 ml/atmometer in the 10-7-7-7-7-10 row spacing. The highest rate of evaporation occurred with the 10-in. row spacing which had a MDWE of 6.3 ml/atmometer. The MDWE in the LaGrue cultivar was 6.7 ml, 6.9 ml and 7.3 for the 7-in., 10-7-7-7-7-10-in. and 10-in. row spacings, respectively (Fig. 3).

The effect of row spacing on the vertical progress of sheath blight is less clear. As an average of all cultivars, yield differences between row spacings were not statistically different for either the non-inoculated or inoculated treatments (Table 1). Visual disease ratings across row spacings were not statistically different. Statistical analysis of the visual ratings did indicate a highly significant cultivar-row spacing interaction. Although a trend toward less sheath blight in the wider spacing was evident, in three of the cultivars visual ratings of the various spacings were not statistically different within individual cultivars when analyzed separately (Table 2).

Cultivar susceptibility and canopy type are linked together into one package. The canopy also adjusts to different plant populations and row spacings. Data are not available to extrapolate or correlate moisture losses from atmometers to the rate of vertical sheath blight growth on the rice plant. Theoretically, wider row spacing would create unfavorable environmental conditions for fungal growth and ultimately restrict the vertical growth rate of the fungus. While measurable differences in evaporation were recorded for different row spacings, they did not appear to translate into different rates of upward sheath blight progress on the plants nor reductions in yield losses caused by sheath blight. However, during the course of this test the weather was abnormally hot and dry, which may have overwhelmed any environmental advantage gained from a wider row spacing. The test will be conducted again in 1994 to gather additional data.

Table 1. Mean yield and sheath blight evaluations over four rice cultivars from paired non-inoculated and *Rhizoctonia solani* inoculated plots at different row spacings.

Row Spacing[z]	Plants Per Row Foot[y]	Non-inoculated Yield lb/acre[x]	Non-inoculated Visual S.B.[w]	Inoculated[v] Yield lb/acre	Inoculated[v] Infected Tillers[u]	Inoculated[v] Visual S.B.[w]	Yield Loss lb/acre[t]
7	15.4	7163a	2.0a	6257a	5.1	5.5a	907a
10-7-10	14.8	7550a	2.2a	6417a	5.4	5.3a	1133a
10	15.8	7164a	2.8a	6084a	5.5	5.2a	1081a

[z]Row spacings were 7-in., four 7-in. bordered by 10-in. (10-7-7-7-7-10), and 10-in. centers.
[y]Plots were planted 7 May 1993 and number of tillers per row foot determined 2 June 1993.
[x]Values within a column followed by the same letter are not statistically different at $P = 0.05$.
[w]Plots were visually rated on 25 August 1993 using the scale of 0 = no disease to 9 = maximum vertical disease progress and severe yield loss.
[v]Inoculated with *Rhizoctonia solani* on 7 July 1993 and due to low disease pressure were inoculated again on 15 July 1993.
[u]The mean number of diseased tillers per row foot was determined on 23 July 1993 prior to permanent flood.
[t]Mean difference between yields from non-inoculated and inoculated plots.

Table 2. Mean yield and sheath blight evaluations from paired non-inoculated and *Rhizoctonia solani* inoculated plots in four rice cultivars planted on different row spacings.

Cultivar	Row[z] Spacing	Tillers Per Row Foot[y]	Non-Inoc Yield lb/acre[x]	Non-Inoc Visual Prog.[w]	Inoculated[v] Yield lb/acre	Inoculated[v] Infected Plants[u]	Inoculated[v] Visual Prog.[w]	Yield Loss lb/acre[t]
Cypress	7	12.9	7018a	1.9a	6314a	8.2	6.0a	704a
Cypress	10-7-10	15.2	7697a	2.4a	6624a	7.5	6.5a	1073a
Cypress	10	15.9	7978a	3.4a	6305a	6.6	5.8a	1674a
Lagrue	7	16.9	8164a	1.8a	7196a	3.1	6.0a	968a
Lagrue	10-7-10	16.6	8855a	2.1a	7283a	4.4	5.1a	1572a
Lagrue	10	17.3	8043a	2.3a	7195a	3.1	4.7a	848a
Jackson	7	15.9	7038a	2.3a	6045a	6.1	6.2a	993a
Jackson	10-7-10	13.3	6292a	1.8a	5154a	3.8	2.9a	1138a
Jackson	10	13.4	5735a	1.8a	4935a	6.1	4.0a	800a
Adair	7	15.7	6433a	2.2a	5472a	3.0	4.0a	961a
Adair	10-7-10	14.2	7356a	2.3a	6608a	5.7	6.7a	748a
Adair	10	16.6	6902a	3.8a	5900a	6.0	6.4a	1001a

[z]Row spacings were 7-in., four 7-in. bordered by 10-in. (10-7-7-7-7-10) and 10-in. centers.
[y]Plots were planted 7 May 1993 and number of tillers per row foot determined 2 June 1993 prior to permanent flood.
[x]Values within a column followed by the same letter are not statistically different at $P = 0.05$.
[w]Plots were visually rated on 25 August 1993 using the scale of 0 = no disease to 9 = maximum vertical disease progress and severe yield loss.
[v]Plots were inoculated with *Rhizoctonia solani* on 7 July 1993 and due to low disease pressure were inoculated again on 15 July 1993.
[u]The mean number of diseased tillers per row foot was determined on 23 July 1993.
[t]Mean difference between yields from non-inoculated and inoculated plots.

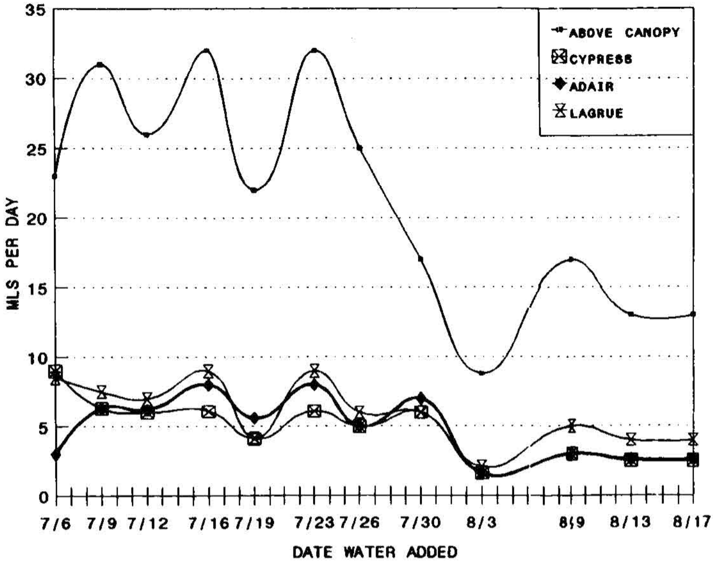

Fig. 1. Mean daily water evaporation from white porous atmometers within the canopy of three rice cultivars compared with that from atmometers placed outside the canopy.

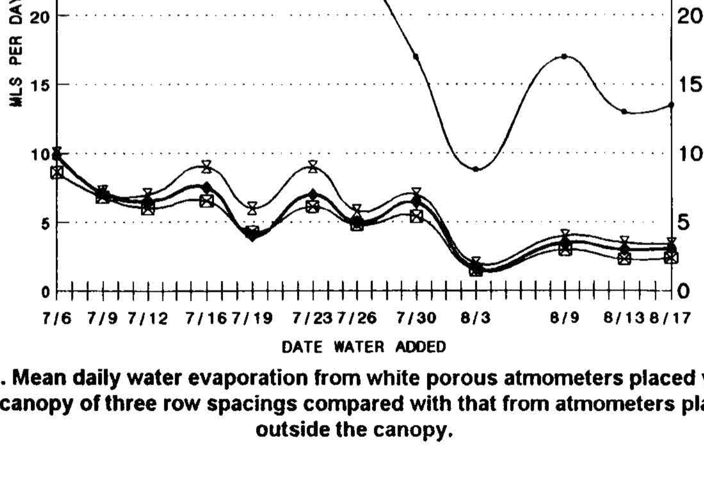

Fig. 2. Mean daily water evaporation from white porous atmometers placed within the canopy of three row spacings compared with that from atmometers placed outside the canopy.

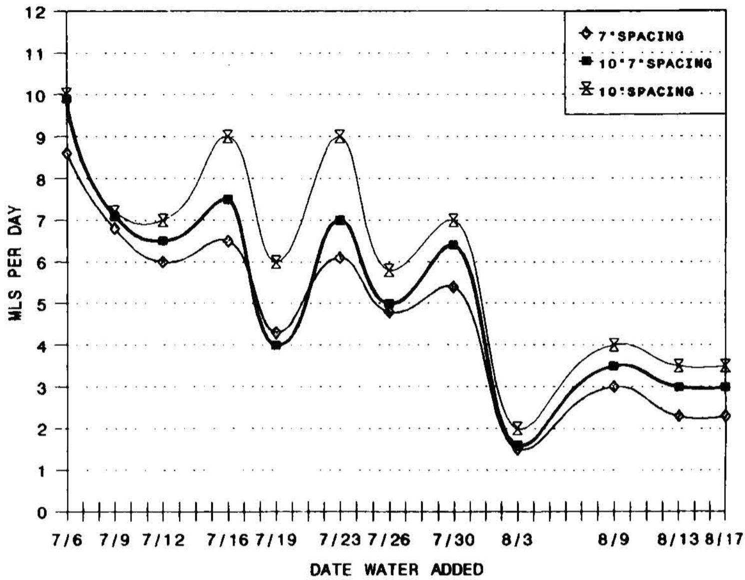

Fig 3. Mean daily water evaporation from white porous atmometers placed within the canopy of the LaGrue rice cultivar at three row spacings.

ECONOMIC EVALUATION OF FUNGICIDES AND IMPROVEMENT OF SCOUTINGPROCEDURES TO SUPPRESS SHEATH BLIGHT

Gary L. Cloud

ABSTRACT

Sheath blight has been a serious rice disease since the mid 1970s. Sheath blight is controlled with fungicides applied at specific growth stages, tolerant rice varieties and stubble burning to reduce sheath blight inoculum. Although tolerant varieties are commercially available, yield losses can result from sheath blight damage. Chemical control has, for a number of years, been the primary means of suppressing sheath blight in production fields. Recently, the efficacy of fungicides to suppress sheath blight in fields has been low due to 1) inaccuracy of assessing sheath blight, 2) inaccurate sheath blight thresholds to trigger fungicide applications and 3) the method of fungicide application. The objectives of this study are to evaluate 1) the economic efficacy of commercial fungicides to suppress sheath blight in production fields, 2) the accuracy of the currently used sheath blight thresholds and 3) the method of assessing sheath blight. Results from this study indicate that the sheath blight ratings taken with the positive stop method did not correlate with yield any time during the growing season. The percentage of tillers infected method correlated with yield at specific growth stages primarily later in the growing season. Fungicide applications made at 1/2-in. internode elongation (IE) and 10 days later provided significantly higher yields than untreated check plots in two of the four harvested large-block fields. Fungicide trials conducted in small plots applied with backpack sprayers provided significant reductions in sheath blight levels and significantly higher yields than untreated check plots at both locations. Results obtained from this test indicate improvements can be made 1) in the scouting procedures used to assess sheath blight and 2) in sheath blight thresholds used to trigger fungicide applications.

INTRODUCTION

Sheath blight (*Rhizoctonia solani*) is the most prevalent rice disease in Arkansas. Sheath blight is a chronic problem to rice producers because of 1) the use of rotation crops susceptible to *R. solani*, particularly soybean, sorghum and corn; 2) shortened rotation intervals with rotation crops; 3) shallow disk cultivation, no-till cultivation and water seeding; and 4) the use of very susceptible semi-dwarf rice varieties planted in dense stands under high fertilizer regimes (Jones, 1989). Forty percent reductions in grain yields have been reported under severe disease pressure.

Current control recommendations for sheath blight include fungicide applications made at specific rice growth stages, planting tolerant rice varieties and stubble burning to destroy sheath blight inoculum. In the past, the use of fungicides has represented the most common means of suppressing sheath blight in rice productions fields (Jones et al., 1987). In Arkansas, fungicide applications are made at 1/2-in. internode elongation (IE) followed by a second application 10 days later.

Recently, reports have appeared in the literature concerning the lack of sheath blight suppression fungicides provide in production fields (Moore, 1991). It has been speculated that the decline in fungicide performance is due to the lack of accurate methods used to assess sheath blight levels, inaccurate sheath blight thresholds used as indicators for fungicide applications, the development and release of rice cultivars tolerant to *R. solani* and methods used to apply fungicides that result in inadequate penetration and coverage of the rice plant.

Various methods have been developed to assess sheath blight levels, including the positive stop method (average number of locations in a field in which one or more lesions of sheath blight are observed) and percentage of tillers infected (number of tillers exhibiting sheath blight within a given area). Research has shown that 5% tillers infected consistently results in economic returns to growers when fungicides are applied (Jones et al., 1987; Groth et al., 1992). However, no research has been conducted to evaluate the thresholds necessary to ensure economic returns with the positive stop method. Arkansas and Mississippi utilize the positive stop method while Louisiana and Texas use the percentage of tillers infected method.

In the past, 15% infection based on the positive stop method (average number of locations in a field in which one or more sheath blight lesions were observed) was considered to be the economic disease threshold for fungicide applications for all varieties. This threshold was based on the 'Lebonnet' variety, which has few similarities to varieties grown today. With the development and widespread use of 'Lemont' and other semi-dwarf varieties, it became apparent that the sheath blight threshold for these newer varieties was high at 15% and was reduced to 5-10% (Marchetti, 1983). Marchetti and Bollich (1991) reported that rice varieties differ greatly in yield losses attributed to sheath blight damage. Based on this research, three categories were established, primarily based on susceptibility to sheath blight and canopy architecture in which each category has different sheath blight thresholds (Cloud et al., 1992). The three categories are 1) closed canopy, highly susceptible, 2) open canopy, highly susceptible and 3) open canopy, tolerant.

Due to the lack of large-block fungicide trials conducted in production fields, the lack of accurate sheath blight thresholds and the lack of accurate methods used to assess sheath blight levels, the purpose of this study is (1) to compare the economic effectiveness of commercial fungicides applied with agricultural aircraft in production fields and (2) to evaluate the accuracy of the positive stop and percentage of tillers infected methods to assess sheath blight levels as related to yield losses in large-block and small-plot fungicide studies under natural sheath blight infestations.

MATERIALS AND METHODS

Large-block Fungicide Trials

Five commercial fields were selected as sites for the large-block study. Fields were selected on the basis of the variety planted, size of field and uniformity of sheath blight severity. Lemont, which is highly susceptible to sheath blight, was the rice variety grown at each of the test site locations.

Plot dimensions were 200 ft wide X 1000 ft long. Plots were arranged in a randomized complete block design with three replications per treatment. Fungicide treatments, including rates and timing of applications, are listed in Table 1. The 10-oz product/acre and 6-oz + 6-oz product/acre rates of Tilt 3.6EC were not used at all large-block locations. Refer to Tables 2-9 for specific rates of Tilt 3.6EC used. Benlate at a rate of 1.0 lb product/acre was not used in the large-block fungicide trials but was a fungicide treatment in the small-plot fungicide trials. Latron CS-7 (Rohm & Haas 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 nozzles (Spray Systems Co., Wheaton, IL) with 30 lb/in.^{2}. Fungicides were applied at 1/2-in. IE followed by a second application 10 days later for all fungicide treatments with the exception of Tilt 3.6EC applied at a rate of 10 oz product/acre. 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 ten locations per plot included +/- rating (+ = one or more sheath blight lesions/3 linear row ft), number of tillers infected (number of tillers exhibiting sheath blight lesions/3 linear row ft) 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 (determine the initial infection level), 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 calculated at 13%. Milling yield samples were taken from each plot to determine total and head rice yields for each treatment. Due to weed problems, one field in Jefferson County was not harvested.

Levels of economic return were determined using the 1993 price for long-grain rice of $5.39/bu. The cost for fungicides was calculated using $16.33/lb for Benlate 50WP, $2.50/oz for Tilt 3.6EC and $17.00/pt for Rovral 4F. These prices will vary slightly with geographical location. Custom aerial application was included in the program cost estimate at $4.00/acre.

Mean yield data was statistically analyzed to determine significant differences (P = 0.05 level). Results of grain yields and milling yields from fungicide-treated plots were economically compared to those from untreated plots within a given field to determine the economic benefits of fungicides. Sheath blight disease ratings were analyzed by regression analysis to determine correlations between disease level and yield at any of the four rating dates.

Small-plot Fungicide Trials

Two commercial rice fields were selected as sites for the small-plot fungicide study. Lemont was the rice variety grown at the two test site locations.

Plots were arranged in a randomized complete block design with five replications per treatment. Plot dimensions were 7 ft wide X 20 ft long. Fungicide treatments including rates and timing of applications are listed in Table 1. Untreated plots served as control plots. Fungicides were applied with a CO^2 backpack sprayer. Spray equipment included XR #8003 flat fan nozzles (Spraying Systems Co., Wheaton, IL), 30 lb/in.^{2} to deliver 20 gal/acre. Fungicides were applied at 1/2-in. IE followed by a second application 10 days later for all fungicide treatments with the exception of Tilt 3.6EC applied at a rate of 10 oz product/acre.

Sheath blight ratings taken at two predetermined locations/plot included the 0-9 rating system where 0 = no disease and 9 = disease symptoms on the flag leaf/3 linear ft of row. Four disease ratings were taken throughout the experiment: 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. Averages of the 0 to 9 ratings were taken for each treatment at each of the four rating dates and reported in Tables 10 and 12.

Plots were harvested in the locations rated for disease by hand-clipping panicles from two 3-ft^2 areas/plot. Harvested panicles from each subplot were separately placed in paper bags, air-dried in a forced air drier and thrashed with a stationary thrasher. Grain weights were taken and adjusted to 13% moisture and converted to bu/acre. Milling yields were determined from the subplot samples at one of the two test site locations.

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

RESULTS

Large-block Fungicide Trials

Disease ratings taken in those fields with significant differences in yield from fungicide treatments were analyzed by regression analysis to determine the correlation between sheath blight levels and yield loss. Disease ratings taken at the Armstrong farm location resulted in no significant differences with the +/- ratings at any of the four rating dates (Table 2). No significant correlation was found between the ratings and yield losses. Significant differences at the fourth rating date were revealed with the percentage of tillers infected ratings (Table 2). A significant correlation (r^2 = 0.88) was observed between the ratings taken and the yields corresponding to those treatments. No significant differences were observed with the 0-9 ratings, and no correlation was revealed between ratings and yield (Table 2). Grain yields at the Armstrong location ranged from 8.9 to 12.5 bu/acre compared to untreated check plots, and all fungicide-treated plots were significantly higher (*P* = 0.05) than the untreated plots (Table 3). Milling yields were significantly higher (*P* = 0.05) in plots treated with Tilt 3.6EC (6 + 6 oz/acre) than in untreated plots. Net returns for fungicide treatments with Tilt 3.6EC, Benlate 50WP and Rovral 4F were $18.88, $10.74 and $6.50/acre, respectively (Table 4).

At the Feather farm location, no significant differences were revealed with the +/- ratings taken at any of the four rating dates (Table 5). Significant differences were observed with the percentage of tillers infected ratings taken during the second and fourth rating dates (Table 5). Significant correlations (r^2 = 0.75 and r^2 = 0.79) were observed between the ratings taken at the second and fourth rating date, respectively, and yield. Significant differences were revealed in the 0-9 ratings taken at the third and fourth rating dates (Table 5). Significant correlations (r^2 = 0.91 and r^2 = 0.86) were revealed between the ratings taken at the third and fourth rating dates, respectively, to yield. Grain yield increases ranged from 14.5 to 19.6 bu/acre compared to untreated check plots, and all fungicide-treated plots were significantly higher (*P* = 0.05) than the untreated plots (Table 6). Results from this test did not reveal increases in milling yields from fungicide treatments. Net returns for Tilt 3.6EC (6 + 6 oz/acre), Tilt 3.6EC (10 oz/acre), Benlate 50WP (1.5 + 1.5 lb/acre) and Rovral 4F were $49.57, $53.29, $32.42 and $63.45/acre, respectively over the untreated check plots (Table 7).

No significant differences in grain or milling yields were observed at the other two test site locations harvested (Tables 8 and 9). Economic data were not calculated for these test sites due to the lack of significance.

Small-plot Fungicide Trials

At the Buckshot farm test site, significant differences in sheath blight levels were observed at the third and fourth rating dates (Table 10). Fungicide treatments that provided the greatest suppression of sheath blight included Benlate 50WP at the 1.0-lb/acre and 1.5-lb/acre rates, followed by Rovral 4F, Tilt 3.6EC at the 6.0-oz/acre and 10-oz/acre rates (Table 10).

Plots treated with Tilt 3.6EC (10 oz/acre), Benlate 50WP (1.0 lb/acre/application), Benlate 50WP (1.5 lb/acre/application) and Rovral 4F (1.0 pt/acre/application) had significantly higher yields (P = 0.05) than the untreated check plots (Table 11). Milling yield data were significantly higher (P = 0.05) in plots treated with Benlate 50WP (1.0 lb/acre/application) and Rovral 4F (1.0 pt/acre/application) than the untreated check plots.

At the McNeil farm test site, no significant differences in sheath blight levels were observed at the four rating dates (Table 12). It appears from these data that sheath blight did not progress during the later stages of the season as did that at the Buckshot farm test location. Plots treated with Tilt 3.6EC (6 oz/acre/application), Tilt 3.6EC (10 oz/acre), Benlate 50WP (1.0 lb/acre/application) and Benlate 50WP (1.5 lb/acre/application) had significantly higher (P = 0.05) yields than untreated check plots (Table 13). Milling yields were not taken at this location.

DISCUSSION

Results collected from the large-block and small-plot fungicide trials indicated that economic yield responses can be obtained when fungicides are applied to suppress sheath blight. Although the four fields selected had sheath blight levels greater than the threshold established for Lemont rice, (10% at 1/2-in. IE and 10 days later) (Cloud et al., 1992), economic returns from fungicide applications were measured on only two of the fields tested. The inconsistent results in economic returns indicate that a number of factors influence sheath blight development, including high temperatures, humid conditions, high nitrogen fertilizer levels, thick stands of rice and susceptible rice varieties. The fields that showed significant yield increases from fungicide treatments had high levels of sheath blight early in the season, thick stands of rice and optimum weather conditions for sheath blight.

The lack of consistent economic returns to growers from fungicide applications could also be the result of the inability to predict yield losses based on sheath blight levels at 1/2-in. IE. Results from this study indicated a strong correlation between sheath blight levels and yield loss 20 to 30 days after 1/2-in. IE. Similar results have been reported by other researchers (Fox and Moore, personal communications). Currently, we use the +/- method to assess sheath blight levels in rice production fields. This method did not provide a significant correlation with yield loss at any rating date or location. The percentage of tillers infected method did provide a significant correlation with yield loss at specific rating dates. Further research is required under more controlled conditions to develop a scouting procedure to accurately assess sheath blight levels in rice production fields and specifically determine more accurate sheath blight thresholds for each of the three categories of rice varieties to trigger fungicide applications.

The lack of consistent results from fungicides to suppress sheath blight and provide an economic return could result from the current method of fungicide application, agricultural aircraft, which could be minimizing fungicide penetration into the canopy and coverage of the plant. Hollier and Groth (1991) reported that fungicides applied with agricultural aircraft at the recommended growth stages resulted in the upper third of the rice canopy collecting the majority of the fungicides. During this period of time, sheath blight resides in the lower third of the rice canopy, which is outside the fungicide treated area. This lack of adequate plant coverage could result in a reduction in the efficacy of fungicides to suppress sheath blight.

Improvements in scouting procedures, estimation of accurate sheath blight thresholds and improvement in the method of application are needed to increase the probability economic returns will result from fungicide applications.

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Table 1. Fungicide rates and timing of application used in the large-block and small plot fungicide trials.

Fungicide[z]	Formulated Rate/acre	Timing of Application[y]
Tilt 3.6EC (Ciba)	6.0 fl oz	1/2-in. IE fb 10 days later
Tilt 3.6EC (Ciba)	10.0 fl oz	1/2-in. IE
Benlate 50WP (DuPont)	1.0 lb	1/2-in. IE fb 10 days later
Benlate 50WP (DuPont)	1.5 lb	1/2-in. IE fb 10 days later
Rovral 4F (Rhone Poulenc)	1.0 pt	1/2-in. IE fb 10 days later

[z]not all fungicide treatments were incorporated in all of the large block fungicide trials. Refer to individual test sites for specific fungicide treatments.
[y]fb (followed by) refers to the timing of the second fungicide application.

Table 2. Foliar sheath blight ratings in response to various foliar fungicide applications in large-block fungicide tests at Armstrong Farm, Chicot County, 1993.

Fungicide Treatment	1[z]	2	3	4
+/- rating				
Untreated	77%a	82%a	88%a	92%a
Tilt 3.6EC (6 +6)	62%a	70%a	74%a	76%a
Benlate 50WP (1.5 + 1.5)	69%a	87%a	88%a	89%a
Rovral 4F (1.0 + 1.0)	60%a	66%a	68%a	76%a
% Tillers				
Untreated	14.5%a	15.4%a	32.4%a	56.1%a
Tilt 3.6EC (6 + 6)	11.7%a	26.0%a	28.0%a	37.5%b
Benlate 50WP (1.5 + 1.5)	14.5%a	30.8%a	39.0%a	39.5%b
Rovral 4F (1.0 + 1.0)	15.6%a	22.2%a	22.2%a	40.1%b
0-9 rating				
Untreated	1a	2a	3.8a	5.3a
Tilt 3.6EC (6 + 6)	1a	2a	2.3a	5.3a
Benlate 50WP (1.5 + 1.5)	2a	3a	4.3a	5.6a
Rovral 4F (1.0 + 1.0)	1a	2a	2.6ab	6.0a

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

Table 3. The effect of various fungicide treatments on Lemont yield (bu/acre) and milling quality in a large-block fungicide test in Lemont rice at Armstrong Farm, Chicot County, 1993.

Fungicide Treatment	Yield[z] bu/acre	Milling Yield[b]
Untreated	135.9b	49/66
Tilt 3.6EC (6 + 6)	146.3a	52/66
Benlate 50WP (1.5 + 1.5)	148.4a	50/66
Rovral 4F (1.0 + 1.0)	144.8a	51/66

[z]Numbers in a column followed by the same letter are not significantly different ($P = 0.05$).
[y]Head rice/total milling yields in percentage.

Table 4. Economic response of foliar fungicide applications used to suppress sheath blight in large-block fungicide tests with Lemont rice at Armstrong Farm, Chicot County, 1993.

Fungicide Treatment	Yield[z] Increase	Total Net[y] Return
Untreated	—	—
Tilt 3.6EC (6 + 6)	$56.05 (10.4)	$18.88
Benlate 50WP (1.5 + 1.5)	$67.37 (12.5)	$10.74
Rovral 4F (1.0 + 1.0)	$47.97 (8.9)	$6.50

[z]Value of yield increase based on rice price/bu = $5.39 with bu/acre in parentheses.
[y]Total net return is the fungicide cost and fungicide application cost subtracted from the total gross return.

Table 5. Foliar sheath blight ratings in response to various foliar fungicide applications in large-block fungicide tests at Feather Farm #1, White County, 1993.

Fungicide Treatment	1	2	3	4
+/- rating				
Untreated	40%a	56%a	76%a	100%a
Tilt 3.6EC (6 + 6)	33%a	42%a	77%a	90%a
Tilt 3.6EC (10 oz)	43%a	46%a	80%a	95%a
Benlate 50WP (1.5 + 1.5)	40%a	66%a	80%a	85%a
Rovral 4F (1.0 + 1.0)	30%a	60%a	90%a	95%a
% Tillers				
Untreated	6.5%a	11.4%a	12.3%a	33.5%a
Tilt 3.6EC (6 + 6)	2.4%b	3.8%b	17.3%a	21.6%b
Tilt 3.6EC (10 oz)	2.7%b	3.2%b	11.8%a	18.6%b
Benlate 50WP (1.5 + 1.5)	2.8%b	3.9%b	10.8%a	11.5%b
Rovral 4F (1.0 + 1.0)	1.2%b	4.0%b	26.3%a	31.6%a
0-9 rating				
Untreated	1a	1.3a	5.8a	7.3a
Tilt 3.6EC (6 + 6)	1a	0.6a	2.3b	4.5b
Tilt 3.6EC (10 oz)	1a	1.3a	3.3b	5.3b
Benlate 50WP (1.5 + 1.5)	1a	1.6a	3.0b	4.8b
Rovral 4F (1.0 + 1.0)	1a	1.6a	3.6b	4.4b

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

Table 6. The effect of various fungicide treatments on Lemont grain yield (bu/acre) and milling yields (percentage) in a large=block fungicide test in Lemont rice at Feather Farm #1, White County, 1993.

Fungicide Treatment	Yield[z] (bu/acre)	Milling Yield[b]
Untreated	134.0a	53/67
Tilt 3.6EC (6 + 6)	148.5b	50/68
Tilt 3.6EC (10 oz)	151.0b	51/68
Benlate 50WP (1.5 + 1.5)	150.5b	52/69
Rovral 4F (1.0 + 1.0)	153.6b	52/67

[z]Numbers in a column followed by the same letter are not significantly different ($P = 0.05$).
[y]Head rice/total milling yields in percentage.

Table 7. Economic response of foliar fungicide applications used to suppress sheath blight in large-block fungicide tests with Lemont rice at Feather Farm #1, White Count, 1993.

Fungicide Treatment	Yield[z] Increase/acre	Total Net[y] Return/acre
Untreated	----	----
Tilt 3.6EC (6 + 6)	$78.15 (14.5)	$49.57
Tilt 3.6EC (10 oz)	$91.63 (17.0)	$53.29
Benlate 50WP (1.5 + 1.5)	$88.93 (16.5)	$32.42
Rovral 4F (1.0 + 1.0)	$105.64 (19.6)	$63.45

[z]Value of yield increase based on rice price/bu = $5.39 and bu/acre increase in parentheses.
[y]Total net return is the fungicide cost and fungicide application cost subtracted from the total gross return.

Table 8. The effect of various fungicide treatments on Lemont grain yield (bu/acre) and milling yield (percentage) in a large-block fungicide test in Lemont rice at Mascagnia Farm, Chicot County, 1993.

Fungicide Treatment	Yield[z] (bu/acre)	Milling Yield[b]
Untreated	168.6a	57/67
Tilt 3.6EC (10 oz)	169.4a	56/66
Benlate 50WP (1.5 + 1.5)	171.0a	55/67
Rovral 4F (1.0 + 1.0)	172.3a	56/67

[z]Numbers in a row followed by the same letter are not significantly different (P = 0.05).
[y]Head rice/total milled rice yield in percentage.

Table 9. The effect of various fungicide treatments on Lemont grain yield (bu/acre) and milling yield (percentage) in large-block fungicide tests at Feather Farm #2, White County, 1993.

Fungicide Treatment	Yield[z] (bu/acre)	Milling Yield[b]
Untreated	150.5a	51/67
Tilt 3.6EC (6 + 6)	145.9a	52/66
Tilt 3.6EC (10 oz)	150.7a	49/67
Benlate 50WP (1.5 + 1.5)	149.8a	50/66
Rovral 4F (1.0 + 1.0)	147.7a	53/67

[z]Numbers in a column followed by the same letter are not significantly different (P = 0.05).
[y]Head rice/total milled rice yield in percentage.

Table 10. Foliar sheath blight ratings in response to various foliar fungicide applications in the small-plot fungicide test in Lemont rice at Buckshot Farm, Jefferson County, 1993.

Fungicide Treatment	1[z]	2	3	4
Untreated	1[y]	3	6	7
Tilt 3.6EC (6 + 6)	1	2	4	4
Tilt 3.6EC (10 oz)	2	2	3	4
Benlate 50WP (1.0 + 1.0)	2	3	3	3
Benlate 50WP (1.5 + 1.5)	1	2	3	3
Rovral 4F (1.0 +1.0)	1	2	3	4

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

[y]0-9 foliar rating (0 = no disease; 9 = disease symptoms on the head).

Table 11. The effect of various fungicide treatments on Lemont grain yield (bu/acre) and milling yields (percentage) in small-plot fungicide tests at Buckshot Farms, Jefferson County, 1993.

Fungicide Treatment	Yield[z] (bu/acre)	Milling Yield[b]
Untreated	88.9cde	56/69
Tilt 3.6EC (6 + 6)	86.0de	48/69
Tilt 3.6EC (10)	109.7ab	52/69
Benlate 50WP (1.0 + 1.0)	107.4ab	60/71
Benlate 50WP (1.5 + 1.5)	120.9a	56/69
Rovral 4F (1.0 + 1.0)	112.5ab	60/71

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

[y]Head rice/total milled rice yield in percentage.

Table 12. Foliar sheath blight ratings in response to various foliar fungicide applications in small-plot fungicide tests at McNeil Farm, Lonoke County, 1993.

Fungicide Treatment	1[z]	2	3	4
Untreated	1[z]	1	3	3
Tilt 3.6EC (6 + 6)	1	1	1	2
Tilt 3.6EC (10)	1	1	1	1
Benlate 50WP (1.0 + 1.0)	1	1	1	3
Benlate 50WP (1.5 +1.5)	1	2	3	3
Rovral 4F (1.0 + 1.0)	1	1	2	2

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

[y]0 - 9 foliar rating (0 = no disease; 9 = disease symptoms on the head).

Table 13. The effect of various fungicide treatments on Lemont grain yield (bu/acre) in the small-plot fungicide test at McNeil Farms, Lonoke County, 1993.

Fungicide Treatment	Yield[z] (bu/acre)
Untreated	98.0b
Tilt 3.6EC (6 + 6)	113.6a
Tilt 3.6EC (10 oz)	118.3a
Benlate 50WP (1.0 + 1.0)	105.5a
Benlate 50WP (1.5 +1.5)	110.3a
Rovral 4F (1.0 + 1.0)	104.1ab

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

RICE CULTURE

MANAGEMENT OF AGRONOMIC FACTORS IN RICE PRODUCTION

1. *GRAIN YIELD RESPONSE OF 'ADAIR', 'BENGAL', 'CYPRESS', 'LAGRUE' AND SEVERAL EXPERIMENTAL RICE LINES TO NITROGEN FERTILIZATION*

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

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. Nitrogen fertilizer rates ranging from 0 to 180 lb N/acre are applied in a single preflood (SPF) application and in the conventional three-way-split (3WS) application. The SPF application was added in 1993 to the study because the cultivars released over the past decade have responded better when most of the N fertilizer was applied preflood. In general, the rice cultivars studied in 1993 responded equally well or better when the N fertilizer was applied in a SPF application compared to a 3WS application. Rice cultivar 'Adair' reached top grain yields when 90 to 120 lb N/acre was applied in a SPF application and when 120 to 150 lb N/acre was applied in a 3WS application. 'Bengal' generally required 120 to 150 lb N/acre to reach top grain yields at all locations and responded better to the SPF application at two locations and similarly to both application methods at the other locations. 'Cypress' usually required 120 to 150 lb N/acre to reach top grain yields at all locations and at most locations responded similarly to the SPF and 3WS application methods. In both years of study, across all locations, 'LaGrue' showed a preference for the 120-lb N/acre rate and preferred the SPF to the 3WS application

when they were compared in 1993. The four experimental rice lines, studied at only select locations in 1993, generally preferred the SPF to the 3WS application.

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 an 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 cultivars Adair and LaGrue, plus two experimental rice lines, RU9101142 and RU9101133, in the study. Adair and LaGrue are in their second year of testing. Two new semidwarf cultivars, Bengal and Cypress, out of the Louisiana program, are in their second year of study. Bengal is a medium-grain and Cypress is a long-grain type. In addition, Louisiana has two long-grain, semidwarf experimental lines, RU8902031 and RU9102085, in the study this year.

PROCEDURES

Locations and corresponding soil series for the studies 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).

In 1992, the experimental design was a randomized complete block with five replications. The N fertilizer rates were 0, 60, 90, 120, 150 and 180 lb N/acre applied as urea in three split applications (i.e., preflood, 1/2-in. internode elongation and 10 days after 1/2-in. internode elongation. The two experimental semidwarfs received an additional N rate of 210 lb N/acre.

In 1993, 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 and the recommended three-way split application 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. Weed control was achieved with standard herbicide practices. 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, unless previous history at a site required draining and drying for control of straighthead. No sites required draining in 1992 or 1993. At maturity, 12 ft. of the center four rows of each plot were harvested with a small combine, 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 protected LSD where appropriate.

RESULTS AND DISCUSSION

Rice cultivars released over the past decade have generally required more N fertilizer than their predecessors and have responded better when most of the N fertilizer is applied preflood. In addition, some of the cultivars appeared to respond similarly or better when the N fertilizer was applied in an SPF application compared to the traditional 3WS application. The response of the new cultivars to the preflood N fertilization resulted in the addition of a SPF N application in the rice cultivar x nitrogen study in 1993. Only the traditional 3WS application method was used in 1992.

Adair produced excellent grain yields at all locations in 1992 when 120 to 150 lb N/acre was applied in a 3WS application (Table 1). In 1993, Adair reached top grain yields when 90 to 120 lb N/acre was applied in a SPF or when 120 to 150 lb N/acre was applied in a 3WS application (Table 2). Adair reached top grain yields at RREC and SEBES with a smaller amount of N fertilizer when it was applied in a SPF application. Similarly, Adair had higher grain yields at NEREC in 1993 when the N fertilizer was applied in a SPF application compared to a 3WS application (Table 3). Only at PTES did Adair respond better to a 3WS application.

Bengal, the only medium-grain rice cultivar in the study, showed no significant grain yield increases in 1992 at any of the locations when more than 120 lb N/acre was applied in a 3WS application (Table 4). There were trends towards higher yields at three of the four locations when 150 to 180 lb N/acre was applied. In 1993, Bengal responded significantly better to a SPF than a 3WS N application at RREC and PTES at the 60-lb N/acre rate and at RREC at the 90-lb N/acre rate (Table 5). Bengal responded similarly when N was applied in SPF or 3WS application at SEBES and NEREC in 1993 (Table 6). No significant grain yield increases were observed when more than 120 lb N/acre was applied at NEREC, although at SEBES significant yield increases were evident up to 180 lb N/acre.

Cypress showed no significant grain yield increases when more than 90 lb N/acre was applied at PTES and when more than 120 lb N/acre was applied as 3WS at NEREC, RREC and SEBES in 1992 (Table 7). In 1993, Cypress showed no significant grain yield increases when more than 120 lb N/acre was applied at NEREC, PTES or RREC (Table 8). In addition, there were no significant grain yield differences at these locations when the N fertilizer was applied in a SPF application compared to a 3WS application. Conversely, Cypress responded better to the N fertilizer applied in a SPF application at SEBES in 1993. No significant yield increases were found with the SPF application when more than 120 lb N/acre was applied at SEBES, and this yield was comparable to that obtained with the 3WS application when 150 lb N/acre was applied.

LaGrue displayed no significant grain yield increases at any of the locations in 1992 when more than 120 lb N/acre was applied in a 3WS application (Table 9). In 1993, LaGrue responded better to the N fertilizer applied in a SPF application at PTES, RREC and SEBES (Table 10). No significant yield increases were found when more than 90 lb N/acre was applied SPF at PTES and RREC and when more than 120 lb N/acre was applied at SEBES. LaGrue responded similarly to the two N application methods at NEREC and showed no significant grain yield increases when more than 150 lb N/acre was applied (Table 11).

There was enough available seed to study Arkansas experimental rice line RU9101142 at only two locations in 1993 (Table 12). Rice line RU9101142 responded better to the N fertilizer applied in a SPF application compared to the 3WS application. No significant yield increases were found with line RU9101142 when more than 120 lb N/acre was applied in a SPF application at RREC and when more than 150 lb N/acre was applied SPF at SEBES. Arkansas experimental rice line RU9101133 had enough seed available to be tested at only one location in 1993 and responded similarly with both application methods (Table 13). Louisiana experimental rice lines RU8902031 and RU9102085 were able to be tested only at RREC in 1993 due to the small amount of seed available (Table 14). Both of these rice lines responded numerically better to the SPF N application and had top numerical yields at the 120-lb N/acre rate.

SIGNIFICANCE OF FINDINGS

Cultivars released over the past decade have responded better when most of the N fertilizer was applied preflood. Consequently, a single preflood application was added in 1993 to the N fertilizer response study to compare to the conventional three-way split application. All of the cultivars studied in 1993, Adair, Bengal, Cypress, LaGrue and the four experimental rice lines, showed at least equal and in most cases higher grain yields when the N fertilizer was applied in a single preflood application compared to the three-way split application. These data, along with other data collected over the past several years, indicate that there should be a gradual shift from the conventional three-way-split application to a single preflood application if the full yield potential of the new cultivars is to be realized. In general, all of the cultivars studied obtained top grain yields when 120 to 150 lb N/acre were applied.

Table 1. Grain yield of 'Adair' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

N rate	NEREC[z]	PTES	RREC	SEBES
lb N/acre	lb/acre			
0	2735	5154	—	3101
60	5553	6971	—	4556
90	7114	7645	—	6369
120	7902	7796	—	8209
150	8249	8571	—	8516
180	8331	7853	—	6416
LSD 0.05	616	667	—	719

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

Table 2. Grain yield of 'Adair' rice as influenced by nitrogen (N) fertilizer rate, application method and location in 1993.

	PTES[z]		RREC		SEBES	
N rate	SPF[y]	3WS	SPF	3WS	SPF	3WS
lb N/acre	lb/acre					
0	4695	4069	2435	2252	2669	2768
60	6448	5914	6043	4060	4903	4028
90	6409	6804	7277	6361	6221	4765
120	6920	7514	6602	6379	7522	6029
150	6640	7518	5500	7461	7543	7450
180	6328	6899	6019	6934	7527	7873
LSD w/In[x] Mainplot	756		956		1183	
LSD Between Mainplots	534		880		1234	

[z]PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas.
[y]SPF = single preflood; 3WS = three-way split
[x]LSD's at 0.05 level of probability.

Table 3. Grain yield of 'Adair' rice as influenced by nitrogen (N) fertilizer rate and application method at the Northeast Research and Extension Center, Keiser, Arkansas, 1993.

Application method	Grain yield	N rate	Grain Yield
	lb/acre	lb N/acre	lb/acre
Single Preflood	5766	0	2630
		60	4535
3-way Split	5394	90	5671
		120	6666
LSD 0.05	255	150	6870
		180	7107
		LSD 0.05	533

Table 4. Grain yield of 'Bengal' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

N rate	NEREC[z]	PTES	RREC	SEBES
lb N/acre	lb/acre			
0	3831	5083	3900	3127
60	6211	7022	4811	6647
90	6969	7228	5768	7803
120	7937	8162	6400	8939
150	8145	8330	6554	9349
180	8543	8512	6256	8737
210	8474	8738	6306	8322
LSD 0.05	801	617	503	903

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

Table 5. Grain yield of 'Bengal' rice as influenced by nitrogen (N) fertilizer rate, application method and location in 1993.

	PTES[z]		RREC	
N rate	SPF[y]	3WS	SPF	3WS
lb N/acre	lb/acre			
0	4821	4222	2273	2642
60	6973	5640	6377	4621
90	6775	6626	7028	5651
120	7584	7166	7145	6775
150	6713	7236	7160	7070
180	6600	6862	6922	7209
LSD w/in[x] Mainplot	755		1227	
LSD Between Mainplot	731		1176	

[z]PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas.
[y]SPF = single preflood; 3WS = three-way split.
[x]LSD's at 0.05 level of probability.

Table 6. Grain yield of 'Bengal' rice as influenced by nitrogen (N) fertilizer rate, application method[z] and location in 1993.

N rate	NEREC[y]	SEBES
lb N/acre	----lb/acre----	
0	1808	2095
60	5099	4628
90	6047	5428
120	6986	6685
150	7281	7228
180	7523	8397
LSD 0.05	565	898

[z]No significant difference between the two application methods at these locations.
[y]NEREC = Northeast Research and Extension Center, Keiser, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas.

Table 7. Grain yield of 'Cypress' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

N rate	NEREC[z]	PTES	RREC	SEBES
lb N/acre	----lb/acre----			
0	3211	5033	2861	3643
60	5587	6609	4188	5540
90	6485	7214	3993	6030
120	7585	7399	4913	6362
150	7655	7324	5651	7139
180	7468	7190	6125	7532
210	6538	7330	5324	6720
LSD 0.05	775	803	1104	1162

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

Table 8. Grain yield of 'Cypress' rice as influenced by nitrogen (N) fertilizer rate, application method and location in 1993.

				SEBES[y]	
N rate	NEREC[z]	PTES	RREC	SPF[x]	3WS
lb N/acre	----lb/acre----				
0	1928	4077	2245	1854	1718
60	4309	5390	4859	5886	3608
90	5569	5541	5938	5904	4614
120	6262	5993	6665	7398	5543
150	6638	6375	6967	7519	6908
180	6201	5948	7054	7464	8038
LSD 0.05	534	412	609	1190[w]	1230[v]

[z]NEREC = Northeast Research and Extension Center, Keiser, Arkansas; PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas.
[y]The application methods were significantly different only at SEBES.
[x]SPF = single preflood; 3WS - three-way split
[w]LSD for comparing within an application method.
[v]LSD for comparing between application methods.

Table 9. Grain yield of 'LaGrue' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

N rate	NEREC[z]	PTES	RREC	SEBES
lb N/acre		lb/acre		
0	3048	4450	—	2997
60	5690	5869	—	5412
90	7349	6630	—	7117
120	8376	7324	—	8458
150	8317	7711	—	8914
180	8261	7579	—	7771
LSD 0.05	662	726	—	810

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

Table 10. Grain yield of 'LaGrue' rice as influenced by nitrogen (N) fertilizer rate, application method and location in 1993.

	PTES[z]		RREC		SEBES	
N rate	SPF[y]	3WS	SPF	3WS	SPF	3WS
lb N/acre			lb/acre			
0	4536	4482	2120	2269	2352	2402
60	6273	6492	6828	5327	5773	3806
90	7487	6566	7098	5564	6989	4696
120	6951	6879	6618	6782	8018	6105
150	6528	7180	6783	7270	7982	7244
180	5629	6932	5691	7119	8575	8736
LSD w/In[x] Mainplot	688		1111		1190	
LSD Between Mainplots	712		1040		1230	

[z]PTES = Pine Tree Experiment Station, Colt, Arkansas; RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas.
[y]SPF = single preflood; 3WS = three-way split
[x]LSD's at 0.05 level of probability.

Table 11. Grain yield of 'LaGrue' rice as influenced by nitrogen (N) fertilizer rate and application method at the Northeast Research and Extension Center, Keiser, Arkansas, 1993.[z]

N rate	Grain yield
lb N/acre	lb/acre
0	2506
60	4274
90	5273
120	5294
150	6969
180	6687
LSD 0.05	1544

[z]No significant difference between the two application methods at this location.

Table 12. Grain yield of Arkansas experimental rice line RU9101142 as influenced by nitrogen (N) fertilizer rate, application method and location in 1993.

	RREC[z]		SEBES[y]	
N rate	SPF[x]	3WS	SPF	3WS
lb N/acre	lb/acre			
0	1154	1438	907	1198
60	4957	3481	3577	2349
90	5816	4322	5039	3540
120	7023	5458	6052	4464
150	6828	6953	7058	6152
180	6806	6882	7416	6107
LSD w/in[w] Mainplot	860		717	
LSD Between Mainplot	806		836	

[z]RREC = Rice Research and Extension Center, Stuttgart, Arkansas; SEBES = Southeast Branch Experiment Station, Rohwer, Arkansas.
[y]Mainplot means (LSD 0.05 =3.58 lb/acre): SPF = 5447 lb/acre > 3WS = 4756 lb/acre.
[x]SPF = single preflood; 3WS - three-way split
[w]LSD's at 0.05 level of probability.

Table 13. Grain yield of Arkansas experimental rice line RU9101133 as influenced by nitrogen (N) fertilizer rate and application methods at the Rice Research and Extension Center, Stuttgart, Arkansas, 1993.

N rate	Grain yield[z]
lb N/acre	lb/acre
0	1570
60	3434
90	4721
120	5853
150	6383
180	6538
LSD 0.05	963

[z]No significant difference between the two application methods (SPF = 3WS).

Table 14. Grain yield of Louisiana experimental rice lines RU8902031 and RU9102085 as influenced by nitrogen (N) fertilizer rate and application method at the Rice Research and Extension Center, Stuttgart, Arkansas, 1993.

	RU8902031		RU9102085	
N rate	SPF[z]	3WS	SPF	3WS
lb N/acre	lb/acre			
0	2314	2211	1637	1745
60	6948	4788	4677	3624
90	7034	6165	5316	5522
120	7276	6388	6859	5068
150	6633	7131	6201	6018
180	5785	6592	6869	6750
LSD w/in[y] Mainplot	1003		1420	
LSD Between Mainplot	1010		1686	

[z]SPF = single preflood; 3WS = three-way split.
[y]LSD's at 0.05 level of probability.

MANAGEMENT OF AGRONOMIC FACTORS IN RICE PRODUCTION

2. INFLUENCE OF SPLIT APPLYING THE PREFLOOD NITROGEN FERTILIZER ON RICE GROWTH AND ACCUMULATION AND PARTITIONING OF NITROGEN BY THE RICE PLANT

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ABSTRACT

Uniform application of the preflood nitrogen (N) fertilizer continues to be a problem for Arkansas rice farmers; therefore, studies were conducted to evaluate alternate N application methods. Additional studies were conducted to gain knowledge on N uptake, partitioning and loss from the rice plant. Results of a two-year study on the influence of split applying the preflood N on rice growth showed that highest fertilizer N uptake was achieved when the fertilizer N was applied at preflood (71-80%), followed in decreasing order by fertilizer N applied at preflush (38-57%), preplant (17-40%) and postflood (13-40%). The higher fertilizer N uptake and grain yield achieved when the fertilizer N was applied preflood indicates that the grower and applicator should make every effort to apply the fertilizer N at preflood. The only split application method that resulted in grain yields comparable to the single preflood application in both years of the study was when one-fourth was applied at preflush and three-fourths at preflood. Split applying one-fourth of the preflood N at preplant or postflood resulted in a yield decrease in one of the two years of study. When one-half of the preflood N was split applied at preplant, preflush or postflood, a yield decrease always resulted.

According to the second study on the accumulation and partitioning of N by the rice plant, the uptake and subsequent loss of N from the rice plant during the reproductive, grain filling and maturation growth

stages can vary from 5 to 25% of the applied fertilizer N. When the native soil N lost is added to the fertilizer N lost, the overall loss from the rice plant can be as great as 60 lb N/acre/year. The N loss from the rice plant varied among cultivars and increased as N rate and temperature increased.

INTRODUCTION

The central focus of this project is to study the influence of nitrogen (N) from fertilizers, crop residues and soils on rice growth and grain yield. The high preflood N rates required by the new rice cultivars to obtain optimum yields are difficult to broadcast evenly by aerial applicators. Producers have questioned if they can split apply some of the preflood N fertilizer preplant, preflush or postflood without suffering a detrimental loss in fertilizer N uptake and grain yield by rice. Results are reported from a two-year study on the fertilizer N uptake and grain yield of rice when a portion of the preflood N fertilizer is split applied at preplant, preflush or postflood.

Basic understanding of how the rice plant accumulates and partitions N from fertilizer and soil is useful in planning future N fertilizer application and management strategies in rice as well as in breeding more N-efficient cultivars. The second study on the accumulation and partitioning of N in the rice plant using the isotopic tracer ^{15}N has found some interesting results on the transfer of N to the panicle and the loss of N from the rice foliage.

PROCEDURES

The two-year study (1991 and 1992) on the influence of split applying the preflood N application on fertilizer N uptake and grain yields of 'Lemont' rice was conducted at the Rice Research and Extension Center, Stuttgart, Arkansas (RREC), on a Crowley silt loam. Urea labeled with ^{15}N was applied at a rate of 120 lb N/acre in a single preflood or preplant application and in a variety of split applications in which a portion of the preflood N was applied at preplant, preflush or postflood. Preplant fertilizer N was applied about four weeks prior to flooding, preflush N about two weeks prior to flooding, preflood N the day prior to flooding and postflood N one and two weeks after flooding. Measurement parameters reported are fertilizer ^{15}N uptake and rice grain yield. A randomized complete block design with four replications was utilized.

Research on the accumulation and partitioning of N by the rice plant involved three separate tests and was conducted at RREC on a

Crowley silt loam. Urea labeled with ^{15}N was applied in two split applications at 80, 120, 160 and 200 lb N/acre in one study, and in the other two studies the preflood N (120 lb N/acre) and the midseason N (45 lb N/acre) accumulation were monitored separately with ^{15}N. The preflood and midseason N uptake and the partitioning to the stems, sheaths, leaves and panicles were monitored several times during the season to measure the accumulation and translocation of the N in the rice plant. Three cultivars, 'Newbonnet', Lemont and 'Lebonnet', were used in the studies because they represent the types of rice cultivars grown in Arkansas. Measurement parameters included total dry matter, N fertilizer and total N uptake in individual plant parts and total plant. Split-plot and randomized complete block experimental designs were used.

RESULTS AND DISCUSSION

Results from a two-year study on the influence of split applying the preflood N on rice growth showed that when some of the preflood N is split applied preplant, preflush or postflood, there is a significant chance that rice grain yields will suffer (Table 1). Highest fertilizer N uptake was achieved when the fertilizer N was applied at preflood (71-80%), followed in decreasing order by fertilizer N applied at preflush (38-57%), preplant (17-40%) and postflood (13-40%). The higher fertilizer N uptake and grain yield achieved when the fertilizer N was applied preflood indicates that the grower and applicator should make every effort to evenly apply the fertilizer N at preflood. This can be achieved by reducing the rate and swath width by one-half, allowing for a more even distribution of the same total rate of N. The only split application method that resulted in grain yields comparable to the single preflood application in both years of the study was when one-fourth was applied at preflush and three-fourths at preflood. The split application methods that resulted in yields comparable to the single preflood application in one of the two years of the study was when one-fourth was applied at preplant or postflood and three-fourths at preflood. When one-half of the preflood N was applied preplant, preflush or postflood, grain yields always declined significantly compared to the single preflood application. Consequently, the preflood fertilizer N should be split only when absolutely necessary, and at least three-fourths of the fertilizer allotted for preflood should be applied at preflood.

The second study on the accumulation and partitioning of ^{15}N-labeled urea by the rice plant indicated that fertilizer ^{15}N uptake from the preflood N application increased until 21 d after application, at which time it peaked at 62% of the applied N; there was no significant difference between years; thus the years were combined (Table 2). The fertilizer ^{15}N in the rice plant from the preflood N application stayed relatively constant from 21 d after application until heading + 21 d then decreased from 60 to 52% by maturity.

When fertilizer ^{15}N was applied at midseason, maximum fertilizer ^{15}N uptake (74% of the applied N) was observed at the first sampling, 7 d after application (Table 3). Contrary to the preflood N application, the amount of fertilizer ^{15}N in the rice plant from the midseason application began to decrease as the rice plant approached heading and decreased further during grain filling. The fertilizer ^{15}N in the rice plant had decreased from a maximum of 74% of the applied N at 7 d after application to only 56% of the applied N by maturity.

Variability in the decline of fertilizer ^{15}N recovery by the rice plant between panicle differentiation and maturity is also evident in other studies. Norman et al. (1992) found that the percentage of preflood fertilizer ^{15}N in Lebonnet and Lemont rice plants reached a maximum of 79% of the applied N at 28 d after application, decreased to 67% by heading and decreased further to only 54% at maturity. In the current study, the preflood fertilizer ^{15}N stayed relatively constant in the Newbonnet rice plants at ~ 60% of the applied N until heading + 21 d, and then decreased to 52% at maturity (Table 2). Wilson et al. (1989) found only a decreasing trend in the amount of preflood and midseason fertilizer ^{15}N accumulated in Newbonnet rice plants between panicle differentiation and maturity. When N was applied in split applications (Norman et al., 1992), the percentage of fertilizer ^{15}N in the rice plants (i.e., Lebonnet and Lemont) reached a maximum of 72% at 14 d prior to heading, decreased to 65% by heading and decreased further to 54% by maturity. This is similar to what we found in this study with the midseason fertilizer ^{15}N accumulation. Guindo et al. (1994) found that the loss of fertilizer ^{15}N from the Lebonnet and Lemont cultivars increased as fertilizer N rate increased, varied between cultivars and was more pronounced the year that had the highest temperatures during grain filling.

Although the magnitude of the loss of fertilizer ^{15}N from the rice plant is variable, the loss can be as great as 25% of the fertilizer ^{15}N applied or 30 lb N/acre (Norman et al., 1992). In addition, the fertilizer N usually constitutes about one-half of the total N accumulated by the rice plant, and nonlabeled native soil N is lost along with the fertilizer ^{15}N. Consequently, the total N loss from the rice plant could be twice as great as the fertilizer ^{15}N loss or as much as 60 lb N/acre.

The impact of the loss of N from the rice plant on grain yield is unclear and deserves further study. What is clear, however, is that the rice plant should be sampled no later than heading to insure measurement of maximum fertilizer N uptake by rice when ^{15}N is used. It would be prudent to sample the rice plant at panicle differentiation when measuring uptake of preplant and preflood N applications and between 7 and 14 d after the midseason N application when measuring uptake of N applied at midseason or in split applications.

Panicle dry matter increased between heading + 21 d and maturity with both the preflood and midseason N application (Table 4). Total N and fertilizer ^{15}N in the panicle did not differ between heading + 21 d and maturity with the preflood application. Total N accumulation in the panicle did not differ between years (data not shown); however, the percentage of fertilizer ^{15}N recovered in the rice panicles in 1991 was higher than that in 1990 (32 and 29%, respectively; LSD = 2.8% at P = 0.05). This difference suggests an influence of climate or environment on fertilizer N accumulation.

However, the total N in the whole plant and the percentage of fertilizer ^{15}N in the whole plant and panicle from the midseason ^{15}N application remained constant (Tables 3 and 4). This appears to indicate that the total N accumulation in the panicle between heading + 21 d and maturity was derived from the uptake of native soil N and from N remobilized and translocated from vegetative tissues whereas the fertilizer ^{15}N in the panicle was solely derived from the translocation of fertilizer ^{15}N from vegetative tissues. The harvest indices for total N and fertilizer ^{15}N support these suggestions on translocation (Table 5). The harvest index at heading + 21 d was similar to that at maturity for total N; however, it was greater at maturity for fertilizer ^{15}N. Nitrogen harvest indices or translocation efficiencies should be interpreted with caution in light of the N loss from the plant.

SIGNIFICANCE OF FINDINGS

Results from a two-year study on the influence of split applying the preflood N on rice growth showed that the only split application method that resulted in grain yields comparable to the single preflood application in both years of the study was one-fourth applied at preflush and three-fourths at preflood. Split applying one-fourth of the preflood N at preplant or postflood resulted in a yield decrease in one of the two years of study. When one-half of the preflood N was split applied at preplant, preflush or postflood, a yield decrease always resulted. The second study on the accumulation and partitioning of N by the rice plant showed that the uptake and subsequent loss of N from the rice plant during the reproductive, grain filling and maturation growth stages can vary from 5 to 25% of the applied fertilizer N. When the native soil N lost is added to the fertilizer N lost, the overall loss can be as great as 60 lb N/acre from the rice plant per year. The N loss from the rice plant was found to vary among cultivars and increase as fertilizer N rate and temperature increased.

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Table 1. Influence of application time on early fertilizer nitrogen (N) uptake and rice grain yields

Fertilizer N application					Fertilizer N Uptake		Grain Yield	
			PostFlood[z]					
Preplant	Preflush	Preflood	1 wk	2 wk	1991	1992	1991	1992
lb/acre					%		bu/acre	
30*[y]		90			40	23	176	184
	30*	90			57	43	181	192
30		90*			80	72	179	187
60*		60			33	17	158	164
	60*	60			53	38	166	182
60		60*			78	75	160	167
120*					27	17	125	141
		120*			76	71	177	198
		90	30*		13	37	158	189
		90		30*	20	40	163	191
		60	60*		13	32	142	174
		60		60*	15	32	146	179
LSD (0.05)					9.8	8.7	9.6	10.2

[z]Postflood treatments applied into the water 1 and 2 weeks (wk) after flooding.
[y]Asterisk (*) indicates fertilizer N application monitored with the tracer ^{15}N.

Table 2. Total nitrogen (N) and fertilizer ^{15}N accumulation by 'Newbonnet' rice after fertilizer ^{15}N was applied in a single preflood application in.

Sampling Time[z]	Total N		Fertilizer ^{15}N
	1990	1991	1990-1991
	---g/m²---		% of applied
7 DAP	2.6	3.0	15
14 DAP	6.0	7.4	42
21 DAP	8.9	10.2	62
28 DAP	11.9	11.5	62
Hdg	13.6	13.4	61
Hdg+21D	16.6	14.0	60
Maturity	14.5	13.1	52

[z]DAP = days after preflood N application (12.7 g N/m² applied as ^{15}N-labeled urea). 7 DAP = tillering; 14 DAP = maximum tillering; 21 DAP = panicle initiation; 28 DAP = panicle differentiation; Hdg = heading (62 DAP); Hdg+21D = heading + 21 days (83 DAP).

Note: LSD (P = 0.05) to compare sampling times for total N within same year = 1.9; LSD (P = 0.05) to compare sampling times for total N in different years = 1.8; LSD (P = 0.05) to compare sampling times for fertilizer ^{15}N accumulation = 7.

Table 3. Total dry matter, total nitrogen (N) and fertilizer ^{15}N accumulation by 'Newbonnet' rice after fertilizer ^{15}N was applied at midseason in 1990.

Sampling Time[z]	Dry Matter	Total N	Fertilizer ^{15}N
	---g/m²---		% of applied
7 DAM[y]	678	11.4	74
14 DAM	935	14.3	72
21 DAM	1165	14.5	66
Hdg	1486	14.8	62
Hdg+10D	1567	15.1	62
Hdg+21D	2085	15.4	58
Maturity	2067	15.8	56
LSD (0.05)	144	2.4	11

[z]DAM = days after midseason N application (7.7 g N/m² as commercial-urea at preflood + 5.0 g N/m² as ^{15}N-labeled urea at panicle differentiation).

[y]7DAM = panicle differentiation (PD) plus 7 days; 14 DAM = PD + 14 days; 21 DAM = booting stage; Hdg = heading (35 DAM); Hdg+21D = heading + 21 days.

Table 4. Total dry matter, total nitrogen (N) and fertilizer ^{15}N accumulation in the 'Newbonnet' rice panicles as influenced by timing of fertilizer ^{15}N application.

Fertilizer ^{15}N Timing[z]	Sampling time[y]	Panicle Dry Matter	Panicle Total N	Panicle Fertilizer ^{15}N
		g/m²		% of applied N
Preflood	Hdg+21D	800	8.0	30
	Maturity	929	8.5	31
	LSD (0.05)	53	NS[x]	NS
Midseason	Hdg+21D	887	8.9	34
	Maturity	1045	10.6	39
	LSD (0.05)	58	1.4	NS

[z]Preflood N application = 12.7 g N/m² as ^{15}N-labeled urea (averaged across years); Midseason N application = 7.7 g N/m² as commercial urea at preflood + 5.0 g N/m² as 15N-labeled-urea at panicle differentiation in 1990.

[y]Hdg+21D = heading + 21 days.

[x]NS = non-significant at 5% probability level.

Table 5. Harvest index (HI) of total nitrogen (TN) and fertilizer ^{15}N (FN) as influenced by timing of fertilizer ^{15}N application.

Fertilizer ^{15}N Timing[y]	Sampling times[x]	HI[z] TN	HI[z] FN
Preflood	Hdg+21D	0.52	0.49
	Maturity	0.62	0.61
	LSD (0.05)	0.03	0.03
Midseason	Hdg+21D	0.58	0.58
	Maturity	0.67	0.71
	LSD (0.05)	NS[w]	0.02

[z]HI = ratio of panicle N content to whole plant N content.

[y]Preflood N application = 12.7 g N/m² as ^{15}N-labeled urea (averaged across years); Midseason N application = 7.7 g N/m² as commercial urea at preflood + 5.0 g N/m² as ^{15}N-labeled urea at panicle differentiation in 1990.

[x]Hdg+21D = heading + 21 days.

[w]NS = non-significant at 5% probability level.

DEVELOPMENT OF THE DD50 DATABASE FOR NEW RICE CULTIVARS

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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 gather development data for promising new lines. In 1993 the study, conducted on a Crowley silt loam at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas, included two seeding methods (drill and water), two seeding dates and three replicates. The drill-seeded study had 12 cultivars/lines whereas the water-seeded study contained seven of the most common cultivars. Data from this study were combined with data from previous years to formulate updated threshold values for the 1994 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 plant development based on accumulation of DD50 units from date of 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 in 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 were conducted in 1993 to add a water-seeded data base to the program.

MATERIALS AND METHODS

The 1993 study was conducted at the University of Arkansas Rice Research and Extension Center on a Crowley silt loam soil. Twelve cultivars/lines were seeded in the drill-seeded portion of the study on 19 April and 21 May. Seven cultivars were seeded on 23 April and 26 May in the water-seeded study. The drill-seeded rice was seeded at a rate of 100 lb/acre in nine-row plots (7-in. spacing), 15 ft in length. With water seeding, the soil was first grooved by running a drain drill over the plots (without seed) and then flooding the soil. Presoaked seed was broadcast into the flood water by hand. Emergence was defined as seedlings with a 0.5- to 1.0-in. coleoptile at the same population density as for drill-seeded rice. The "pin point" flooding system was used for weed control. Additionally, for the water-seeded study, the early-season N application was made just prior to the final seedbed preparation. 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. Cultivars included in both the drill- and water-seeded studies included 'Adair', 'Bengal', 'LaGrue', 'Alan', 'Katy', 'Orion' 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. Data collected included the following: maximum and minimum daily temperatures, length of elongating internodes at three-day intervals beginning 35 days after seeding emergence, date of 50% heading and grain yields at maturity adjusted to 12% moisture. The temperature data were then converted into DD50 accumulations from seedling emergence until the development stage of interest. Yield data were subjected to statistical analysis.

RESULTS AND DISCUSSION

Degree day accumulation from seedling emergence to internode elongation (0.5 in.) varied with cultivar and method of seeding (Table 1). Water seeding resulted in significantly lower accumulation of DD50 units from emergence to internode elongation for LaGrue, Maybelle and Katy with similar trends occurring for several of the other cultivars. This is likely the result of higher average temperatures at the growing point of the rice plant during seedling development where the flood is in place with the water-seeded rice but not for the drill-seeded rice.

Date of seeding had much less effect on DD50 accumulation as compared to method of seeding and cultivar.

Two cultivars, LaGrue and Maybelle, also required substantially fewer DD50 units from emergence to heading under water seeding as compared to drill seeding (Table 2). This effect was largely the result of fewer DD50 units needed between emergence and internode elongation since the DD50 accumulation between internode elongation and heading for the two cultivars was similar for drill and water seeding. The other five cultivars included in the water-seeded study showed only minor variation in the DD50 units accumulated between emergence and heading when compared to the drill-seeded rice.

LaGrue had the highest grain yields for the early seeding date and second highest for the late seeding date under drill-seeded conditions (Table 3). Under the water seeding system, Bengal had the highest yields when seeding was early whereas Adair had the highest yields for the late seeding date. 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 for the early date. This may have been the result of our limited experience with water seeding culture.

SIGNIFICANCE OF THE FINDINGS

Data from this study will be utilized to include thresholds for water seeding in the 1994 DD50 program. These will be tentative; however, it appears that only LaGrue and Maybelle thresholds will need appreciable modification to correct for water seeding as compared to drill seeding. Additional studies will be conducted in 1994 to verify the 1993 results and to extend the data base to additional cultivars. Additionally, RU9101142 (Kaybonnet) will be included in the 1994 DD50 program for drill-seeded rice.

Table 1. DD50 accumulations from emergence to internode elongation as influenced by cultivar, method of seeding and date of emergence, Rice Research and Extension Center, Stuttgart, Arkansas, 1993.

	Drill Seed		Water Seed	
Variety/Line	4 May	29 May	4 May	3 June
	DD50 units			
Adair	1320	1289	1121	1188
Bengal	1442	1383	1442	1220
LaGrue	1264	1289	1067	1096
RU9101145	1264	1383	--	--
RU9101133	1442	1551	--	--
Kaybonnet	1381	1415	--	--
RU9101185	1350	1415	--	--
RU9101179	1350	1415	--	--
Alan	1236	1289	1149	1188
Katy	1412	1511	1262	1282
Orion	1442	1479	1236	1410
Maybelle	1264	1289	1036	1125

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, 1993.

	Drill Seed		Water Seed	
Cultivar/Line	4 May	29 May	4 May	3 June
	DD50 units			
Adair	1942	2082	1942	1850
Bengal	2133	2109	2227	2130
LaGrue	2070	2139	1878	1820
RU9101145	2038	2231	--	--
RU9101133	2133	2231	--	--
Kaybonnet	2102	2139	--	--
RU9101185	2227	2261	--	--
RU9101179	2164	2291	--	--
Alan	1878	2057	1910	1850
Katy	2133	2261	2195	2098
Orion	2102	2139	2195	2160
Maybelle	1784	1890	1505	1538

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	
Cultivar/Line	4 May	29 May	4 May	3 June
	-----	-----	lb/acre	-----
Adair	6407	5163	4568	5851
Bengal	6922	4819	5893	5004
LaGrue	7946	5471	4727	5319
RU9101145	6625	4192	--	--
RU9101133	6780	3960	--	--
Kaybonnet	6439	4078	--	--
RU9101185	7418	5766	--	--
RU9101179	6719	4813	--	--
Alan	6582	4347	4870	4657
Katy	5583	4108	4439	3523
Orion	7183	4953	4912	4300
Maybelle	4840	4535	--	3903
LSD (0.05)	1097	1103	975	719

INFLUENCE OF SOLUBLE SALT ON RICE PRODUCTION

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ABSTRACT

A field study was conducted during 1992 and 1993 to evaluate 20 of the more common rice varieties produced in Arkansas for salinity tolerance. Two levels of salinity, 2000 lb/acre NaCl and a control, were imposed on each variety. The salt was applied at the three-leaf growth stage of development. Stand density and grain yields were measured for each variety. The addition of salt reduced stand counts for all varieties both years ranging from 16 to 86% and grain yields from 5.5% to 51%. A significant correlation between stand loss and yield loss was measured (r = 0.57, P = 0.0001). However, the variability of the correlation was due to the ability of some varieties to recover grain yield after the stand was thinned. A similar study was conducted during 1993 to evaluate the influence of applications of 2000 lb/acre of poultry litter or 40 lb/acre of phosphorus (P) on rice produced on salt-affected soils.

INTRODUCTION

Salt has a significant effect on rice production in some counties in Arkansas. The major influences of salinity on plant growth include possible nutrient toxicity, particularly chloride (Cl^-) or sulfate (SO_4^-), or the restriction of water uptake due to alteration of the water potential (Kafkafi, 1984; Meiri, 1984). One method of amelioration of salt-affected soils is through the process of leaching. This involves flushing the salts deeper into the soil with water until the salts are removed from the root zone. However, typical soils used for rice production in the southern U.S. do not easily allow leaching. Therefore, other methods of amelioration are needed. Recently, success has been achieved in amelioration of precision-graded soils, including soils that may have had exposed sodic horizons, by applications of poultry litter (Miller et al., 1991). Hileman et al. (1980) utilized composted organic matter to ameliorate saline soils. Consequently, interest was expressed in evaluating the use of poultry litter as a soil amendment to improve productivity on saline soils.

Rice varieties have been shown to have variability in their inherent ability to withstand certain levels of salt. Other problems, such as diseases, are controlled by selecting for resistance among varieties and crosses between varieties. Most of the common varieties have not been evaluated under field conditions for salt tolerance. Therefore, the objectives of the current studies were 1) to evaluate the tolerance of several of the rice varieties commonly produced in the southern U.S. to artificially imposed saline conditions and 2) to evaluate the influence of poultry litter and phosphorus (P) applications on rice produced on saline soils.

MATERIALS AND METHODS

Experiment I

The first experiment was conducted during 1992 and 1993 at the University of Arkansas Southeast Branch Experiment Station at Rohwer, Arkansas. Twenty rice varieties were grown on an Hebert silt loam. Standard weed control and fertilization practices were used.

The rice was seeded into plots 15 ft long and nine rows wide on 6-in. spacings. The experiment was arranged in a split plot design with salt levels as the main plot and varieties as the sub plot. Three salt levels were established by applying NaCl at rates of 0, 1 and 2 tons/acre/year. The salt was applied at the three-leaf growth stage. Each of 20 varieties, consisting of 10 short-season varieties and 10 long-season varieties, was grown at each salt level. Measurements were taken to determine stand reduction and grain yields as response variables.

Stand counts were taken immediately before and seven days after application of the salt. Each of the different salt levels was contained in a separate bay to prevent salt movement, and irrigation was facilitated such that water from a high-salt area did not flow into a low-salt area. Soil samples were taken prior to planting, and water samples were taken during the first flush irrigation and the first flush irrigation following the salt applications. Analysis of the water samples is not yet complete.

Experiment II

An additional experiment was conducted during 1993 to evaluate the influence of poultry litter and P applications onto salt-affected soils. The experiment was arranged in a split-split plot design with the five salt treatments, four poultry litter and P treatments and two varieties. The five salt treatments included 0, 1 and 2 tons NaCl/acre either preplant incorporated (ppi) or at the three-leaf growth stage. The four poultry litter and P treatments included a control, 2000 lb/acre poultry litter, 40 lb/acre of P and poultry litter plus P. The two varieties used in this study were 'Katy' and 'Bengal'. Stand counts were made before and seven days after the salt application and grain yields were determined at maturity.

RESULTS AND DISCUSSION

Experiment I

Significant stand reductions were measured for all varieties evaluated at both levels of salinity (Table 1). The highest rate of applied salt (2 tons/acre/year) reduced the stand to zero; consequently, the emphasis of this discussion will focus on comparison of one salt level (1 ton/acre/year) with the control (no salt added). Stand loss was significantly more pronounced for most varieties during 1993 compared to 1992. This is the result of the cumulative additions of salt to the soil. Thus, the initial salt level was higher in 1993 than in 1992. This illustrates an important point. As salts are added to fields by pumping saline irrigation water, the salts can accumulate, and the problem will become worse as time progresses.

The average grain yield reduction due to added salinity ranged from 5.5% for 'Tebonnet' to 56.4% for 'Newrex' (Table 2) based on averaged yields of 1992 and 1993. If a classification scheme is used such that a reduction of less than 25% is considered tolerant, seven varieties fall into this category (Table 2). The number of moderately susceptible varieties (yield reduction between 25 and 50%) is 10, while two of the varieties evaluated were highly susceptible (greater than 50% reduction). Of the seven most tolerant varieties evaluated, 'Alan' had the highest yield in the salted treatment. Although Tebonnet resulted in only 5.5% yield reduction, the control yields were relatively low (4507 lb/acre). Consequently, an overall higher-yielding variety may be more desirable.

The relationship between grain yields and stand reduction was significant (r = 0.57, P = 0.0001). Although the correlation is not strong, as evidenced by the correlation coefficient, some of the variability cannot be accounted for by the correlation alone. Other characteristics should be considered when evaluating the tolerance of a particular variety. For example, Alan was the highest-yielding variety evaluated but showed considerable stand loss. The stand reductions for 'Orion' were similar to those for Alan, but the yield reduction was much greater. Because of this relationship, it is recommended that stand reduction, overall grain yields and relative yield reduction all be considered when selecting a salt-tolerant variety.

Experiment II

Addition of P was of greater benefit than addition of poultry litter for reclaiming salt affected soils (Table 3). Grain yields from the P addition were significantly higher than from the poultry litter and poultry litter plus P. However, the P plots lacked about 50 lb/acre being significantly higher yielding than the control. Therefore, conclusive evidence is not yet available. A trend for reduced yields following addition of poultry litter, with or without P, on salt affected soils was observed.

Bengal resulted in greater yields at the low salt levels than Katy (Table 4). However, at the high salt rates, neither variety performed well. Bengal is apparently more salt tolerant than Katy. Application of 2000 lb/acre NaCl prior to planting inhibited germination and, subsequently, resulted in reduced grain yields of Katy compared to application of the salt at the three-leaf growth stage; therefore, presence of salt in the soil prior to planting is apparently more detrimental than application of salt with the irrigation water. However, continued use of saline irrigation water can result in salt accumulation in the soil and eventually be just as detrimental.

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Table 1. Stand response of field-grown rice varieties to salt (2000 lb NaCl/acre) during 1992 and 1993.

	Stand Count					
	1992			1993		
Variety	I.S.[z]	F.S.	R.S.R	I.S.	F.S.	R.S.R
	—plants/ft²—		%	—plants/ft²—		%
Alan	23.5	13.1	44.3	21.9	4.7	78.5
L202	13.4	9.3	30.6	16.9	2.5	85.2
Maybelle	13.6	9.7	28.7	16.3	6.2	62.0
Millie	22.6	16.5	27.0	18.9	7.9	58.2
Tebonnet	19.8	12.3	37.9	14.6	7.7	47.3
Jackson	16.0	8.7	45.6	18.7	3.6	80.7
RT 4716	15.7	8.0	49.0	18.3	4.9	73.2
RT 7015	17.7	8.1	54.2	18.1	2.5	86.2
Newrex	14.1	5.9	58.2	16.5	5.0	69.7
Texmont	14.0	11.3	19.3	14.3	4.6	67.8
Orion	15.1	7.7	49.0	19.2	7.4	61.5
Katy	13.6	7.1	47.8	18.7	8.6	54.0
Lemont	13.3	6.9	48.1	13.8	6.7	51.4
Newbonnet	15.5	8.3	46.5	16.3	7.3	55.2
Mars	15.1	7.1	53.0	19.1	5.7	70.2
Lacassine	13.1	5.7	56.5	16.9	9.3	45.0
Gulfmont	11.7	7.7	34.2	16.2	6.7	58.6
Jasmine 85	19.4	16.3	16.0	16.0	7.0	56.3
Rico 1	24.3	9.3	61.7	14.0	5.9	57.9
Rexmont	17.1	8.6	49.7	14.6	5.4	63.0

[z]I.S. = Initial stand; F.S. = stand seven days after salt application; R.S.R. = relative stand reduction

Table 2. Grain yields of rice varieties in response to salt (2000 lb NaCl/acre) from 1992 and 1993.

	Grain Yields		
Variety	Unsalted	Saline	Relative Reduction
	---lb/acre---		% of unsalted
Tebonnet	4507	4260	5.5
Alan	6455	5665	12.2
Millie	6059	5163	14.8
Jasmine 85	5731	4837	15.6
Gulfmont	6536	5421	17.1
RT 4716	4565	3705	18.8
Texmont	5741	4594	20.0
Lacassine	5834	4262	27.0
Newbonnet	6652	4844	27.2
Lemont	6792	4864	28.4
Jackson	6268	4381	30.1
Mars	5953	4050	32.0
Rexmont	7057	4362	38.2
Katy	6345	3885	38.8
Rico I	7850	4628	41.0
L202	7010	4102	41.5
Orion	7118	4087	42.6
RT 7015	6521	3188	51.1
Newrex	5146	2243	56.4
LSD (Between salt trts.)	1856		
LSD (Same salt trts.)	1877		

Table 3. Influence of poultry litter and phosphorus (P) applications on the grain yields and stand establishment of rice produced on salinized soil during 1993.

Treatment[z]	Grain Yield	Stand Reduction[y]
	lb/acre	%
Unamended Control	2220	13
Poultry Litter (1 ton/acre)	2012	18
P (40 lb/acre)	2600	18
Poultry Litter + P	1808	23
$LSD_{(0.05)}$	428	n.s.[x]

[z]Treatment means are averages across all salt treatments.
[y]Stand reduction resulting from salt application.
[x]n.s. = not significant at the 0.05 level of probability.

Table 4. Influence of applied salts (NaCl) and cultivar on rice grain yields during 1993.

Salt Treatment[z]	Grain Yields Katy		Bengal
	----lb/acre----		
Control	3634		6563
2000 lb/acre ppi[y]	630		3969
2000 lb/acre 3-LF	2589		3327
4000 lb/acre ppi	384		122
4000 lb/acre 3-LF	99		184
LSD(0.05) (w/in varieties)		905	
$LSD_{(0.05)}$(between varieties)		1507	

[z]Means are averaged across amendment treatments.

[y]ppi = salt incorporated prior to planting; 3-LF = salt applied at the three-leaf growth stage.

RICE PRODUCTION ON SALT-AFFECTED SOILS

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ABSTRACT

Three field experiments and one laboratory experiment were conducted to examine 1) the distribution and chemistry of salt in representative Delta soils and 2) the effect on rice yields of additions of phosphorus, zinc and poultry litter to salt-affected soils. High levels of salt, primarily sodium chloride and sodium sulfate, were found in the subsoils of certain soils in both Poinsett and Prairie Counties. These results suggest that irrigation may be leading to an accumulation of salt in some rice soils in the Delta. In another field study, when a silt loam soil to which artificial irrigation waters had been applied was allowed to dry, significant amounts of salt moved upward and accumulated in the 0- to 10-cm depth of the soil. This suggests that during dry periods, salt that has accumulated in the subsoil can move upward into the root zone where it is much more likely to damage seedling rice. In a laboratory study, it was found that the electrical conductivity (a measure of "saltiness") of a soil rapidly attained the same value as that of the water with which it had been irrigated. In a field study, yields of rice were significantly increased at four out of five sites by application of either fresh or composted litter at rates ranging from 1000 to 4000 lb/acre. However, this response may have had more to do with soil alkalinity than soil salinity.

INTRODUCTION

Salinity continues to be mentioned as one of the major problems facing rice producers in Arkansas. The sensitivity of many cultivars of rice at the seedling stage to salinity has been well established (Baser et al., 1992). Less is known regarding how salt moves in the soil and what management strategies may be employed to minimize the adverse effects of salinity. In terms of salt movement in the soil, we are currently attempting to determine if irrigation over a period of years is resulting in the accumulation of salt within the soil profile. As the soil dries, it may be that this salt moves upward in the soil profile ("wicks") into the root zone of the seedling rice, causing salinity damage. If this is what is happening, it is likely that the severity of the salinity problem will increase in the years to come. In the meantime, it is important that we attempt to develop management strategies to counteract the effects of salt accumulation in our rice soils. A particularly contentious issue in this regard is application of potash (potassium chloride) to soils showing signs of salt accumulation but testing low in potassium. We are attempting to determine if the application of additional chloride to these soils significantly increases the likelihood of salinity damage or if addition of needed potassium actually decreases the likelihood of salt damage. Other management strategies we are testing involve preplant applications of phosphorus and poultry litter and combinations of these. We are attempting not only to gain a more fundamental understanding of the problem, but also to develop management techniques that the rice producer can use currently to minimize loses due to salinity.

PROCEDURES

Experiment 1

Five producer fields with histories of salt problems were selected for the test. Two (Huber A and B) were located in Poinsett County, two (Marek and Prislovsky) in Prairie County and one (McClean) in Arkansas County. Surface (0-15 cm) soil samples were collected prior to application of amendments and submitted to the University of Arkansas Soil Testing Laboratory for routine analysis. The experimental design at each site was a randomized factorial with five rates of poultry litter (0, 1000, 2000 and 4000 lb/acre composted litter and 1000 lb/acre fresh litter), two rates of phosphorus (0 and 20 lb P/acre as TSP) and two rates of zinc (0 and 20 lb Zn/acre as $ZnSO_4$). All treatments were applied preplant incorporated. There were four replications per treatment. Biomass and grain yields were determined at physiological maturity.

Experiment 2

Soil samples were taken with a bucket auger in 4-in. increments to a depth of 28 in. at the two Prairie County and the two Poinsett County sites described above. Soil samples were transported to Fayetteville in insulated containers, frozen, then thawed, mixed and analyzed for moisture, pH, electrical conductivity (EC) and water soluble (1:2 soil:water) nitrate, chloride, sulfate, calcium, magnesium, potassium and sodium. Anions were determined by ion chromatography and cations by inductively coupled argon plasma spectroscopy.

Experiment 3

Twenty-two microplots were established at the University of Arkansas Rice Research and Extension Center in Arkansas County by driving galvanized steel rectangles (76.5 cm x 76.5 cm x 30 cm) 25 cm deep into the soil. One plot was irrigated only with deionized water. The other 21 plots, arranged in three replications, were irrigated with one of seven different synthetic irrigation waters. Each plot in the third replication was instrumented with suction cup lysimeters and tensiometers at depths of 10, 20 and 30 cm. All plots received a total of 1 pore volume of synthetic irrigation water in 0.1-pore volume increments. The instrumented (third) replication subsequently was irrigated with another 1 pore volume of synthetic irrigation water. All the plots were fitted with rain shelters.

The EC and SAR (sodium adsorption ratio) of the irrigation waters was relatively uniform (ranging from 1.59-1.80 dS/m and 2.65-3.09, respectively). The relative proportions of cations in all the waters was the same and similar to those representative of natural irrigation waters found in Arkansas County. The seven irrigation waters differed in their relative concentrations of anions (chloride, nitrate and sulfate).

After infiltration of 1 pore volume of solution, soil solution samples were taken with lysimeters, and soil water tension was measured using the tensiometers. In the non-instrumented replications (reps 1 and 2), the soil was sampled in 5-cm depth increments to a depth of 35 cm. Then these two replications were allowed to dry for approximately five weeks and soil was sampled to 35 cm as previously described. All soil and water samples were analyzed for pH, EC and water-soluble (saturated paste extract) sodium, calcium, magnesium, potassium, chloride, nitrate and sulfate.

Experiment 4

In a laboratory experiment, pure salt solutions, consisting of NaCl, $NaSO_4$, $MgSO_4$ or $MgCl_2$, were added to 20 g of a Crowley silt loam from RREC in a 2:1 solution to soil ratio at the following EC's: 0.1, 0.2, 0.4, 0.8, 1.6, 3.2, 6.4 and 12.8 dS/m. Following addition of salt solutions, soils were shaken and incubated at room temperature for 16 hours, and resultant soil EC's were measured with a conductance meter. These salts provided various combinations of mono- and divalent cations and anions with NaCl and $MgSO_4$ being the two salts that were composed of only monovalent or divalent ions, respectively.

RESULTS AND DISCUSSION

Experiment 1

Rice grain yields as a function of litter and phosphorus treatments are presented in Table 1. There was a statistically significant ($\alpha = 0.05$) response to litter at all locations except the Prislovsky site. A statistically significant ($\alpha = 0.05$) response to P was observed at only the Huber A and B sites. The litter x phosphorus interaction was not significant at $\alpha = 0.05$ but would have been significant at $\alpha = 0.10$ at both of the Huber sites and at the McClean site. At none of the sites was there a response to zinc. At the sites where a response to both litter and P was observed (the Huber A and B sites), application of either 4000 lb compost/acre or 1000 lb fresh litter/acre without additional P tended to produce grain yields that were higher than those produced by the P-only (no litter) treatment. The soil pH at both the Huber sites was very high (near 8 in the surface 12 in.), and this may account for the response to both litter and P. At this pH there should also have been a response to zinc, but none was observed. The McClean site is of interest in that there was a significant response to litter applications even though the control (no litter) treatment yield was high (7844 lb grain/acre). Previous data had suggested that a response to litter was unlikely when control treatment yields were above 7000 lb/acre, as was the case at the Prislovsky site.

Experiment 2

Surface soil pH was high at all four of the sites. At the two Huber sites, the pH of the soil in the 0- to 12-in. depth was near 8, while at the Marek and Prislovsky sites, this same depth had a pH of 7.6-7.8. Some nitrates were detected in the 0- to 4-in. depth at some sites, but the amounts were small. At all sites the EC values began to increase at approximately the 20-in. depth and continued to increase to a depth of 28 in. The anions responsible for these increases were chloride and sulfate while the cation was sodium. Levels of anions and cations were quite high in these lower depths at all four locations. Depth distribution of these soluble salts was probably affected by sampling time. Prior to sampling, the rainfall pattern in the spring of 1993 was one of frequent frontal passages at three- to five-day intervals with each front producing rainfall of 0.5 in. or greater. This would tend to cause the salts to remain in the lower part of the soil profile rather than moving to the surface with evaporating water.

Experiment 3

Probably the most significant result of this study was the observation that significant amounts of salt were retained in the soil profile and that these salts tended to migrate toward the soil surface when the soil was allowed to dry. Drying increased the EC of the 0- to 3-in. soil depth by 50% relative to the value prior to drying. The anion that tended to accumulate nearest the soil surface was chloride, high concentrations of which are known to be toxic to seedling rice.

Experiment 4

The relationships between EC's in the salt solutions and the corresponding EC's in the Crowley soil are presented in Fig. 1. A high EC of a poor-quality, salt-contaminated irrigation water in Arkansas is about 4 dS/m (J. Gilmour, personal communication); thus the highest solution EC selected in this study was over three times that found under natural conditions. Straight line relationships were observed for all salt solutions. The slope of the lines for all salts were similar, ranging from 0.86 to 0.92. There did not appear to be a relationship between slope and salt, suggesting that changes in the EC response of the soil to additions of saline water was not salt dependent. These slopes indicate that the EC of the soil was at least 86% of the EC of the saturating salt solution. Thus, when a non-saline soil is initially irrigated with salt-contaminated water, the EC of the soil will be roughly the EC of the water. This response may be soil dependent and should be evaluated among soils with different chemical and mineralogical characteristics. Soil EC response to repeated additions of salt-contaminated water will be evaluated in a future study.

SIGNIFICANCE OF FINDINGS

The limited data available at this time suggest that accumulation of soluble salts in the subsoil as a result of irrigation may be occurring in some Delta soils. This is cause for some concern, and further studies designed to test this hypothesis are definitely needed. Our data support the theory that salinity damage of seedling rice may be caused by upward translocation of accumulated salts into the root zone during periods of low rainfall. Our results also indicate that what is often believed to be salinity problems may actually be alkalinity (high pH) problems. While the soil at our experimental locations showed evidence of salinization, it also had pH values of greater than 7.5. It was difficult, therefore, to establish whether applications of litter and/or P were ameliorating a salinity problem or an alkalinity problem. Previous work with poultry litter on a variety of soil types, coupled with recent findings (Wilson et al., 1994) on the response of rice to P and/or poultry litter applications on artificially salinized soils, suggests that alkaline soils are more likely to respond favorably to P and/or litter applications than are saline soils.

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Table 1. Effect of litter and phosphorus applications on rice grain yields in 1993 at five sites having a history of salinity problems.

	Rice Grain Yield									
	Huber A		Huber B		Marek		Prislovsky		McClean	
Litter rate	-P[z]	+P[y]	-P	+P	-P	+P	-P	+P	-P	+P
	lb grain/acre									
4000 lb/acre compost	7364	7491	7077	7076	6619	6599	7927	8294	9443	9115
1000 lb/acre fresh	7447	7177	6812	6881	6719	6364	8457	8091	8998	9304
2000 lb/acre compost	6755	7087	6603	6996	6814	6661	8250	7766	8277	8667
1000 lb/acre compost	6520	6992	6428	6975	5828	5854	8220	8265	8404	8328
No Litter	6052	6777	5534	6464	6158	6074	7723	8221	7844	8763
LSD (0.05)[x]	222		244		NS		NS		NS	

[z]No inorganic P added.
[y]P added at 20 lb P/acre as TSP.
[x]LSD (0.05) for comparing -P and +P means within a given treatment.

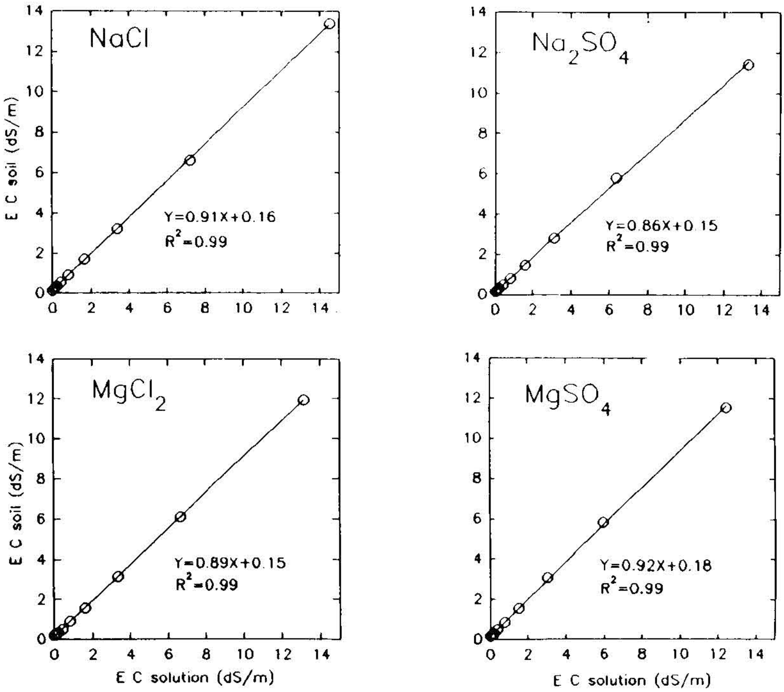

Fig. 1. Soil electrical conductivity (EC soil) as a function of equilibrating salt solution electrical conductivity (EC solution).

EVALUATION OF SOIL TEST PROCEDURES FOR PREDICTING AVAILABLE PHOSPHORUS FOR RICE

Y.H. Teo, C.A. Beyrouty, D.M. Miller, P.A. Moore and R.J. Norman

ABSTRACT

The Mehlich-3 extract appears to be inconsistent in identifying soils in which a fertilizer phosphorus (P) response by rice would be expected. Consequently, a greenhouse study was conducted to relate soil test levels measured with different extracting solutions to P uptake by the rice cultivar 'Lemont'. Soils were sampled from three fields in which fertilizer P responses by rice have been documented. Rice was grown in these soils at five fertilizer P rates of 0, 5, 10, 20 and 40 mg P/kg soil. Plants were harvested at 24, 31 and 124 days after flooding and shoots measured for P uptake and dry weight accumulation. Soils were extracted with Mehlich-3, Bray-1, Olsen and anion exchange resin (resin) at each harvest. Maximum shoot dry weight occurred at the 10- to 20-mg P/kg soil fertilizer rates, depending upon soil. Maximum number of panicles and florets were measured at 20 and 40 mg P/kg soil, respectively, while maximum kernel weight was found at 10 mg P/kg soil. The resin appeared to extract an amount of P most closely correlated with that used by the plant, while the Mehlich-3 extracted a quantity of P least correlated with uptake. A mechanistic model was used to compare the ability of the four extraction methods to provide accurate soils information as inputs for predicting P uptake by rice. Mehlich-3, Bray-1 and Olsen resulted in overprediction of P uptake while the resin consistently resulted in a 1:1 relationship between predicted and observed P uptake. Thus, plant uptake data and model outputs both suggest that the resin is the best predictor of plant-available P under flooded conditions.

INTRODUCTION

In Arkansas, plant-available P for flood-irrigated rice (*Oryza sativa* L.) is estimated by first extracting an aerobic sample of soil with Mehlich-3 solution. This solution has a pH of 2.5 and is designed to extract several plant nutrients besides P. Phosphorus fertilization is not normally recommended for rice unless the soil tests lower than 25 lb P/acre. However, recent studies suggest that Mehlich-3 does not consistently predict P response to flood-irrigated rice. Thus, a study was conducted to evaluate several chemical extractants that could be used by the soil testing laboratory for routine analysis of plant-available P for rice grown under flooded conditions.

MATERIALS AND METHODS

A greenhouse study was conducted to relate soil test P levels measured with different extracting solutions to P uptake by the rice cultivar Lemont. The soils selected for this study were a Crowley silt loam collected from Arkansas County (Crowley) and Hillemann silt loams collected from Poinsett (Hillemann-Poinsett) and Cross (Hillemann-Cross) Counties. Samples of each soil were collected from the top 5 cm of control plots (0 P applied) established for a P response field study in each of the three counties (Norman et al., 1992). Soils were sieved, air dried and chemically analyzed for plant nutrients in Mehlich-3 extracts of non-flooded soil samples. Available P levels were 84 kg P/ha in the Crowley, 22 kg P/ha in the Hillemann-Poinsett and 4 kg P/ha in the Hillemann-Cross.

Five fertilizer P treatments of 0 (control), 5, 10, 20 and 40 mg P/kg soil (oven dry basis) were prepared by spraying appropriate amounts of KH_2PO_4 dissolved in solution onto moist (field capacity) soil. Following incubation for three weeks, the soils were air-dried, sieved through a 2-mm screen and mixed. Two kilograms of soil were packed into each pot, seeded and thinned to five plants at the three-leaf stage followed by fertilization with urea at the rate of 180 kg N/ha and flooding to 5 cm depth.

Plant height and tiller number were measured at 24 (37 days after emergence-active tillering), 31 (44 days after emergence-active tillering) and 124 (137 days after emergence-50% heading) days after flooding (DAF). At 124 DAF, panicle and floret numbers were counted and kernel dry weight measured. Shoots were removed at each sampling date and oven dried for 72 hr at 60 C, and dry weights were determined. Dried shoot tissue was ground, wet ashed with sulfuric acid and hydrogen peroxide and analyzed for total P.

At day 0 (aerobic control) and at each subsequent sampling time, pots were placed in N_2-purged glove bags and soils fractionated for organic P, nonoccluded P, occluded P, calcium P, total P and solution P. In addition, soil was extracted with Bray-1 (Olsen and Sommers, 1982), Olsen (Olsen and Sommers, 1982), Mehlich-3 (Hanlon and Johnson, 1984) and resin (Sibbesen, 1977) for measurement of plant-available P. Phosphorus in all fractions was determined colorimetrically.

Simple correlations were conducted between plant growth parameters and P fractions for each soil series and DAF combination to identify significant relationships.

Soil and plant parameters measured at 24 DAF were input into the Barber-Cushman nutrient uptake model to predict P uptake by rice at 31 DAF. A linear regression model was used to identify the soil test method providing the closest 1:1 relationship between predicted and observed P uptake. The chemical extractant resulting in the closest 1:1 relationship between observed and predicted P uptake is suggested to be the most appropriate for assessing plant-available soil P.

The greenhouse experiment was a split-split-split plot. The whole plot portion was a randomized complete block design with three replications, with soil series as the whole plot factor, DAF as the split plot factor, rate of fertilizer P applied as the split-split plot factor and P obtained with each chemical extractant as the split-split-split plot factor. A protected LSD was used to separate means where appropriate.

RESULTS AND DISCUSSION

Shoot dry weight was affected by the P rate x soil and P rate x DAF two-way interactions (Table 1). Shoot dry weight was consistently higher on the Crowley silt loam than on either of the Hillemann soils. Compared to the zero P control, maximum shoot dry weight occurred at the 10-mg P/kg rate on the Crowley soil and at the 20-mg P/kg rate on the Hillemann-Cross and Hillemann-Poinsett soils. Shoots responded to decreasing rates of P fertilization as the plant developed. A shoot dry weight increase at 24 DAF was found only at the 40-mg P/kg rate while a dry weight increase was found at 5 mg P/kg at 124 DAF. Yield components were also affected by P rate (Table 2). Maximum numbers of panicles and florets were measured at 20 and 40 mg P/kg, respectively. Kernel weight, however, peaked at 10 mg P/kg.

Shoot dry weight, concentration of P in shoots and total P uptake were correlated to P concentration in the soil solution and nonoccluded aluminum and iron phosphates (Table 3). These growth and uptake parameters were not related to P found in the organic, occluded or calcium phosphate fractions. These relationships were found for all three soils and at all three harvest dates, suggesting that assessment of plant-available P in a soil necessitates the quantification of P in solution and in the nonoccluded fraction.

The relationships between shoot dry weight, concentration of P in shoots and total P uptake with P extracted from aerobic soils by four different extractants are presented in Table 4. The fewest number of relationships between these plant parameters and extractable P were found when Mehlich-3 was the extracting solution. The greatest number of relationships were found when the resin was used to extract soil P. These data suggest that of the four methods of extracting plant-available P, the resin method extracts an amount of P most closely correlated with that used by the rice plant.

Figure 1 shows the amount of extractable P obtained with each of the four extracting solutions for each soil and sampling time. Both Mehlich-3 and Bray-1 consistently extracted more P than Olsen or the resin, while the resin extracted less P than the other three solutions. The Mehlich-3 and Bray solutions are acidic and would be expected to solubilize calcium P and possibly some organic P as well. The Olsen solution is adjusted to pH 8.5 and would likely solubilize P held as iron and aluminum precipitates that might not solubilize during the growing season. The resin, however, does not alter the pH of the soil and, consequently, should extract only the forms of P that are readily available during the growing season.

The Barber-Cushman uptake model was used to select the most accurate extractant for measuring plant-available P. We have shown in previous studies that this model accurately predicts P uptake by field-grown, flood-irrigated rice during vegetative growth. We were interested in using the model to relate predicted P uptake by the rice plant with observed P uptake for the four extracting solutions. Table 5 provides the intercepts and slopes of the lines relating predicted P uptake with observed P uptake for each extractant and soil. An asterisk by a value for slope indicates that the value is different from 1.00, and an asterisk by a value for intercept indicates that the value is different from 0. Comparison of slopes shows that Mehlich-3 and Bray-1 overpredicted P uptake on the Crowley by 21 and 25%, respectively. Similarly, Mehlich-3, Bray-1 and Olsen overpredicted P uptake on the Hillemann-Poinsett by 77, 67 and 21%, respectively. The resin consistently resulted in a 1:1 relationship between predicted and observed P uptake for all three soils.

SIGNIFICANCE OF FINDINGS

Results from this study showed that rice growth and uptake of P are related to P found in the soil solution and as nonoccluded forms of iron and aluminum. Four solutions for extracting plant-available P were compared: Mehlich-3, Bray-1, Olsen and resin. The resin was found to more consistently extract solution and nonoccluded P than the other extractants. Thus, the resin technique was a better predictor of plant-available P than the other methods evaluated and should be considered when developing soil test procedures.

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Table 1. Shoot dry weight affected by phosphorus (P) rate x soil and P rate x days after flooding interactions.

	Soil			Days after Flooding		
P rate	Crowley	Hilemann Poinsett	Hillemann Cross	24	31	124
mg P/kg	g/pot			g/pot		
0	11.89[z]	7.85	4.14	1.16[y]	2.59	20.15
5	13.79	9.19	4.35	1.44	3.30	22.58
10	16.67	9.75	5.25	1.75	4.63	25.28
20	16.61	13.05	6.72	2.43	5.76	28.41
40	18.05	15.66	8.36	3.55	6.88	31.65

[z]LSD(0.05) within soil = 2.21; between soils = 2.30.

[y]LSD(0.05) within a day after flooding = 2.10; between days after flooding = 2.36.

Table 2. Panicle and floret number and kernel weight as affected by applied phosphorus (P).

P rate	Panicle	Floret	Kernel wt.
mg P/kg	---------- no/pot----------		g/pot
0	3.6	188	0.9
5	6.4	304	2.0
10	7.8	428	2.9
20	10.3	470	2.5
40	10.8	582	3.4
LSD (0.05)	1.6	89	1.4

Table 3. Significant correlation coefficients between several rice growth parameters and phosphorus (P) fractions determined under anaerobic conditions (n=15) for three soils at three harvest dates.

	Soil Solution P			Nonoccluded Al-P and Fe-P		
Parameter	24 DAF[z]	31 DAF	124 DAF	24 DAF	31 DAF	124 DAF
	---------- Crowley ----------					
Shoot Dry Weight	0.701**	0.680**	0.535*	NS[y]	0.564*	NS
% P in Shoot	0.693*	0.678**	NS	0.874***	0.905***	0.784***
Total P Uptake	0.804***	0.802**	NS	0.599*	0.856***	0.713**
	---------- Hillemann-Poinsett ----------					
Shoot Dry Weight	0.814***	0.838***	0.703**	0.627*	NS	NS
% P in Shoot	0.762**	NS	0.809***	0.931***	0.837***	0.764***
Total P Uptake	0.887***	0.645**	0.807***	0.765**	0.673**	NS
	---------- Hillemann-Cross ----------					
Shoot Dry Weight	0.729***	0.736**	0.850***	0.793**	0.579*	0.708***
% P in Shoot	0.618*	0.876***	0.898***	0.874***	0.934***	0.927***
Total P Uptake	0.736**	0.790***	0.952***	0.880**	0.689**	0.885***

*, ** and *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively.
[z]DAF = days after flooding.
[y]NS = not significant at 0.05 probability level.

Table 4. Significant correlation coefficients between shoot dry weight, % phosphorus (P) in shoot and total P uptake measured at three flooding dates with P extracted by the four chemical extractants measured at 0 DAF (n=15).

Soil	Parameter	24 DAF[z]	31 DAF	124 DAF	24 DAF	31 DAF	124 DAF
		Mehlich-3			Bray-1		
A[y]	Shoot Dry Weight	NS[x]	NS	NS	NS	NS	0.516*
	%P in Shoot	NS	0.533*	NS	NS	NS	NS
	Total P Uptake	NS	NS	NS	NS	NS	NS
P	Shoot Dry Weight	NS	NS	NS	0.667**	NS	NS
	%P in Shoot	NS	NS	NS	NS	NS	0.588*
	Total P Uptake	NS	NS	NS	NS	0.678**	0.555*
C	Shoot Dry Weight	NS	0.743**	NS	NS	NS	NS
	%P in Shoot	NS	NS	NS	0.694**	0.763**	NS
	Total P Uptake	NS	NS	NS	0.645**	0.770**	NS
		Olsen			Resin		
A	Shoot Dry Weight	NS	0.706**	NS	NS	0.707**	NS
	%P in Shoot	NS	NS	NS	NS	0.613*	0.645**
	Total P Uptake	0.787***	NS	NS	0.681**	0.740**	0.713**
P	Shoot Dry Weight	NS	NS	NS	NS	NS	NS
	%P in Shoot	0.757**	NS	NS	NS	NS	0.796***
	Total P Uptake	0.617*	NS	NS	0.608*	0.630*	0.664**
C	Shoot Dry Weight	0.746**	NS	0.726**	NS	0.841***	NS
	%P in Shoot	0.600*	NS	NS	0.645**	NS	0.779***
	Total P Uptake	0.675**	NS	NS	NS	NS	0.856***

*, ** and *** Significant at 0.05, 0.01 and 0.001 probability levels, respectively.
[z]DAF = days after flooding.
[y]A = Crowley, P = Hillemann-Poinsett, C = Hillemann-Cross.
[x]NS = not significant at 0.05 probability level.

Table 5. Estimated intercepts and slopes between predicted and observed phosphorus (P) uptake by rice for three soils and chemical extractant methods.

Soil	Method	Intercept	Slope
Crowley	Mehlich-3	34.8	1.21*
	Bray-1	30.4	1.25*
	Olsen	48.2	0.92
	Resin	28.0	1.01
	SE[z]	54.1	0.14
Hillemann-Cross	Mehlich-3	-5.4	1.19
	Bray-1	0.1	1.14
	Olsen	-5.4	1.09
	Resin	-4.2	0.98
	SE	5.1	0.05
Hillemann-Poinsett	Mehlich-3	-117.8**	1.77*
	Bray-1	-75.1**	1.67*
	Olsen	18.9	1.21*
	Resin	9.5	1.03
	SE	27.4	0.11

*, ** Significant at 0.05, 0.01, and 0.001 probability levels, respectively.
[z]Standard Error

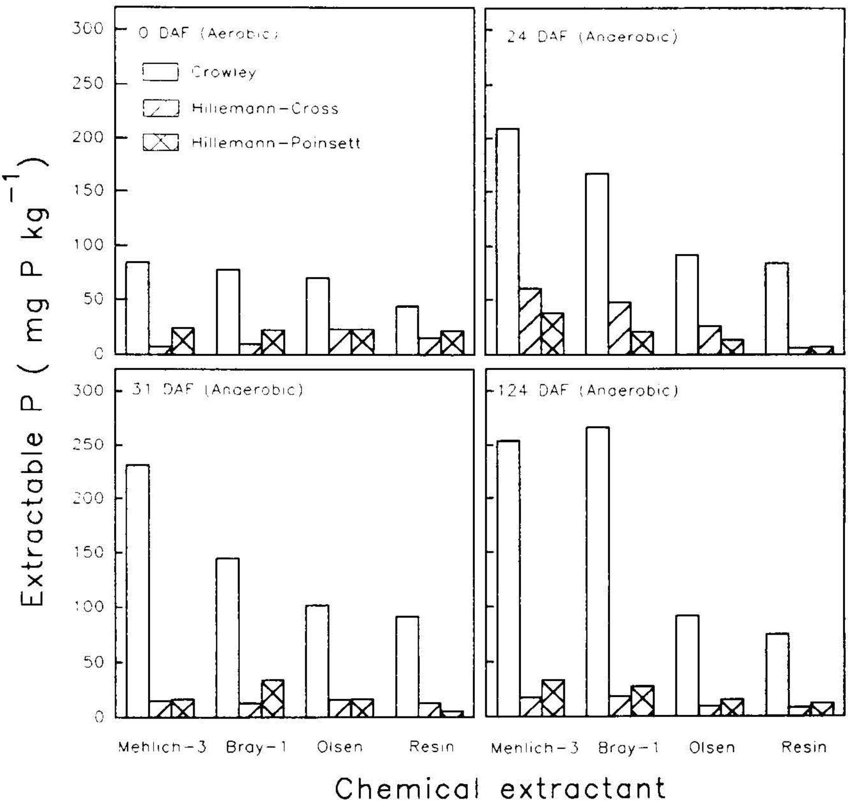

Fig. 1. Extractable soil phosphorus (P) concentration as a function of soil, chemical extractant and days after flooding (DAF).

RICE GROWTH RESPONSE TO WATER SEEDING

C.A. Beyrouty, R.J. Norman, R.S. Helms and B.R. Wells

ABSTRACT

A field study was conducted to evaluate root and shoot growth of the rice cultivars 'Lacassine' and 'Katy' grown in drill-seeded or water-seeded management. Drill-seeded rice was planted at a rate of 110 lb/acre and managed as recommended for standard practices. For the water-seeded rice, pregerminated seed was hand broadcast into flooded plots at a seeding rate of 132 lb/acre. The flood was removed until seedling emergence after which it was reapplied. There were no differences in grain yields or head rice yields between water- and drill-seeded rice, although Lacassine outyielded Katy by about 1400 to 1700 lb/acre. In general, total shoot dry weights were greater for water-seeded rice throughout the season, while root length densities were 35 to 115% greater for drill-seeded rice up to heading.

INTRODUCTION

There is considerable interest in water seeding rice in Arkansas, yet little is known about the growth and development of water-seeded rice grown on Arkansas soils and under our climatic conditions. Research has shown that rice cultivars differ in their rooting patterns throughout the soil profile, possibly impacting seedling establishment under water-seeded culture. Changes in cultivar root growth as a result of seeding into a flood may also impact nitrogen uptake. Fertilizer timing strategies will have to be developed that will optimize uptake. Before recommendations can be developed concerning management of water-seeded rice, comparisons must be made of the growth and development of water-seeded and drill-seeded rice.

MATERIALS AND METHODS

The first of a multi-year field study was conducted to identify the growth and yield response of rice to drill seeding and water seeding. Two cultivars (Lacassine and Katy) were either drill 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 drill-seeded plots. Rice was drill seeded at a rate of 110 lb/acre. Recommended practices for timing of the application and removal of the floodwater for drill-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 of water for 24 hours to initiate germination. Pregerminated seed was hand broadcast into flooded plots at a rate that was 20% greater than for drill-seeded rice. It was anticipated that lower emergence would result from poorer soil contact by water seeding. Following water seeding, the flood water was removed until emergence, after which time the flood was re-applied. Subsequent floodwater management paralleled that for the drill-seeded rice.

Measurements of tiller number, plant height, shoot dry weights and root length were made at mid tillering, beginning internode elongation, 50% heading and dough stage for all treatments.

RESULTS AND DISCUSSION

Although there was a denser planting for water-seeded rice, the number of rice plants that emerged was similar for both seeding treatments. Final population densities of Katy and Lacassine were 46 and 93 plants/ft^2, respectively, regardless of planting treatment. Prior to application of the flood to the drill-seeded rice, water-seeded rice produced between 60 and 76 tillers/ft^2 in contrast to only 19 tillers/ft^2 for drill-seeded rice. However, by heading tiller numbers were similar for all treatments, ranging from 33 to 44 tillers/ft^2. Yields were 1400 to 1700 lb/acre lower for Katy than for Lacassine on both water- and drill-seeded rice, and water seeding did not appear to affect yields. Grain yields of water- and drill-seeded Katy were 5378 and 5398 lb/acre, respectively, while water- and drill-seeded Lacassine yielded 6775 and 7053 lb/acre, respectively. No differences in head rice yields were noted in response to planting treatment or cultivar, with an average head rice yield of 61% for all treatment combinations. Plant dry weights were 9 to 189% greater for water-seeded rice than for drill-seeded rice throughout most of the season (Table 1). Root lengths measured to a soil depth of 42 cm were 35 to 115% greater for drill-seeded than for water-seeded rice up to internode elongation, following which root lengths were similar for all treatment combinations (Fig. 1).

SIGNIFICANCE OF FINDINGS

The data suggest that although plant morphological changes occur in response to water seeding, yields equal to those of drill-seeded rice can be achieved. Additional studies will be conducted in which the influence of environment, soil and fertilizer management are assessed.

Table 1. Total shoot dry weight (leaf, stem and panicle) of water- and drill-seeded rice.

	Water-seeded				Drill-seeded			
Cultivar	MT[z]	IE	HD	D	MT	IE	HD	D
	kg/ha							
Katy	2,329	7,080	9,860	15,552	804	5,374	9,035	11,719
Lacassine	2,304	7,301	13,805	16,171	865	5,507	9,175	10,448

[z]MT = mid-tillering, IE = internode elongation, HD = heading, D = dough stage.

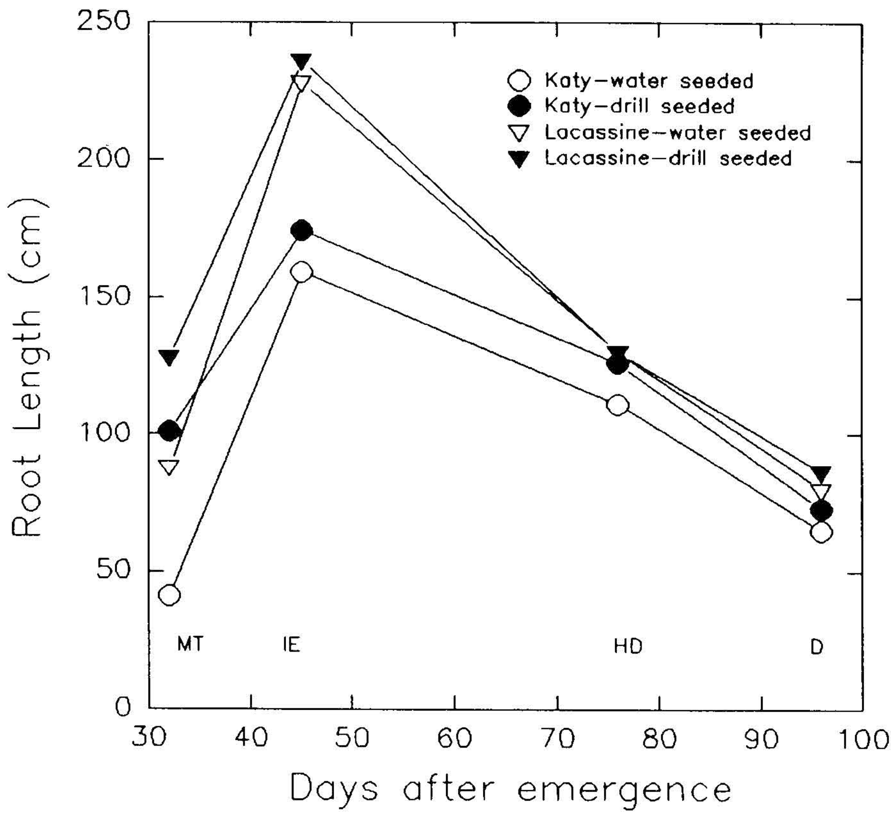

Fig. 1. Root length response of water- and drill-seeded rice. MT = mid-tillering, IE = internode elongation, HD = heading, D = dough stage.

RICE PRODUCTION MANAGEMENT SUPPORT SYSTEM

T.A. Costello, J.A. Ferguson, K.W. VanDevender, B.R. Wells, R.J. Norman, N.A. Slaton, P.A. Counce, T.J. Siebenmorgen and R.S. Helms

ABSTRACT

Concepts of artificial intelligence and computer-based tools for rice production management were tested. Several stand-alone software products were developed for use by rice growers. The original plan was to link these into an integrated package. The individual components have been tested and found to be functional; however, the complexity and detailed input required may limit their widespread use. Further efforts to integrate the components were not attempted. An advanced prototype of the weed management software has been reviewed by Extension agents and judged to be mechanically functional. It has been suggested that the most important role for the software would be for training new agents and not for general use by growers. Integration of this product (and fertilizer management software) into future Extension programs remains uncertain due to a perceived lack of user demand and the significant effort needed to provide annual updates to the knowledge-bases. A software package for rice harvesting will be completed this spring. Preliminary evaluations suggest that this software will provide a tool that will impact recommendations to growers as to optimal harvest timing and combine settings. This report summarizes results for the duration of the project.

INTRODUCTION

A decision maker in production agriculture must balance goals to maximize productivity, reduce expenditures and provide for stewardship of land and water resources. This difficult task requires detailed information regarding all the possible alternatives and their expected outcomes. Many pathways for this information involve computers. Computers can be used as a tool for a grower to predict the consequences of a proposed management practice and to provide access to expert guidelines for implementing an action plan. Hopefully, then, the actions taken would be optimal for each grower, resulting in economic and environmental benefits. These concepts were the basis for research efforts aimed at developing and testing software products for the rice grower.

PROCEDURES AND DISCUSSION

The software products that were developed through the prototype stage included modules geared toward the following management topics: 1) weed management, 2) fertilizer management, 3) harvest management, 4) scheduling and 5) "what-if" simulation. These will be described individually.

A prototype expert system for rice weed management was developed and used as a guide for development of subsequent modules. Originally, logic was coded in rules using a commercial expert system shell; however, this classic example of an expert system application was found to be too slow and too big to be used by growers. We overcame these difficulties by eliminating the commercial shell with custom-designed software that reduced the size of the package, speeded execution and lessened memory requirements of the computer. Input and output routines were coded using an advanced programmer's toolbox. Economic analyses were presented in spreadsheet format. Software usage was supported by on-line context-sensitive help messages and an on-line user's guide. Testing has shown that the revised version of the software operated as designed and provided output to the user in a reasonable amount of time. In 1991, when the knowledge-base was current, recommendations from the software were consistent with the 1991 Rice Research Verification Trials (VanDevender, 1992). Since weed management technology is not static, the software must be updated to provide reliable information. Informal testing by Extension agents has led to uncertainty as to the potential usage by growers due to the requirements for detailed descriptions of the field situation, including weed species present and their densities. Such uncertainty has not led to additional research since the question is no longer one of technical feasibility but of evaluating the potential costs and benefits of distributing and maintaining the software.

A prototype fertilizer management support system, RiceFertility, was completed in 1992. Validation was accomplished using the 1992 Rice Research Verification Trials. The knowledge-base at that time was accurate except for errors in the representation of the logic for diagnosing zinc deficiency. The user-interface, modeled after RiceWeed, was acceptable. The software included standard nitrogen rate recommendations, an implementation of the plant area method for customizing mid-season nitrogen rates and logic for diagnosing non-nitrogen fertility problems.

A harvesting expert system, RiceHarvest, has been designed and will be completed in the spring of 1994. The prototype system will allow a grower to select an optimal grain moisture content to begin harvest based on an economic analysis of the harvest system and predictions of the impact of weather on field yield and head rice yield. When completed, this system will capture and deliver the state-of-the-art in harvest research to growers who are interested in optimizing the harvested value of their crop.

A prototype electronic calendar program was developed in 1992. The program was designed to help identify conflicts in scheduling, improve planning and facilitate pesticide usage record-keeping. The concept for this software came from rice growers requesting help in logging pesticide usage. Although the concept was feasible, efforts to implement the software will remain on hold until other related software are available.

A mathematical model of rice growth and development was completed in 1989. A detailed addendum to the model was developed in 1993 to describe complex nitrogen dynamics in the soil. Although it was hoped that the model would provide a tool for growers to attempt "what-if" simulations, the model has remained a research tool. At present, the model is not reliable in predicting rice growth during periods of unusual weather or during pest outbreaks; therefore, its application among growers would not be advisable. Support for model development included the collection of detailed weather data at Stuttgart, Arkansas, using an electronic weather station. Data from 1989 through 1993 have been archived and provide a valuable resource for present and future modeling efforts.

SIGNIFICANCE OF FINDINGS

The researchable questions we addressed in this project were: "What is the suitability of computer software to mimic problem-solving processes of experts?" and "Can this technology provide useful information to growers?" The answer to the first question is clear; we have demonstrated that present technology can provide software that allows management information to be organized and delivered quickly and accurately. The answer to the second question depends on the definition of *useful* information. The software certainly has the capacity to deliver *relevant* information to the grower, but the effort needed to access this information may exceed the perceived benefits. The perceived benefits, of course, will depend upon the educational background and economic situation of each potential user of the software. The potential benefits include elimination of marginal applications of pesticides and fertilizers, increased economic return to the grower and less exposure of the environment to agricultural chemicals. Determining the magnitude of these potential benefits seems to be a key obstacle to adoption of the technology. The tools have the potential to become a routine component of rice management, relied upon by growers to help make decisions that will save money, protect the investment in a crop and properly manage resources.

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1993 RICE RESEARCH VERIFICATION TRIALS

N.A. Slaton, C.A. Stuart, Jr. and R.S. Helms.

ABSTRACT

Twelve Rice Research Verification Trials (RRVT) were conducted during 1993 in the following ten rice-producing counties: Arkansas, Jackson, Lincoln, Jefferson, Mississippi, Phillips, Prairie, Poinsett, White and Woodruff (three fields). Agronomic and economic data for specified operating costs were collected for each verification field. Acreage for the twelve fields totaled 705 acres, and field size ranged from 33 to 100 acres. The mean grain yield was 122 bu/acre. Yields ranged from 98 to 159 bu/acre over the seven different varieties. Nine of the twelve fields were drill or broadcast dry seeded, and three were water seeded either for stand establishment or because of a severe red rice infestation in the soil. Seeding dates ranged from 18 April to 11 June.

The break-even price for each field, excluding charges for land, overhead and management, ranged from $1.93 to $3.26/bu. Based on the weighted means for yield and total specified operating ($261.43/acre) and fixed cost ($55.19/acre), the average break-even price, per acre, was $2.60/bu. Fertilizer cost represented 14.9% of the specified operating cost followed by drying at 12.4%, herbicide at 12.0%, aerial application at 9.9%, irrigation fuel and repairs at 9.4%, seed at 8.3% and fungicide at 2.0%.

INTRODUCTION

Excessive rainfall delayed seeding in many areas of the state and was followed by hot, dry weather, both of which contributed to below-average rice yields. The 1993 average state yield is estimated at 112 bu/acre, 10 bu/acre less than for 1992 production. Average state rice yields have not dropped below 111 bu/acre since 1985.

The Rice Research Verification Trials (RRVT), initiated in 1983, use an interdisciplinary approach that stresses management intensity. Information from the trials helps to improve Extension Service recommendations, increasing the potential for profitable rice production by identifying data gaps, accumulating data bases for rice economic programs, providing training to county agents and assisting in the transfer of research technology.

PROCEDURES

Twelve Rice Research Verification Trials were established during 1993 on a total of 705 acres. Seven varieties, 'Alan', 'Jackson', 'Katy', 'Lacassine', 'Millie', 'Newbonnet' and 'Orion', were seeded in the verification fields with an average field size of 59 acres (Table 1). Fields ranged in size from 33 to 100 acres. Nine of the 12 fields were drill or broadcast dry seeded. The remaining fields were water seeded. Counties participating in the 1993 RRVT were Arkansas, Jackson, Lincoln, Jefferson, Mississippi, Phillips, Prairie, Poinsett, White and Woodruff (three fields). Woodruff County had a water-seeded "double" field that included two separate varieties designated Woodruff-K (for Katy) and Woodruff-N (for Newbonnet) and a dry-seeded field. Field size and soil series for each of the 12 fields are shown in Table 1.

Each verification field was selected prior to seeding. Farmer 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 technical assistance was provided by the appropriate Extension specialist or researcher as needed. Economic analysis was performed by a designated Extension Economist.

RESULTS AND DISCUSSION

Grain yield on the RRVT fields averaged 122 bu/acre (Table 1) compared to the projected mean state yield of 112 bu/acre. Lacassine in Phillips County produced 159 bu/acre, the highest yield recorded in 1993. The conventional-till water-seeded field in Jackson County had the lowest yield (98 bu/acre). The low yield was attributed to several factors, including late seeding date, lodging and unfavorable environmental conditions during the growing season. The 1993 RRVT average yield was 17 bu/acre lower than the RRVT average. Several 1993 RRVT fields produced disappointing yields despite appearing to have above-average yield potential. Usual reasons for low yields, such as high disease levels, poor weed control, poor water management or inadequate N fertilizer, did not appear to apply to these 1993 RRVT fields.

Seeding dates ranged from 18 April to 11 June (Table 2). Dry-seeded fields required an average of 10 days between seeding and emergence. The Lincoln County field, which was the only field seeded with Release-treated seed, required only six days for emergence.

Residual herbicide programs were used extensively for the second consecutive year on each verification field. Propanil applied alone was not used as a grass control option. However, propanil was tankmixed with Bolero, Facet or Prowl on five fields (Table 3). Residual herbicides, namely Facet and Bolero, were applied as a delayed pre-emerge on the dry-seeded fields in Arkansas and Poinsett Counties. Bolero (4 lb/acre) was pre-plant surface applied on the conventional-till water-seeded field (Jackson County). Ordram was applied to the no-till water-seeded field (Woodruff County) after the five-leaf stage. The field was water seeded but drained and dried at the four- to five-leaf stage for nitrogen application. The draining and drying allowed barnyardgrass to sprout. Pre-plant application of nitrogen in this system would have eliminated the need to drain and dry and may have prevented the grass seed from germinating. In general, excellent grass control was obtained at all locations. A second herbicide application for grass control was required in half the Mississippi County RRVT field. A single application of a residual herbicide has been successful in controlling grass in the RRVT program for two consecutive years. An additional herbicide application was required on several fields to control broadleaf and aquatic weeds (Table 3). Herbicide comparisons were initiated in three locations including Arkansas, Jackson and Poinsett County locations (Table 3). Delayed preemergence treatments including Facet 0.67 lb/acre, Facet 0.75 lb/acre and a reduced rate of Facet at 0.4 lb/acre and Bolero at 2 pt/acre were compared at the Arkansas County site. All treatments provided excellent barnyardgrass control, but only the Bolero and Facet tankmix treatment controlled sprangletop. Excellent grass and red rice control were obtained with 3 or 4 pt/acre Bolero in Jackson County. The delayed preemergence application of Bolero plus Facet used in Poinsett County provided excellent control of barnyardgrass, signalgrass and crabgrass. Sprangletop control was poor due to late timing since the field was seeded into an eight-day-old seedbed that enabled sprangletop to germinate and emerge before herbicide application.

Phosphorus and potassium were preplant incorporated to the Arkansas County field and the no-till water-seeded fields in Woodruff

County. Zinc EDTA Chelate was applied to the Arkansas County field at the four-leaf stage due to a past history of zinc deficiency. Zinc deficiency was not apparent in this field in 1993.

Foliar fungicides (Rovral or Benlate) were applied to two of the twelve RRVT fields (Table 3). Although sheath blight was present in all fields, only the Lincoln and White County fields required treatment. One application of Rovral was used to treat sheath blight at the Lincoln County location. The White County location, seeded in 'Millie', required treatment for blast disease. In general, neither blast nor sheath blight caused severe yield losses in any RRVT. Fungicide cost averaged only $5.31/acre. The low average cost of fungicide in 1993 reflects the low disease levels encountered.

ECONOMIC ANALYSIS

The break-even grain price for each field, excluding charges for land, overhead and management, ranged from $1.93 to $3.26/bu (Table 4). Based on the weighted means for yield and total specified operating ($262.43/acre) and fixed costs ($55.19/acre), the average break-even price was $2.60/bu (Table 4). Specified operating costs were 13% lower than in 1992 due to fewer fungicide, herbicide and fertilizer applications. The highest yielding field in 1993 (Phillips County) also had the lowest per-acre cost of production. The Woodruff County water-seeded field had the third lowest operating cost per bushel. Nitrogen fertilizer was the single highest input cost, representing 14.9% of the total. Among direct crop inputs, grain drying cost represented 12.4%, herbicides 12.0%, aerial application of pesticides and fertilizer 9.9%, seed 8.3% and fungicides 2.3% of the specified operating cost.

SIGNIFICANCE OF FINDINGS

1. In 1993 the RRVT average yield was 122 bu/acre, the lowest in the RRVT since 1988. Six 1993 RRVT fields yielded lower than the lowest 1992 yield of 122 bu/acre. Low yields were attributed in part to extremely high day and night temperatures. Factors such as inadequate water and nitrogen, disease, late seeding date and weeds were not considered to be major factors in the low yields. Many of these fields appeared to have excellent yield potential prior to harvest. A large number of blanks and partially filled grains were found in several of these fields.

2. Five of the 1993 fields were either in the same field or adjacent to 1992 RRVT fields and were managed similarly in both years. Yield comparisons between years indicate that yields

were 8 to 38 bu/acre lower in 1993 (Table 4). Two major factors that differed and may have contributed to lower yields in 1993 were higher temperatures in late summer and seeding date in the case of the Jackson County location.

3. Different herbicides or rates were compared in three RRVT fields (Table 3). Residual herbicide programs provided excellent grass control for the second consecutive year.
4. The grower was successful in using the no-till water-seeding method in Woodruff County, establishing a stand and reducing time, labor and fuel associated with seedbed preparation. The field was water seeded for stand establishment and drained and allowed to dry at the five-leaf stage prior to N application.
5. Excellent red rice control was obtained for the second consecutive year in the Jackson County water-seeded field. The low yield in 1993 was attributed in part to late seeding and severe lodging.

Table 1. Acreage, soil series, previous crop, yield and cultivar for the 1993 Rice Research Verification Trials.

County-Seeding Method[z]	Acres	Soil Series[y]	Previous Crop	Yield[x] Grain	Milling	Cultivar
				bu/acre	%	
Arkansas-d	70	Crowley & Stuttgart silt loam	Soybean	151	NA[w]	Orion
Jackson-ws	84	Foley Calhoun Complex	Rice	98	58/66	Alan
Jefferson-bd	100	Portland clay	Rice	138	57/67	Katy
Lincoln-d	33	Desha clay	Soybean	133	NA	Lacassine
Mississippi-d	63	Sharkey & Steele silty clay loam	Soybean	104	55/67	Alan
Phillips-bd	38	Tunica & Newellton silty clay	Layout - leveled	159	NA	Lacassine
Poinsett-d	71	Tunica silt loam	Cotton	110	51/67	Jackson
Prairie-d	54	Kobel silty clay loam	Soybean	109	58/67	Katy
White-bd	80	Oaklimeter & Tichnor silt loam	Rice	114	NA	Millie
Woodruff-K-ws	28	Henry & Calloway silt loam	Soybean	125	56/69	Katy
Woodruff-N-ws	32	Henry & Calloway silt loam	Soybean	132	60/69	Newbonnet
Woodruff-bd	52	Calhoun & Calloway silt loam	Rice	107	55/67	Katy
Average	705.0			122		

[z]Seeding method, d = drilled, bd = broadcast dry, ws = water seeding.
[y]Predominant soil series in field determined by the County Soil Survey
[x]Grain yields reported at 12% moisture; Milling yield = whole kernel/total
[w]NA = milling yields not available.

Table 2. Seeding, emergence and harvest dates, seeding rate, stand density and nitrogen rates applied in a three-way split application for the 1993 Rice Verification Trials.

Location-Seeding Method[z]	Stand Density	Seeding Rate	Nitrogen Rate Urea (45%)	Date of Seeding	Date of Emergence	Date of Harvest
	/ft^2	lb/acre	lb/acre	m-d	m-d	m-d
Arkansas-d	31	101	180-100-80	4-21	5-02	9-7
Jackson-ws	28	135	220-100	6-11	6-14	10-25
Jefferson-bd	19	135	200-65-65	5-17	6-02	9-27
Lincoln-d	21	113	260-65-65	5-28	6-03	9-25
Mississippi-d	44	151	220-65-65	4-29	5-08	8-24
Phillips-bd	25	135	250-100-100	4-22	5-03	9-01
Poinsett-d	29	112	220-65-100	5-09	5-17	9-08
Prairie-d	34	133	190-100-100	5-16	6-01	10-8
White-bd	15	135	205-150	5-21	6-01	9-27
Woodruff-bd	21	135	210-120-60	4-29	5-14	10-1
Woodruff-K-ws	18	158	170-100-100	4-18	4-30	9-10
Woodruff-N-ws	15	135	170-100-100	4-18	4-30	9-10

[z]Seeding method, d - drilled, bd = broadcast dry, ws = water seeded.

Table 3. Pesticide[z] treatment rate and dates of application on 1993 RRVT fields.

Location-Seeding Method[y]	Pesticide Treatments and (Dates) of Application[x]
Arkansas-d	Facet 0.75 lb 20 acres; Facet 0.67 lb (5/6) 20 acres; Facet 0.4 lb + Bolero 2 pt 30 acres (5/6); 2,4 - D 1 qt (5/6)
Jackson-ws	Bolero 3 pt (6/9) 42 acres; Bolero 4 pt (6/9) 42 acres; Londax 1.33 oz impregnated on Ammonium Sulfate 50 lb (6/30); Furadan 3G 20 lb (7/13)
Jefferson-bd	Bolero 3 pt + Propanil 3 qt (6/12)
Lincoln-d	Ordram 20 lb (6/24); Londax 1 oz (6/26); Rovral 1 pt (7/21)
Mississippi-d	Bolero 3 pt + Propanil 3 qt (5/6); Ordram 20 lb (6/5) 35 acres
Phillips-bd	Bolero 3 pt + Propanil 2 qt acres (5/7) 19 acres; Bolero 2 pt + Propanil 2 qt (5/7) 19 acres; Londax 0.75 oz (6/3)
Poinsett-d	Facet 0.5 lb + Bolero 2 pt (5/18) 36 acres; Facet 0.6 lb + Bolero 2pt (5/18) 35 acres; Stam 4 qt + Londax 1 oz 9 acres; Whip 0.4 pt (6/21) 8 acres
Prairie-d	Londax 1.0 oz (7/3); Furadan 3G 18 lb (7/5)
White-bd	Facet 0.67 lb + Propanil 1 qt (6/4); Benlate 1.5 lb (8/14); Benlate 1 lb (8/28)
Woodruff-bd	Stam 3 qt + Prowl 2 pt (5/27); Whip 0.5 pt (7/1) 7 acres
Woodruff-K-ws	Londax 0.75 oz (5/6); Ordram 20 lb (6/9)
Woodruff-N-ws	Londax 0.75 oz (5/6); Ordram 20 lb (6/9)

[z]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.

[y]Seeding method, d = drilled, bd = broadcast dry, ws = water seeded.

[x]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.

Table 4. Selected economic information for the 1993 Rice Research Verification Trials.

County-Seeding Method[z]	SCI[y]	SOC	SFC	TSC	Break-even[x]
	$/acre	$/acre	$/acre	$/acre	$/bu
Arkansas-d	133.50	290.05	73.52	363.57	2.41
Jackson-W-ws	158.16	270.77	49.70	330.48	3.26
Jefferson-bd	98.60	251.57	57.33	308.91	2.24
Lincoln-d	148.42	295.23	50.48	345.71	2.60
Mississippi-d	113.48	239.42	54.96	294.37	2.83
Phillips-bd	135.44	262.87	43.59	306.46	2.93
Poinsett-d	120.63	252.81	56.16	308.97	2.81
Prairie-d	104.62	240.28	76.44	316.72	2.91
White-bd	166.27	281.70	51.63	333.24	2.92
Woodruff-bd	106.68	231.97	46.97	278.93	2.58
Woodruff-K-ws	132.50	263.51	39.66	303.16	2.43
Woodruff-N-ws	135.50	262.13	39.66	301.78	2.29
Mean	130.72	261.43	55.19	316.62	2.60

[z]Seeding method, d = drilled, bd = broadcast dry, ws = water seeded.

[z]SCI = Specific crop inputs from specified operating cost including herbicide, fungicide, insecticide, fertilizer and aerial application cost; SOC = Specified operating cost includes SCI costs, irrigation, seed, machinery operation, hauling, drying and interest on operating capital; SFC = Specified fixed cost including depreciation, interest, taxes and insurance; TSC = Total specified operating and ownership cost.

[y]Breakeven price calculated by dividing yield in bu/acre by TSC.

Table 5. Comparison of 1993 and 1992 RRVT yields of five counties with RRVT fields in the same or adjacent fields in both years.

County	Variety	1993 Emerge Date	1993 Yield	1992 Emerge Date	1992 Yield
Arkansas	Orion	5/2	151	4/28	174
Jackson[z]	Alan	6/14	98	5/21	133
Poinsett	Jackson	5/17	110	4/18	148
White	Millie	6/1	114	5/14	122
Woodruff	Katy	5/14	107	4/20	124

[z]Water-seeded field in 1992 and 1993. In 1992 variety was 'Jackson'.

PERFORMANCE TESTING OF RICE IRRIGATION PUMPING PLANTS

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

ABSTRACT

Preliminary work has revealed that the average rice irrigation pumping plant in Arkansas 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 pumped 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 pumping cost factor over which the producer has some control.

Pumping plant evaluations during the 1993 growing season involved 42 tests on 28 different wells. The overall average efficiency of 75% that was measured for 12 of the 28 wells was better than previously measured wells. However, the performance efficiency varied from 49% to 98%. All producers received information on fuel use and pumping capacity, and recommendations for improvements were made for seven of the wells.

INTRODUCTION

Preliminary testing efforts on irrigation pumping plants have established sound performance testing techniques and have revealed that continued work is needed in order to provide the best information to the rice producer (Irrigation Pumping Plant Performance Handbook, 1982). The objectives for the project are as follows:

1. Provide producers with information on irrigation pumping plant performance and make suggestions for improving this performance when appropriate.

2. Provide producers with information on selection of new equipment for optimum performance and efficiency.
3. 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 last 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 will help Arkansas rice producers make more informed decisions relative to their pumping equipment and costs.

PROCEDURE

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

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

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

This specific information is then evaluated to determine recommendations on improving pumping efficiency that can be made to the producer. The recommendations sometimes are made at the test site, but it is often necessary to gather other information before making a recommendation. If a recommendation is implemented, then a follow-up test is conducted if possible.

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 staffs. Scheduling is on a first-come, first-served basis, but 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

Pumping plant evaluations were continued during the 1993 growing season. Forty-two tests were conducted on 28 different wells in five counties: Crittenden, Mississippi, Phillips, Poinsett and Woodruff. Twenty of the evaluations were on diesel-powered wells, nineteen on electric-powered and three on a propane-powered well. Useful information on pumping capacity and fuel consumption were provided to the producers. A summary of this information is presented in Table 1 with a more complete presentation of the data in Tables 2 and 3. Only 16 of the 20 diesel evaluations are shown in Table 2 because it was not possible to make complete evaluations on the other four tests.

In nearly every case, the producer thought the well was pumping more water than was actually measured during the evaluation. One producer suspected his well's performance because it had become difficult to keep his rice watered, even though he had fewer acres. The test revealed that his well was pumping 1650 gpm when it should have been yielding nearer 2200 gpm. He called his well driller that day and made arrangements for them to work on the well. A retest of the well is planned for this season.

Calculations on a propane unit indicated that a fuel cost savings of approximately $1300/year could be realized by converting to a diesel-powered unit. At this savings, it would be possible to pay for the diesel-powered unit in three to four years. 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. Although this did not necessarily affect the well's performance, it did pose a safety hazard, as was pointed out to the producer. Efforts to test another electric well resulted in discovery that the electric panel contactors were burned out. The producer was not aware of this at the time, and he was glad to find it out so he could make repairs before resuming pumping.

Tests on a diesel well revealed that the well probably had screen plugging problems. The well was surging, and the flow rate was only about 70% of what it should have been. The producer was going to have the well screen treated with acid to relieve the plugging. Plans are to test the well again this season.

Tests on two belt-driven electric wells indicated that the pulley ratio and slippage between the motor and pumps resulted in the pumps not turning at the desired speed. This was thought to be the reason why the flow rate of the two wells was significantly lower than expected. One of the producers was going to have his system worked on to address the problem.

There were 19 tests that provided adequate information for determining the specific yield of the well. 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/minute/foot) and ranged from 24-120 gpm/ft and averaged 63 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 wells was measured at 15 locations and ranged from 10 ft to 67 ft, with the average at 24 ft. The depth to water while pumping at these locations varied from 31 ft to 74 ft, and the average was 50 ft. This also varies across the Delta and greatly impacts the pumping hp (horsepower) required.

The specific performance of five different diesel-powered units was determined. Power unit performance is commonly reported as the horsepower hours (hp-hrs) delivered for every gallon (gal) of fuel and is shown in units of hp-hrs/gal. The best performance achieved for these five units ranged from 11.9-15.55 hp-hrs/gal. Nebraska performance standards report that a unit should achieve 16.66 hp-hrs/gal. This 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.

SIGNFICANCE OF FINDINGS

Producers need to know how existing pumping plants are performing in order 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 presented in Extension publications and meetings.

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

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Table 1. 1993 test results on performance of rice irrigation pumping plants.

Energy Source	No. of Tests	Pumping Capacity Range (GPM)[z]	Fuel Consumption Range	Seasonal Fuel Consumption Range[w]
Electric	19	300-2125	7-18 KWH/ac-in[Y]	210-540 KWH/ac[V]
Diesel	20	290-2435	0.39-2.95* gal/ac-in[X] (0.39-0.94)	11.7-88.5* gal/ac[U] (11.7-28.2)
Propane	3	590-1375	1.23-1.53 gal/ac-in	36.9-45.9 gal/ac

[Z]GPM - Gallons per minute
[Y]KWH/ac-in - Kilowatt hours of electricity per acre-inch of water pumped
[X]gal/ac-in - Gallons of fuel per acre-inch of water pumped
[W]Assumes 30 in. pumped per acre
[V]KWH/ac - Kilowatt hours of electricity per acre
[U]gal/ac - Gallons of fuel per acre
*Includes influence of a well with a very low pumping capacity. Range shown in parentheses excludes this well.

Table. 2. 1993 test results on rice irrigation pumping plants, propane and diesel wells.

System Type[z]	Power Unit RPM[y]	Pump RPM	Flow GPM[x]	Fuel Use gph[w]	Fuel Use gal/ac-in[v]	Seasonal Fuel Use gal/ac[u]
Diesel-LST						
3 cylinder	1250	1250	815	1.5	0.83	24.9
	1500	1500	1375	2.6	0.85	25.5
4 cylinder	1200	1090	815	1.1	0.61	18.3
	1500	1360	1270	1.8	0.64	19.2
	1800	1640	1740	2.8	0.73	21.9
	1900	1730	1885	3.4	0.81	24.3
4 cylinder	1300	1300	1045	0.9	0.39	11.7
	1500	1500	1310	1.3	0.45	13.5
	1750	1750	1610	1.9	0.54	16.2
	1900	1900	1775	2.4	0.60	18.0
4 cylinder	1200	1200	1675	1.5	0.40	12.0
	1500	1500	2435	2.9	0.53	15.9
4 cylinder	2000	1670	290	1.9	2.95	88.5
	2175	1810	400	2.1	2.36	70.8
6 cylinder	1750	1590	1290	2.4	0.84	25.2
	1940	1760	1580	3.3	0.94	28.2
Propane LST						
6 cylinder	1300	1300	590	2.0	1.53	45.9
	1500	1500	1035	2.9	1.26	37.8
	1750	1750	1375	3.8	1.23	36.9

[z]LST - Line shaft turbine
[y]RPM - Revolutions per minute
[x]GPM - Gallons of water per minute
[w]gph - Gallons of fuel per hour
[v]gal/ac-in - Gallons of fuel per acre-inch of water
[u]gal/ac - Gallons of fuel per acre. Assumes 30 in. pumped per acre

Table 3. 1993 test results on rice irrigation pumping plants, electric wells.

System Type[z]	Motor	Pump	Flow	Fuel Use	Fuel Use	Seasonal Fuel Use
	RPM[y]	RPM	GPM[x]	KWH[w]	KWH/ac-in[v]	KWH/ac[u]
Electric-LST						
60 hp	1800	1800	2125	47	9.96	298.8
60 hp	1770	1770	1650	50	13.60	408.0
60 hp	1760	—	1450	26	8.10	243.0
30 hp	1750	1750	1350	26	8.67	260.1
—	1750	1750	1395	22	7.10	213.0
50 hp	1800	1800	1080	30	12.50	375.0
60 hp	1770	—	650	15	10.42	312.6
30 hp	1770	—	895	35	17.50	525.0
Electric - SUB						
15 hp	3450	3450	650	11	7.85	235.5
—	3450	3450	1530	32	9.41	282.3
10 hp	3450	3450	350	12	15.00	450.0
7.5 hp	3450	3450	300	8	12.00	360.0
15 hp	3450	3450	760	15	8.93	267.9
15 hp	3450	3450	665	15	10.14	304.2
—	3450	3450	860	17	8.90	267.0
30 hp	3450	3450	850	24	12.70	381.0
—	3450	3450	585	16	12.30	369.0
—	3450	3450	530	15	12.30	369.0
—	3450	3450	770	17	9.94	298.2

[z] LST - Line shaft turbine; 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-inch of water
[u] KWH/ac - KWH of electricity per acre. Assumes 30 in. pumped per acre

FURROW-IRRIGATED RICE FOLLOWING WHEAT

E.D. Vories, P.A. Counce and B.R. Wells

ABSTRACT

A two-year study addressing the feasibility of producing furrow-irrigated rice behind wheat began with the fall 1991 wheat planting. Wheat raised on bedded soil yielded 3,440 lb/acre in 1992 and 2,261 lb/acre in 1993. After the wheat was harvested, rice was seeded on the soil beds on 20 June 1992 and 19 June 1993. Rice yields averaged 3,450 lb/acre in 1992 and 4,822 lb/acre in 1993. Rice yields were not significantly affected by planting treatment (burned or standing straw) in either year.

INTRODUCTION

Experimentation with furrow-irrigated rice by producers in southeastern Missouri led to studies in Missouri (Hefner and Tracy, 1991) and Arkansas (Vories and Counce, 1992; Vories et al., 1993). Potential benefits of furrow irrigation over a continuous flood on rice include water and associated energy savings through reduced deep percolation and lack of levee seepage; simplified flushing of the soil early in the growing season; savings from not constructing and destroying levees; and easier harvests due to quicker soil drying and not having to work around levees. One area in which the simplified flushing and reduced soil work might be particularly valuable is the timely planting of rice following wheat. The objective of this research was to investigate the feasibility of producing furrow-irrigated rice behind wheat.

PROCEDURES

'Cardinal' wheat was seeded on 4 October 1991 and 9 October 1992 on 38-in. beds with 500-ft row lengths. Because the soil beds could not be reworked between the wheat harvest and planting of rice, the beds had to be firm enough to support the combine without rutting. Wheat was harvested on 19 June 1992 and 18 June 1993, leading to extremely late plantings for the rice crops.

The rice study was conducted as a randomized complete block with three replications. Two rice-planting treatments were 1) burning the wheat stubble before planting rice and 2) planting rice into standing wheat stubble. 'Alan' rice was used in the study and seeds were treated with gibberellic acid (Release) to facilitate a rapid, uniform emergence. The rice was drill seeded with an 8-in. drill spacing. No tillage was used on any of the plots between the wheat harvest and rice planting.

Two areas of 2 ft by 75 ft were harvested with a small-plot rice combine from each plot in 1992. The harvest length was reduced to 50 ft in 1993. Moisture content was determined for each harvest sample, and grain yields were adjusted to a 12% moisture content.

1992

Rice plots were 19 ft wide (six 38-in. beds) by 400 ft long, with a 19-ft buffer between adjacent plots (treatments). Rice was seeded on 20 June. All plots were fertilized at the rate of 174 lb N/acre. The N was split among early-season (10 July), IE and IE+two weeks applications (100 lb fb 37 lb fb 37 lb). A "burndown" herbicide application (20 oz/acre Roundup D-Pak) was made on all plots with standing wheat stubble. All subsequent herbicide applications were the same for all treatments. All plots were flushed twice per week. Rice was harvested 6 November.

1993

Rice plots were 38 ft wide (twelve 38-in. beds) by 400 ft long, with a 13-ft buffer between adjacent plots. Rice was seeded on 19 June. All plots were fertilized at the rate of 137 lb N/acre. The N was split between early season (9 July) and IE applications (100 lb fb 37 lb). A burndown herbicide application (20 oz/acre Roundup D-Pak) was made on all plots. In 1992, only the standing-stubble plots received the burndown herbicide. However, the wheat straw did not burn completely in 1993, and some areas of weeds remained after burning. All subsequent herbicide applications were the same for all treatments. All plots were flushed 2-3 times per week. Rice was harvested 15 October.

RESULTS AND DISCUSSION

In 1992, the wheat crop yielded 3440 lb/acre (at 13% moisture) with a test weight of 58 lb/bu, similar to other fields of Cardinal in the area. In 1993, the wheat crop yielded 2261 lb/acre with a test weight of 58 lb/bu. In addition to poorer yield in 1993, the straw did not burn as well, and a few unburned areas remained.

In 1992, the conditions that followed rice planting led to slow development of the rice crop, with grain filling and maturation periods delayed until fall. The results were a very late harvest (November 6) and low yields (Table 1). Conditions were more favorable in 1993, with an earlier harvest (October 15) and higher yields (Table 1). While the yields were significantly higher in 1993, the planting treatments did not significantly affect rice yield in either year.

SIGNIFICANCE OF FINDINGS

The production of furrow-irrigated rice following wheat will require favorable conditions for the wheat harvest to keep the soil beds in suitable condition for timely rice planting. Favorable fall weather will be required to fill and mature the grain. Higher yields were observed in 1993 than in 1992. In fact, with the great variability in Arkansas rice yields experienced in 1993, the rice in this study yielded as well as some earlier-planted fields. As shorter-season rice cultivars are developed, some of the risks due to weather may be reduced. Similarly, shorter-season wheat cultivars should also aid a wheat/rice double crop.

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Table 1. Rice grain yields from the wheat/furrow-irrigated rice study at Northeast Research and Extension Center, Keiser, Arkansas.

	Grain Yield	
Seedbed Treatment	1992	1993
	----lb/acre @ 12% moisture----	
Burn wheat stubble and plant rice	3580	4700
Plant rice into standing wheat stubble	3310	4940
annual mean	3450	4850
LSD(0.05)[z]	785	

[z]LSD for comparing annual means. No significant differences between seedbed treatments in either year.

DEVELOPMENT OF GROUND-BASED EQUIPMENT PEST CONTROL STRATEGIES IN RICE

Joel T. Walker and William W. Casady

ABSTRACT

In the first six months of this project, a design for a four-wheel-drive diesel-engine-powered machine for application of chemicals and fertilizer to rice has been developed. The machine, currently under construction, will include a wide, self-leveling, light-weight boom to minimize yield reduction due to tire tracks. Electronic control of boom level will facilitate levee crossing. A chemical rate controller will ensure proper chemical coverage even when speed varies due to poor traction or crossing levees.

INTRODUCTION

The long-term objective of this project is to develop ground-based equipment strategies for application of pesticides and fertilizer to rice. The early years of this research will be focused on developing ground-based equipment for application of conventional agricultural chemicals and fertilizers to rice in order to evaluate a) mechanical damage to the crop; b) effectiveness of the applications; c) off-target placement of pesticides; and d) cost of ground-based applications versus aerial applications. Later years of the study will bring investigation and initial development of alternate methods of controlling rice pests. This project was undertaken because application of pesticides (particularly aerial applications) has come under increasing scrutiny in recent years due to concerns for the environment, off-target placement of chemicals and endangered species as well as the expense of chemicals, application and equipment. 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. Some chemicals may be labeled for ground application only. 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. In addition, the widespread use of broadcast agricultural chemicals leads to problems with water pollution, damage to adjacent crops due to off target placement (drift) and high cost. Use of chemicals could be replaced or reduced by technology that uses high-speed-computer-controlled instruments to eliminate pests mechanically or electronically or to place chemicals selectively. To accomplish this, 1) the best alternative methods of pest destruction must be determined and evaluated for effectiveness and cost; 2) an imaging system must be developed to guide the pest destruction systems to the crop pests; and 3) a means of transporting equipment through or over the field must be developed.

PROCEDURES

This is the first year of this project. Development of an engine-powered tractive system for carrying chemicals and equipment through flooded or muddy rice fields was begun with receipt of funding on 1 July 1993. A Research Assistant hired to work on this project began work on 3 January 1994.

RESULTS AND DISCUSSION

After careful consideration of various designs, an existing tractive frame has been modified to four-wheel drive, a 60-horsepower diesel engine has been obtained for installation in the spray tractor, and an order for a 60-ft-wide light-weight fiberglass spray boom with automatic leveling and spray rate controls is under bid. Four-wheel drive is considered a necessity for the muddy, wet conditions usually encountered in rice fields. Tire selection will be critical for proper operation in the field. The existing traction frame was under-powered after application of the four-wheel drive components. A new engine was obtained gratis from John Deere Corporation. The light-weight, self-leveling spray boom will be a key component of the sprayer. Since tire tracks may reduce yield, a wide boom is necessary. But tire tracks may become ruts, causing wallowing of the machine and undesirable changes in boom tip height. Crossing levees can also cause substantial motion of the boom tip. An accurate spray controller is required because the ground speed may vary due to varying traction conditions and levee crossing.

Further development of the tractive unit will proceed with consideration of rice soil conditions, levee crossing, crop and field damage, volume-rate of chemical or fertilizer application, minimization of off-target chemical placement (drift) and typical field size (refilling) as well as operator safety and comfort while crossing levees. The effects of tires on levees during crossing must also be considered. Damage to levees requiring repair after each chemical application would be impractical. Also, the effects on the machine when required to cross levees at various angles must be determined. Low-volume chemical injection systems will be considered in an effort to limit operator exposure to the mixing process, to provide for accurate chemical metering and for control of dosage as ground speed varies due to soil conditions and levee crossing. Later adaptation may include computer monitoring and control to provide for field mapping technology. This could lead to application of chemicals only where particular problems exist. The prototype machine will be further refined and tested in the field during the next growing season.

SIGNIFICANCE OF FINDINGS

Since this project has been underway about six months and the machine has yet to be tested, practical significance is not yet known. The machine will be tested at the Rice Research and Extension Center in Stuttgart during this growing season. Test plots will be developed to assess the effects of tire tracks on yield in the rice crop. Field trials of the machine will assist in identifying practical problems with traction, levee crossing, boom operation and effective field capacity (amount of land covered in a period of time). Development of the machine will continue during this season with investigation of active suspension components to facilitate levee crossing with minimal damage to the levee.

IMPROVEMENT IN DISTRIBUTION OF AERIAL- AND GROUND-APPLIED GRANULAR MATERIALS

Joel T. Walker, Dennis R. Gardisser and Bill Barnes

ABSTRACT

Fourteen aircraft calibration workshops including over 148 analyses of granular material distribution were held this year. Such clinics resulted in substantial improvement in uniformity of granular material distribution by the aircraft tested. Also, two sieve sizes of urea and ammonium sulfate standard grade were studied. Particle mass, height, width, length and terminal velocity were measured for sets of 100 particles of each material and size. A laboratory experiment was conducted to model an agricultural aircraft spreading granular material. An "air-gun" was used to "shoot" particles at a target. Initial velocity of each particle was measured, and initial direction was assumed constant. The impact locations of the particles were recorded and compared with the impact locations predicted by the FERTZ model developed by Walker and Gardisser (1988).

INTRODUCTION

This project, which was terminated 30 June 1993, has aimed to develop equipment and methods to improve the uniformity of fertilizer distribution by aerial equipment. One of the major problems that agricultural aviators face is the wide variety of material they are asked to spread, even varying greatly in properties among loads of the same material. In order to better understand this problem, development (Walker and Gardisser, 1988 and 1989) and verification (Barnes and Walker, 1991; Barnes et al., 1993a, b) of the computer model FERTZ was undertaken.

MATERIALS AND METHODS

The objectives have been largely accomplished through a cooperative effort between research and extension. The principal investigators have developed and continue to use equipment and procedures

(Gardisser et al., 1985, 1990 and 1993) for measuring the dispersion, transport and deposition of particles from aerial equipment. For the past nine years, this equipment has been used at workshops to calibrate and adjust aerial equipment while gathering valuable data. These workshops were performed at the request of the pilots who spend valuable time during the workshops away from their businesses of operating expensive aircraft. State and county Cooperative Extension personnel assist in workshop operation.

Verification of the FERTZ model involved shooting individual fertilizer particles in the lab under controlled conditions while measuring the landing point and as many important variables and particle properties as possible. The FERTZ model was then used to simulate trajectories for these particles. The results of these two tests were compared. For the laboratory test, weight, height, width, length and terminal velocity were measured for individual particles from sets of 100 for each of two different sieve sizes of two different materials. The particles were then launched from an air-gun tube toward a target 25 ft away. The exit end of the gun tube was positioned 43 in. off the ground. A Laserex Model LDP-300 laser pointer was used to sight through the tube at a point located 45 in. above the ground on a sheet of plywood 25 ft away. Particles were projected at about 120 ft/sec (82 mph for a particle leaving an aircraft/spreader traveling 130 mph). A bullet chronograph was used to measure the initial velocity of particles exiting the tube. The X and Y coordinates of the landing point, terminal velocity, exit velocity, angle of the gun and position of target were recorded for individual particles for later use in the FERTZ model. The two materials tested were prilled urea and ammonium sulfate standard grade. The materials were sieved to provide two distinct size classes. Urea was separated using #4 and #5 U.S. standard sieves. The ammonium sulfate was sieved using #5 and #6 sieves. Particle mass was measured using a Fisher Scientific balance, Model A-200 DS. Individual particle dimensions were measured using a Jones and Lamson Optical Comparator and Measuring Machine Model BC-14. First height (shortest dimension) and width (median dimension) were measured; then the stage was rotated 90°, and the length (longest dimension) was measured. An elutriator was used to measure the terminal velocity of individual particles.

RESULTS AND DISCUSSION

As a direct result of the adjustments made at workshops (Walker and Gardisser, 1987), significant improvement has been measured in deposition uniformity from aircraft. In addition, the investigators have collected data on a variety of aircraft/spreader combinations, leading to an understanding of the basic problems of setup and operation of the various equipment (Gardisser and Walker, 1990; Gardisser et al., 1993). Both pilots and rice farmers appreciated the workshops. Fourteen workshops were held this year with 148 analyses performed.

The physical properties were measured, and the average and standard deviation for terminal velocity (ft/min), particle mass (grams) and particle height, width and length (in.) were calculated and are given in Table 1. The initial velocity achieved by the particle (ft/sec), horizontal landing points (X, in.) and vertical landing points (Y, in.) for laboratory trajectories were recorded. The vertical landing points (Y, in.) calculated by the FERTZ simulation were recorded. Since there were no wind effects in the model and the initial direction was assumed constant, the horizontal landing point predicted by the FERTZ model was always on the Y axis. The average and standard deviation for variables listed above were calculated and given in Table 2. From the values in Table 1, the sphericity was calculated. Sphericity was included in the analysis but was not found to be as important as height, width and length. A second variable D was calculated as the difference between the observed vertical landing point and the simulated vertical landing point. This variable was created to test for significant differences between laboratory and model results. The mean value for the horizontal component of the landing point for all of the data was found to be significantly different ($\alpha = 0.05$) from zero. This would indicate that the laboratory setup was not able to adequately control the initial direction of the particles leaving the tube. The univariate procedure was also used to test the hypothesis that the difference in the vertical components of the landing points (between the laboratory and FERTZ model) was zero. The mean value for the difference in the vertical components of the landing points for all of the data was found to be significantly different ($\alpha = 0.05$) from zero. This also indicated that the laboratory setup was not able to adequately control the initial direction of the particles leaving the tube. Thus the mathematical model was not able to accurately predict the trajectories of the particles. The general linear models procedure was used to predict terminal velocity as a function of weight, height, width, length and sphericity. Material type and size were found to be significant, indicating that material type and size would require separate models. The terminal velocity model for all particles had an R-Square of 0.72. This statistical model would allow the terminal velocity to be predicted from the particle weight, width and length. A regression model was used to predict the simulated vertical impact locations as a function of weight, height, width, length, sphericity, terminal velocity and initial velocity. Material type and size were not found to be significant, indicating that the same statistical model could be used for the different material types and sizes. The simulated vertical impact location was modeled for the entire range of data. The final model, which included weight, width, length, terminal velocity and initial velocity, was found to be significant ($\alpha = 0.05$) and had an R-Square of 0.94. Effects of weight, height, width, length, sphericity, terminal velocity and initial velocity on the horizontal impact location could not be determined.

SIGNIFICANCE OF FINDINGS

The aerial application industry is changing rapidly with the addition of turbine engines, recommendations for high total rates of fertilizer application and the introduction of granular herbicides requiring low (10-20 lb/acre) application rates. Results from years of calibration workshops indicate the extreme importance of regular calibration and adjustment of equipment to accommodate changing materials, operating conditions and wear (Gardisser et al., 1993).

Laboratory tests of particles have shown the extremely variable nature of particle trajectories. Terminal velocity was found to be important in predicting the trajectory of the particles. Measuring the variation in particle mass, height, width, length and terminal velocity allowed those values to be quantified for future research. The terminal velocity was highly correlated to particle weight, width and length. While the FERTZ model results were predictable, the correlation with actual particle trajectories was poor. Further research to verify this useful model is recommended.

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Table 1. Simple statistics--mean (std. dev.)-- for weight, height, width, length and terminal velocity, 1993.

Material	Size	N	Weight	Height	Width	Length	Terminal Velocity
			gram	in.	in.	in.	ft/min
Ammonium Sulfate	#5	113	0.0728[z]	0.156	0.181	0.193	1952
			(0.0136)	(0.017)	(0.013)	(0.014)	(115)
Ammonium Sulfate	#6	134	0.0419	0.128	0.152	0.164	1827
			(0.0080)	(0.013)	(0.011)	(0.014)	(98)
Urea	#4	115	0.0766	0.165	0.197	0.219	1856
			(0.0152)	(0.019)	(0.017)	(0.022)	(126)
Urea	#5	136	0.0463	0.147	0.164	0.177	1771
			(0.0093)	(0.014)	(0.014)	(0.017)	(115)

[z]Mean (std. deviation)

Table 2. Statistics--mean (std. dev.)-- for initial velocity, horizontal and vertical landing point and simulated vertical landing point, 1993.

Material	Size	N	Initial Velocity	Air-gun X	Air-gun Y	Simulation Y
			ft/sec	in.	in.	in.
Ammonium Sulfate	#5	113	116[z]	1.99	-12.55	-16.57
			(12)	(5.42)	(5.51)	(3.58)
Ammonium Sulfate	#6	134	124	2.68	-11.82	-15.99
			(13)	(6.26)	(5.34)	(3.21)
Urea	#4	115	115	3.04	-11.68	-15.60
			(12)	(7.18)	(5.81)	(3.18)
Urea	#5	136	118	1.16	-12.24	-18.53
			(10)	(5.69)	(5.07)	(3.69)

[z]Mean (std. deviation)

UTILIZATION OF RICE BRAN PROTEINS IN FOOD

Navam Hettiarachchy, Patti S. Landers, Kaye Griffin and U. Kalapathy

ABSTRACT

Rice bran protein concentrates (RBPC) with varying protein content (34-89%) were prepared using a procedure developed in our laboratory. RBPC with 70% protein was used to test nitrogen solubility, emulsifying and foaming functional properties.

The nitrogen solubility increased to about 50% at pH 2.0 and to about 98% at pH 11.0. Low nitrogen solubility was observed between pH 4.0 and 9.0.

At 1.0 and 3.0% protein concentration, RBPC had higher emulsifying activity (EA) and stability (ES) (EA 75 and 93.8%; ES 70 and 87.5%, respectively) when compared with bovine serum albumin (BSA) protein standard (EA 25 and 62.5%; ES 18.8 and 56.3%, respectively).

At 5.0% protein concentration, RBPC had much lower overrun values at all whipping times (5-30 min) than egg white protein standard. However, the protein in RBPC was able to withstand a longer period of whipping than egg white protein.

These findings demonstrate that RBPC should find wide application in emulsified and foaming food products. The demand for RBPC as a functional food ingredient should be even greater owing to the hypoallerginicity of rice bran protein.

INTRODUCTION

Rice bran is a protein-rich and under-utilized by-product of the rice processing industry. Discovery of a novel use for rice bran would add value to the rice industry. Rice bran contains 15-20% protein (Saunders, 1990) with a high lysine content (Juliano, 1985). This makes rice bran a high-quality protein source for human consumption. Considering the excellent quality of rice bran protein, a need exists to explore various food uses for this product. Rice bran protein has been regarded as hypoallergenic (Landers, 1992). Rice bran protein concentrate could be one of the alternatives that could replace milk and soy protein in infant formulas.

Functionality can be defined as the physicochemical properties and behavior of proteins in a food system, including their interaction with other food components. The functionality of a protein depends on its composition and the structural characteristics of the individual protein fractions that compose it. Knowledge of the functional properties enables the selection of a food protein most suitable for a specific application without requiring exhaustive testing.

There is a need to develop improved protein extraction procedures to better understand the functional properties of rice bran protein at the molecular level.

Solubility, emulsification and foaming are some of the major functional properties of protein that affect their utilization (Kinsella, 1976).

Only a few articles have been published on rice bran protein isolation (Chen and Houston, 1970; Connor et al., 1976; Betschart et al., 1977). Also, limited information is available on the functional properties of rice bran protein (Bera and Mukherjee, 1989). The objectives of our research were 1) to prepare rice bran protein concentrate and 2) to study the functional properties of rice bran protein concentrate.

PROCEDURES

Rice Bran Protein Preparation

A procedure developed in our laboratory was used to prepare rice bran protein concentrates (RBPC). Rice bran protein concentrates with varying protein content (34-89%) were prepared by controlling the conditions (extent of defatting, degree of milling and pH) of extraction.

Protein Functionality

Emulsifying activity and emulsion stability of the RBPC were determined by the modified methods of Yatsumatsu et al. (1992). Bovine serum albumin (BSA) was included as the standard protein for comparison. To 50 ml of protein colloidal solution (1% and 5%, pH 7.0), 50 ml of vegetable oil (IGA 100% soybean oil, IGA, Inc., Chicago, IL) was added, and the oil-protein mixture was emulsified by sonication (control setting 3, 50% duty cycle; Branson model 450, Branson Ultrasonics, Dan bury, CT) for 1 minute. Five milliliters of the emulsion was centrifuged at 130 x g for five minutes. The emulsifying activity was calculated as:

$$\frac{\text{The height of emulsified layer in the centrifuge tube}}{\text{The height of whole layer in the centrifuge tube}} \times 100\%$$

To measure the emulsion stability, the emulsion prepared as above (50 ml) was heated for 30 min at 80 C and cooled, and an aliquot of emulsion (5 ml) was centrifuged at 130 xg for five minutes. Emulsion stability was expressed as:

$$\frac{\text{The height of remaining emulsified layer in the centrifuge tube}}{\text{The height of whole layer in the centrifuge tube}} \times 100\%$$

Foaming Properties

Foam formation. Foam was prepared according to the method of Phillips et al. (1990). The protein colloidal solution (5%, pH 7.0) was whipped for 25 min in a double beater Sunbeam Mixmaster (Sunbeam Appliance Company, Milwaukee WI), and the weight of the foam was measured at 5-min intervals. The overrun, defined as the change in density of a given volume of foam and expressed as percent change in volume, was calculated as:

$$\frac{\text{wt of 100 ml protein suspension/solution - wt of 100 ml foam}}{\text{wt of 100 ml foam}} \times 100\%$$

Foam stability. The drainage from foam was monitored to measure foam stability according to the method of Phillips et al. (1987, 1990). The protein colloidal solution was whipped for a specified time period of 5, 10, 20 or 25 min. After each period of whipping time, the drainage was collected through a hole at the bottom of the bowl. The time required to obtain 50% drainage was used as the index of foam stability.

RESULTS AND DISCUSSION

Rice Bran Protein Concentrate

The protein content in the prepared RBPC ranged from 34% to 89%. The extraction conditions were optimized by varying extent of defatting (% residual oil in bran), milling (varying mesh size) and pH of solubilization (8.0 - 12.0) to obtain products with a range of protein concentrations. RBPC containing 70% protein was found satisfactory to investigate functional properties.

The nitrogen solubility of RBPC was about 50% at pH 2.0 and about 98% at pH 11.0. Low nitrogen solubility (less than 10%) was observed between pH 4.0 - 9.0.

Protein Functionality

Emulsifying properties. Emulsifying activity (EA) and emulsion stability (ES) of both BSA and RBPC are shown in Fig. 1 and 2. At both 1% and 3% protein concentrations, RBPC had higher emulsifying activity (EA 75.0 and 93.8%; ES 70.0 and 87.5%, respectively) than BSA protein standard (EA 25.0 and 62.5%; ES 18.8 and 56.3%, respectively). This study showed that RBPC could be a better emulsifier than BSA and perhaps find a variety of product applications.

Foaming properties. Figure 3 shows foaming property of RBPC and egg white protein. RBPC had much lower overrun values at all whipping times (5-30 min) than egg white protein standard (after 25 min about 700% for egg white and 370% for RBPC). However, with continuous whipping, RBPC overrun increased, indicating progressive foam formation. For egg white protein, overrun decreased slightly after 20 min whipping, indicating that more foam was destroyed than formed. Our results showed that RBPC can withstand a longer period of whipping than egg white protein without foam destruction.

As shown in Fig. 4, foam stability of RBPC was lower than that of egg white protein. However, the stability of RBPC foam increased with increasing whipping time. The stability of egg white protein decreased with increasing whipping time. When measuring foam stability, the drainage of egg white was a clear protein solution, but the drainage of RBPC was fine foam, which passed through the drainage hole very easily. Therefore, the true stability of RBPC might be higher than that measured by drainage.

SIGNIFICANCE OF FINDINGS

By optimizing the conditions (extent of defatting, degree of milling, pH of solubilization and extent of ethanol washing) of extraction, RBPC can be prepared at varying protein levels (34-89%). RBPC with varying protein levels should find various food applications, including specialty hypoallergenic food products.

RBPC had better emulsifying activity and emulsion stability than BSA protein standard. RBPC could foam. Its overrun and foam stability increased with whipping time. It could find use in desserts and toppings and other products that require extended foam stability.

Our results demonstrated that rice protein isolate containing 89% protein can be produced using food-grade solvents. Research is also in progress to obtain almost 100% pure bran protein to investigate hypoallergenic properties and physicochemical properties of rice bran protein that could find utilization in various food products.

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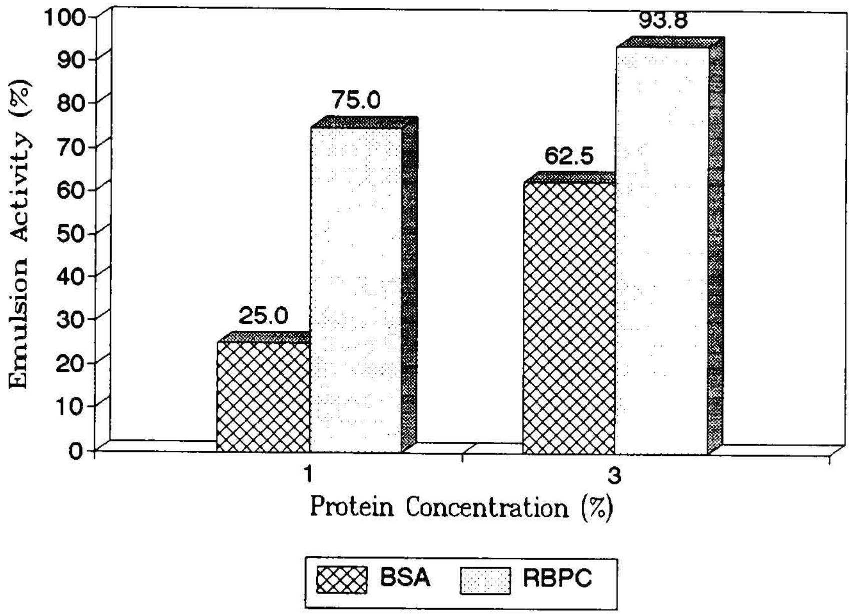

Fig. 1. Emulsion activities of RBPC and BSA.

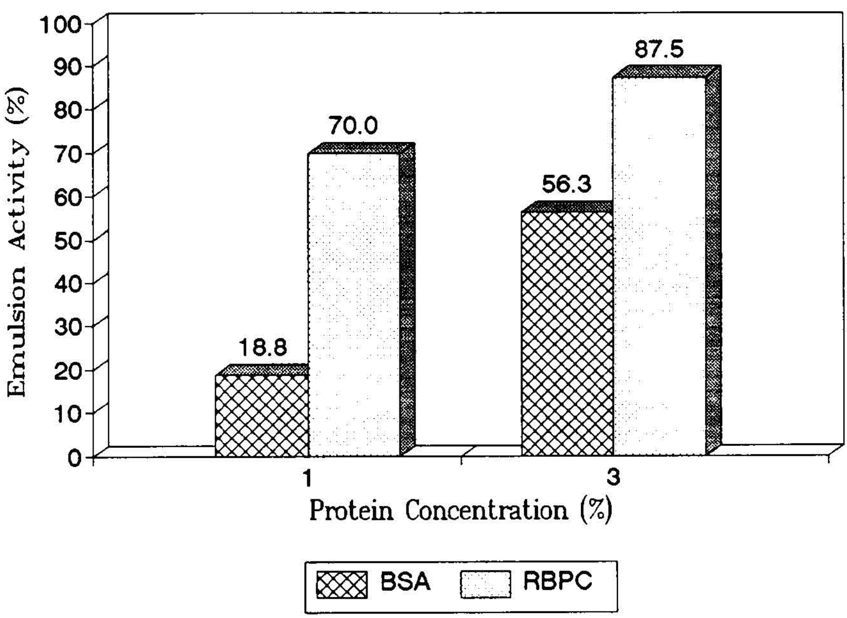

Fig. 2. Emulsion stabilities of RBPC and BSA.

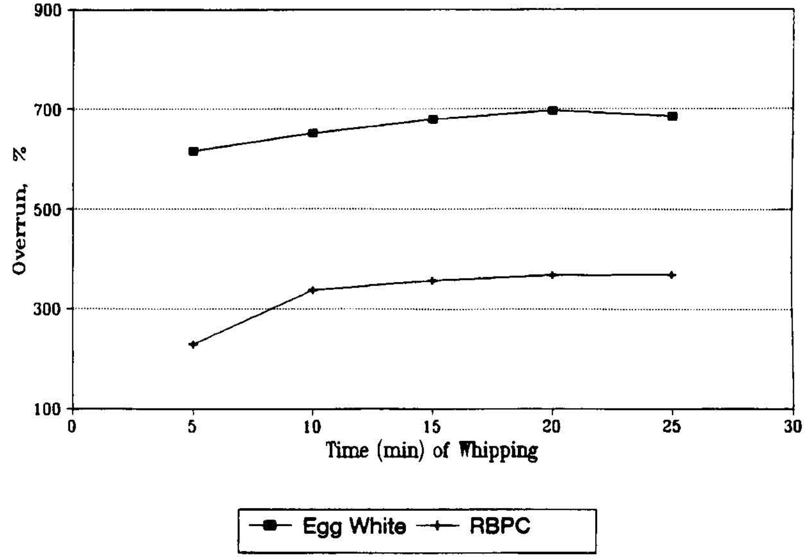

Fig. 3. Overrun property of RBPC and egg white.

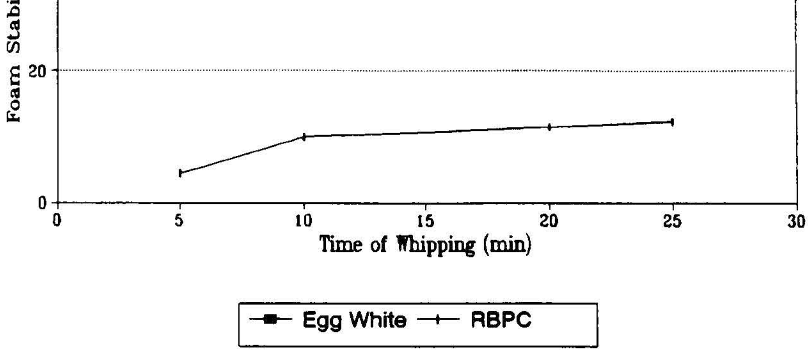

Fig. 4. Foam stability of RBPC and egg white.

DEVELOPMENT OF METHODS TO MAKE SPECIFICATIONS FOR RICE FLOUR

Navam Hettiarchchy, Virginia K. Griffin, Ronald McNew and Karen A.K. Moldenhauer

ABSTRACT

Our research has focused on developing tests that can predict the functionality of rice flour as a food ingredient. In previous work, we found that gelatinization influences functionality. The swelling potential of the starch granule was a method used this past year to determine how the swelling of the starch granules correlate with known tests used in the rice industry, such as amylose content, Brabender visco/amylographs and gel consistency. The swelling factor at 65 C correlated with amylose content, Brabender visco/amylographs and gel consistency at r = 0.854, 0.900 and 0.53, respectively. A texture analyzer was used to determine the firmness of cooked rice flour from long-, medium- and short-grain varieties at 70 C and at room temperature (RT). The increase in firmness from 70 C to room temperature was significant ($P < 0.05$) for all long-, medium- and short-grain varieties tested, except Calmochi-101 and L202, which are short- and long-grain cultivars, respectively.

INTRODUCTION

With the increase in rice consumption in the U.S. over the past few years, there has also been an increase in the use of rice flour as an ingredient in further-processed foods. Arkansas produces about 42% of the rice grown in the United States (USDA, 1994). There are variations in functional properties of flour from different varieties as well as a single variety grown under different conditions. With the variability comes the difficulty of predicting the behavior of flour as well as the difficulty of writing specifications for buyers. Cooking, eating and processing qualities that include flavor, integrity, appearance and texture (firmness, adhesiveness, etc.) are important factors in marketing rice (Juliano, 1985). Since these traits are primarily governed through inheritance, breeding for these quality traits could be beneficial to our rice program.

Although many factors influence cooked rice texture, our research has centered around gelatinization. Gelatinization takes place when rice kernels or rice flour is cooked. Gelatinization is the process in which the starch granule takes on water and becomes swollen. The amount of water absorbed determines the stickiness of the kernel or the viscosity of the flour paste. Gelatinization influences the functionality of the flour as it is used in food processing. In previous work, proteins were correlated with gelatinization (Hamaker and Griffin, 1993; Hamaker et al., 1991; Hamaker and Griffin, 1990). Now research is directed towards the swelling of the starch granule during gelatinization and cooking of rice flour to measure the firmness of pastes. Amylose content is the most commonly used chemical test for rice quality (Juliano, 1985). In combination with amylose content, gel consistency tests and Brabender visco/amylographs were run and used for correlation with the swelling potential in current work. These properties will be useful in gaining a better understanding of how rice flour functions in processed foods. This information should lead to developments of methods to predict functional properties that would in turn help to develop screening tests for the rice breeding program and to help write rice flour specifications for rice processors.

PROCEDURES

The swelling factors of starch granules of 10 varieties ('Calmochi-101', short grain; 'Mars', 'Congui' and 'M-201', medium grain; and 'Katy', 'L-202', 'Lemont', 'Millie', 'Rexmont' and 'Toro II', long grain) were determined. Rice flour (100 mg) from each variety, in duplicate, was placed in a test tube with 10 ml water, and the tube incubated with constant shaking in a water bath at the required temperature (50, 60, 65, 70, 75 or 80 C) for 30 min. After cooling the tubes rapidly to 20 C, 1.0 ml of blue dextran (5mg/ml and mol wt approx. 2,000,000 daltons) was added and centrifuged. The supernatant containing the blue dextran was read at 620 nm. (A tube with only blue dextran and H_2O was included for a control.) This is based on the principle that the blue dextran (dye) with its high molecular size cannot pass through the swollen granule and hence will remain in the supernatant. The higher the swelling of starch granule, the higher will be the detection of blue dextran and the higher the absorbance at 620 nm. The absorbance readings were used to calculate the swelling factor as follows:

$$SF = 1 + \{(7,700/W)[(A_s - A_r)/A_s]\}$$

where SF is the swelling factor, W is weight of rice flour in milligrams, A_s is absorbance of supernatant, A_r is absorbance of reference that contained no starch (Tester and Morrison, 1990).

Amylose content, the most commonly used chemical test for quality, was determined on each of the 10 varieties included in this project. Defatted flour (100 mg) from each variety, in duplicate, was placed in a screw-capped test tube with 1 ml of 95% ethanol and 9 ml of 1 N NaOH. After boiling for 10 minutes, this mixture was brought to volume with water in a 100-ml volumetric flask. A 5-ml portion was transferred into another 100-ml volumetric flask; 1 ml of 1 N acetic acid and 2 ml of Iodine solution were added, and the flask was brought to volume with water. After 20 min, the absorbance was read at 620 nm. Amylose content was determined by reference to a standard curve and expressed on a dry weight basis (Landers et al., 1991).

Brabender visco/amylographs were obtained by mixing 50 g flour and 300 ml water in a blender for 1.5 min. The flour slurry was washed with another 150 ml of water into the viscometer bowl. The contents were heated at 95 C for 20 min, and the peak viscosity was determined as described in AACC procedure 61-01 (AACC, 1991).

Gel consistency results for the 10 varieties were obtained by weighing 100 mg of finely ground (100 mesh) flour (in duplicate) into test tubes. The flour was wetted with 0.2 ml of 95% ethanol containing 0.025% thymol blue following 2 ml of 0.2 N KOH. The tubes were covered, placed in a boiling water bath for 8 min, then cooled in an ice bath for 30 min. The gel consistency was measured and expressed as the total length of the gel in mm, as described by Cagampang et al. (1973).

The Universal TA-XT2 Texture Analyzer was used to determine the strength of the gelatinized paste of the 10 flours. A beaker with rice flour (8 g) and 100 ml water was placed in a boiling water bath, heated to boiling and stirred approximately 20 revolutions/min with a Teflon-coated rod for 15 minutes to keep the flour particles in suspension. The contents were cooled to 70 C, and firmness of the paste was recorded as the force peak of the first compression in Newtons. A beaker of the same cooked flour paste was kept and cooled for 1 hour to room temperature, and the firmness of this cooled paste was recorded using the same procedure as described above.

RESULTS AND DISCUSSION

Swelling factor results (Table 1) indicate that short- and medium-grain rices generally have a higher swelling factor than long-grain rices with the exception of Congui, a medium-grain rice that had a relatively low swelling factor at high temperatures. This indicates a more immediate and complete swelling of the short and medium starch grains (with the one exception) during gelatinization. Results from this procedure showed that the short-grain (Calmochi-101) variety had reached its maximum swelling potential at 65 C while the remaining medium-(M-201) and long-grain (Katy, L-202, Lemont, Millie and Toro II) varieties were still swelling at 80 C. Research is in progress to investigate swelling factors of these rice varieties at temperatures above 80 C to determine varietal differences, if any.

Amylose content, Brabender peak viscosity and gel consistency test results are given in Table 2 for the rice four of each of the 10 rice varieties and correlated to the swelling factor. Although swelling factors at all the temperatures were used for correlations, the swelling factors at 65 C appeared to have the highest correlations. The swelling factor at 65 C correlated with amylose content, Brabender peak viscosity and gel consistency at r = 0.854, 0.900 and 0.530, respectively.

Table 3 shows the firmness of rice pastes cooled to 70 C and room temperature (RT). The increase in firmness from 70 C to room temperature was significant ($P < 0.05$) for all long-, medium- and short-grain varieties, except Calmochi-101 and L-202, which are short and long grain, respectively. Research is in progress to confirm this finding and to explore the feasibility of using flour paste firmness as an indicator for varietal identification.

SIGNIFICANCE OF FINDINGS

By correlating the swelling factor with well-known tests such as amylose content and Brabender visco/amylographs, progress was made in predicting rice quality. With the significant differences in firmness tests on pastes, we hope to improve on that procedure as well as to run tests for gelling characteristics of the cooked flour slurry. We will also explore the feasibility of using flour paste firmness as an indicator for varietal identification.

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Table 1. Swelling factor values[z] of ten cooked rice flours at various temperatures.

		Temperatures, C					
Type	Variety	50	60	65	70	75	80
S	Calmochi-101	6.5	12.6	22.9	23.6	24.2	22.9
M	Congui	6.0	6.0	5.3	5.8	7.0	6.1
M	M-201	5.6	8.3	8.3	8.1	6.8	8.5
M	Mars	8.5	8.7	9.7	10.0	9.5	9.7
L	Katy	3.4	3.1	4.6	6.4	7.1	9.5
L	L-202	2.7	1.0	3.0	4.0	4.9	7.0
L	Lemont	3.6	2.4	4.4	5.5	6.6	8.8
L	Millie	2.1	2.6	1.9	3.7	3.8	4.3
L	Rexmont	4.5	5.6	5.3	5.8	6.3	6.1
L	Toro II	2.8	3.0	4.4	4.5	5.0	8.7

[z]Values are means of duplicate analyses.

Table 2. Amylose content, Brabender peak viscosity and gel consistency of ten rice varieties.[z]

Type	Variety	Amylose Content	Brabender Peak Viscosity	Gel Consistency
		%	BU	mm
S	Calmochi-101	9.5	355	117.5
M	Congui	34.8	595	20.0
M	M-201	19.5	795	56.5
M	Mars	19.7	724	60.0
L	Katy	29.7	790	57.5
L	L-202	34.3	630	34.0
L	Lemont	29.8	808	72.5
L	Millie	30.2	910	33.0
L	Rexmont	31.5	603	25.0
L	Toro II	22.4	740	130.0

[z]Values are means of duplicate analyses.

Table 3. Firmness (Newtons) of rice gels at 70 C and room temperature.[z]

	Temperature[y]	
Variety	70 C	Room Temp.
Calmochi-101	0.194a[x]	0.238a
Congui	0.216ab	0.299abc
M-201	0.272b	0.422e
Mars	0.253ab	0.395de
Katy	0.226ab	0.316bc
L-202	0.201ab	0.253ab
Lemont	0.228ab	0.370cde
Millie	0.240ab	0.370cde
Rexmont	0.235ab	0.336cd
Toro II	0.216ab	0.338cd

[z]Values are means of replicate analysis.

[y]Means in the same column with different superscripts are significantly different by the 5% level LSD. From the analysis of variance, the *P* values were: Variety x Temp, $P = 0.065$; Variety, $P = 0.007$; Temperature, $P < 0.001$.

[x]The increase in firmness from 70 C to room temperature was significant ($P < 0.05$) for all varieties except Calmochi-101 and L-202.

NATURAL ANTIOXIDANTS FROM FENUGREEK AND RICE BRAN

Navam Hettiarachchy, U. Kalapathy and Kaye Griffin

ABSTRACT

Antioxidant activity of extracts from defatted rice bran and fenugreek were investigated in pure soybean oil using oxidative stability instrument (OSI). The rice bran and fenugreek extracts prepared by using the procedures developed in our laboratory exhibited antioxidant activity.

The induction times (the time taken to produce volatiles at 97.8 C) were used to compare the stability of the oil with and without additives. The antioxidant activities (induction times) of the rice bran and fenugreek extracts at 500 ppm (level not restricted by FDA for extracts), synthetic antioxidant butylated hydroxyanisole (BHA)/butylated hydroxytoluene (BHT) mixture at 200 ppm (level restricted to 200 ppm by FDA) and control (oil without additives) were 13.1, 12.1, 13.9 and 11.0 hours, respectively. These preliminary results demonstrate that natural rice bran and fenugreek extracts could be alternate sources for synthetic antioxidants.

INTRODUCTION

Oxidation of lipids in food products causes changes in food composition with the formation of volatile compounds that give objectionable flavors and leads to deterioration of food quality (Erikson, 1982). Currently synthetic antioxidants such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and tertiary butylhydroxyquinone (TBHQ) have been used as antioxidants in foods to reduce deterioration, rancidity and discoloration due to lipid oxidation. The use of synthetic antioxidants, however, has begun to be restricted in food applications because of their toxicity (Baren, 1975; Fazio and Sharma, 1987). Due to these developments, there is a pressing need to find safe and economical antioxidants to replace these synthetic chemicals.

Hence, there is a demand for natural antioxidants by the food industry and consumer.

There has been a continuous search for effective natural antioxidant extracts, and recently several articles have been published on various natural sources as antioxidants (Shahidi et al., 1992; Onyeneho and Hettiarachchy, 1991, 1992, 1993). Only natural antioxidant extracted from rosemary is commercially available. However, its intense herb flavor, insolubility with non-oils, greenish color and high cost limit the use of rosemary in a variety of food applications. Therefore, a need for bland, colorless and cost-effective natural antioxidant extract that will have wide application continues to exist.

Several articles have been published on antioxidant activity of rice seeds and hulls (Ramaratnam et al., 1989a,b; Larson, 1988), but very little information is available on the antioxidant property of rice bran extract (Kanno et al., 1985). The antioxidant activity of fenugreek extract has been reported (Mehta and Zayas, 1993). However, the extractions (from rice bran and fenugreek) involved use of non-food-grade solvents such as chloroform, methanol and dichloroethane, and toxicity may be a concern.

The objectives of our research were to prepare extracts from selected crops using food-grade solvents and to evaluate these extracts for antioxidant activity. Rice bran and fenugreek seed were selected for investigation of antioxidant activity. Rice bran is a protein-rich, underutilized byproduct of the rice processing industry. If a novel use can be found, it would add value to the industry. Fenugreek seed has been used as a spice for decades and has been shown to have medicinal value.

PROCEDURES

Preparation of antioxidant extracts from rice bran and fenugreek

Antioxidant extracts from rice bran and fenugreek seed were prepared using the procedures developed in our laboratory.

The freeze-dried rice bran and fenugreek extracts were tested for antioxidant activity.

Evaluation of antioxidant activity

Extracts from rice bran and fenugreek seed and synthetic antioxidant BHA/BHT mixture were solubilized in soybean oil (15 g) by sonicating for 30 sec in an ice bath to give 500 ppm of extracts and 200 ppm of BHA/BHT mixture. Oils (5 g) containing antioxidants were evaluated for antioxidant activity using oxidative stability instrument (OSI). The induction times (the time taken to produce volatiles) at 97.8 C were taken as a measure of antioxidant activity; the higher the induction time, the higher the time required to produce volatiles (rancidity) and the more effective the antioxidants.

RESULTS AND DISCUSSION

The induction times for oil control, rice bran extract, fenugreek extract and BHA/BHT mixture are listed in Table 1. The induction times for rice bran extract (500 ppm), fenugreek extract (500 ppm), BHA/BHT mixture (200 ppm) and oil control were 13.1, 12.1, 13.9 and 11.0 hours, respectively. These results show that rice bran and fenugreek extracts have antioxidant activity at 500 ppm (level not restricted by FDA) comparable to synthetic antioxidant BHA/BHT mixture at 200 ppm (level restricted to 200 ppm by FDA). Currently, research is in progress to confirm these findings and to optimize conditions (extracting and solubilizing procedure) to produce natural antioxidant extracts from rice bran and fenugreek seed with improved/ enhanced antioxidant activity.

SIGNIFICANCE OF FINDINGS

Antioxidants can be extracted from the rice bran and fenugreek using food-grade solvents. The antioxidant activity of these extracts is comparable to the widely used synthetic antioxidant BHA/BHT mixture. Although the synthetic antioxidants are used well under the permissible limit because of their toxicity and instability at food processing conditions, demands to find safe and economic antioxidants to replace these synthetic chemicals exist. Antioxidant extracts from rice bran and fenugreek could be alternative sources to synthetic antioxidants.

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Table 1. Induction times of the soybean oil with and without antioxidants.

Antioxidant type	ppm	Induction time[z] (hrs)
Control	_	11.0
Rice bran extract	500	13.1
Fenugreek extract	500	12.1
BHA/BHT mixture	200	13.9

[z]Values are means of duplicate analyses.

HARVESTING PERFORMANCE OF A SHELBOURNE REYNOLDS STRIPPER HEADER

T.J. Siebenmorgen, K.E. Bennett, E. Vories and A. Mauromoustakos

ABSTRACT

Harvesting tests were conducted using a Shelbourne Reynolds stripper header in commercial rice fields near Keiser, Arkansas. No significant difference in relative harvest loss occurred with harvester ground speed between 1 and 2 mph; however, loss increased rapidly as speed exceeded 2 mph. Harvest loss was usually higher in 'Millie' than in 'Newbonnet' rice varieties for equivalent harvesting speeds. Maximum harvesting speeds of 3 and 4 mph were achieved in Newbonnet and Millie rice fields, respectively. There were no significant differences in average head rice yield between stripper combine- and conventional combine-harvested samples in either variety. Head rice yields of hand harvested Newbonnet samples were significantly higher than either the stripper combine- or conventional combine-harvested samples; however, these differences were insignificant in Millie.

INTRODUCTION

The Shelbourne Reynolds Engineering (SRE) stripper header, which mounts to most modern self-propelled combines, is designed to strip small grain heads (e.g. rice, wheat, oats, barley) from the grain stalk and deliver the grain to the combine. This stripping process is achieved by eight rows of finger-like teeth spread evenly around the perimeter of a rotor mounted on the front of the header. Most of the crop stalk is left standing in the field following the stripping process. Conversely, conventional cutterbar headers cut the crop stalk beneath the grain. The stalk and grain must then be conveyed into the combine and separated. Cutting, conveying, separating and cleaning this extra material may decrease maximum harvesting speed and increase fuel consumption.

PROCEDURE

Two similar Case IH 1680 self-propelled axial-flow combines were used for testing. One combine was equipped with an SRE SR6000 stripper header (this combine and header will herein be referred to as the "stripper combine"). The other combine was equipped with a conventional Case IH model 1010 rigid grain header (this combine and header will herein be referred to as the "conventional combine"). Both headers were 20 ft wide. Modifications listed in the SRE owner's manual (Shelbourne Reynolds Engineering, 1992) were made to the stripper combine to accommodate use of the stripper header.

The experiment consisted of determining the harvest loss of the stripper combine at field harvesting speeds of 1, 2, 3 and 4 mph. Tests were conducted in laser-leveled commercial rice fields in northeastern Arkansas. Two long-grain varieties of rice, Newbonnet and Millie, were tested. An experienced field harvesting technician representing SRE selected the combine and header settings to minimize harvesting loss prior to actual tests. These stripper combine operating parameters were held constant throughout the tests and included a fan speed of 900 rpm, a rotor speed of 550 rpm and a concave clearance of 1/8 in. Optimal stripper header settings included a stripping rotor speed of 470 rpm and a header auger speed of 170 rpm.

Loss Tests

A test run consisted of harvesting a full header width of rice with both the stripper and conventional combines immediately adjacent to each other over 1000-ft lengths in the bay. The stripper combine harvested rice at one of the four randomized harvesting speeds. The conventional combine served as a control and always harvested at optimal settings (harvesting speed $\leq$ 1 mph, fan speed = 800 rpm, rotor speed = 850 rpm, and rotor clearance = 1.25 in.) as determined by previous research on the Case/IH 1680 with a conventional header (Andrews et al., 1993). This previous research determined that harvest losses were low, generally below 0.5%, at harvesting speeds less than or equal to 1 mph. Rice from each combine was weighed in a weigh wagon after each 1000-ft test run. Any difference between the weight of grain in the two combines represented the total harvesting loss of the stripper combine relative to the conventional combine operating at optimal settings. This relative measured harvest loss ($Loss_{measured}$(%)) was calculated from the following equation:

$$Loss_{measured}\ (\%) = \frac{Wt_{conv} - Wt_{stripper}}{Wt_{conv}} \times 100 \qquad [1]$$

where Wt_{conv} and $Wt_{stripper}$ represented the weight of grain harvested with the conventional and stripper combines, respectively.

Grain Quality Tests

Hand-harvested samples were collected immediately adjacent to the combine test runs by cutting rice stalks well beneath the panicles with a gas-powered hedge trimmer. The stalks were gently placed in burlap bags and transported to a lab where the panicles were manually removed. Panicles were placed in smaller burlap bags and allowed to air dry. Kernels were then manually stripped from panicles. Head rice yields (HRY) of these hand-harvested samples receiving minimal mechanical damage were compared to HRYs of combine-harvested samples.

RESULTS AND DISCUSSION

The best model for predicting harvest loss of the stripper combine relative to the conventional combine was developed using the PROC REG procedure from SAS (SAS, 1989) and included a significant quadratic effect for harvesting speed. The model predicting relative harvest loss ($LOSS_{pred}$(%)) of the SRE stripper header was:

$$Loss_{pred}\ (\%) = b0 + b1 \times Speed + b2 \times Speed^2 \qquad [2]$$

where: *Speed* = Stripper combine harvesting speed (mph)

b0, *b1*, & *b2* = regression coefficients, Table 1.

Other variables, including grain feedrate, harvest moisture content and crop density, were not significant ($P = 0.05$) in predicting harvest loss of the stripper combine relative to that of the conventional combine, although it is speculated that these variables may affect absolute harvest loss similarly for both headers.

Figure 1 illustrates the quadratic relationship between relative harvest loss and harvesting speed for both varieties. This graph indicates no significant differences in relative harvest loss of the stripper combine between 1 and 2 mph; however, loss increased rapidly above 2 mph. Table 1 reveals the crop moisture content and exceptional grain yield of both varieties. The minimum predicted relative harvest loss and associated harvesting speed were found to be approximately 0.3% and 1.7 mph, respectively, for the stripper combine harvesting Newbonnet rice and 4.2% and 1.9 mph, respectively, in Millie.

Maximum harvesting speeds of 3 mph and 4 mph were achieved in the Newbonnet and Millie varieties, respectively. Harvesting speeds greater than this overloaded the shoe and caused the clean grain and tailings augers to "choke up." Although higher harvesting speeds were obtained in Millie than Newbonnet, Table 2 reveals that Newbonnet's average yield and moisture content were approximately 1000 lb/acre and 4.1 percentage points, respectively, higher than Millie's. It is speculated that greater maximum speeds could be attained in "average" yielding rice fields.

Figure 1 also indicates an apparent varietal effect on harvesting loss. Predicted harvest losses in Millie were on the average approximately 4 percentage points higher than in Newbonnet for harvesting speeds between 1 and 2.5 mph; however, Newbonnet's predicted harvest losses approached Millie's at harvesting speeds greater than 2.5 mph. Plant stature and kernel size and the lower moisture content of Millie grain at harvest are possible reasons for differences in harvest loss between the two varieties. Millie has a shorter stalk and a more prominent flagleaf in the crop canopy than Newbonnet.

Figure 2 illustrates comparisons between HRYs from hand-, stripper combine- and conventional combine-harvested Newbonnet samples. The figure shows that HRY followed similar trends for hand-, stripper combine- and conventional combine-harvested samples; however, moisture content at harvest (MC) was found to be non-significant in affecting HRY. The average HRYs for the hand-, stripper combine- and conventional combine-harvested samples were 61.4, 57.3 and 55.3%, respectively. A statistical analysis revealed that differences in HRYs between the hand- and stripper combine-harvested and the hand- and conventional combine-harvested samples were significant; however, differences in HRYs between stripper combine- and conventional combine-harvested samples were not significant.

Head rice yields of Millie samples are illustrated in Figure 3. Head rice yield followed similar trends for hand-, stripper combine- and conventional combine-harvested samples. The average HRY for hand-, stripper combine- and conventional combine-harvested samples were 65.3, 64.5 and 63.6%, respectively. Analysis indicated that there were no significant differences in HRY among the three harvesting methods ($P = 0.05$); however, the range of harvest MCs was much narrower in Millie than in Newbonnet.

CONCLUSIONS

Harvesting speed was found to significantly affect the harvesting performance of a Case IH 1680 combine operating with a Shelbourne Reynolds stripper header. No significant difference in harvest loss occurred at speeds between 1 and 2 mph; however, loss increased quadratically as harvesting speed exceeded 2 mph. The maximum grain handling capacity of the combine operating with the stripper header occurred at harvesting speeds of 4 mph in Millie and 3 mph in Newbonnet, which had a significantly higher average grain yield and moisture content. An apparent varietal difference in harvest performance existed. Loss at any given speed was usually higher in Millie than in Newbonnet. It was speculated that plant stature, in particular the prominence of the flagleaf in the crop canopy, and the lower MC of Millie grain at harvest were contributing factors to harvest loss differences between the two varieties.

Harvest MC was insignificant in affecting HRY in both varieties. Newbonnet hand-harvested samples had significantly higher HRYs than either stripper combine- or conventional combine-harvested samples; however, there were no significant differences in HRY between the stripper combine- and conventional combine-harvested samples. There were no significant differences in HRY between Millie hand-, stripper combine- and conventional combine-harvested samples, although the range of MCs was much narrower in Millie than in Newbonnet.

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Table 1. Regression coefficients for predicted harvest loss equation (equation [2]).

Regression Coefficients	Newbonnet	Millie
b0	7.590	10.972
b1	-8.416	-7.142
b2	2.438	1.885

Table 2. Grain yield and moisture content data of rice during harvesting tests.

Rice Moisture Content	Newbonnet	Millie
average	21.6	17.5
maximum	27.1	18.8
minimum	16.4	14.9
Average Rice Yield, lb/acre		
field tests[z]	8,470	7,480
state[y]	5,850	5,260

[z]Rice yield data were standardized to a 12.5% moisture content (% w.b.).

[y]Comprises the average yield reported by Helms et al. (1993) from five different test locations in Arkansas and one in northeastern Louisiana.

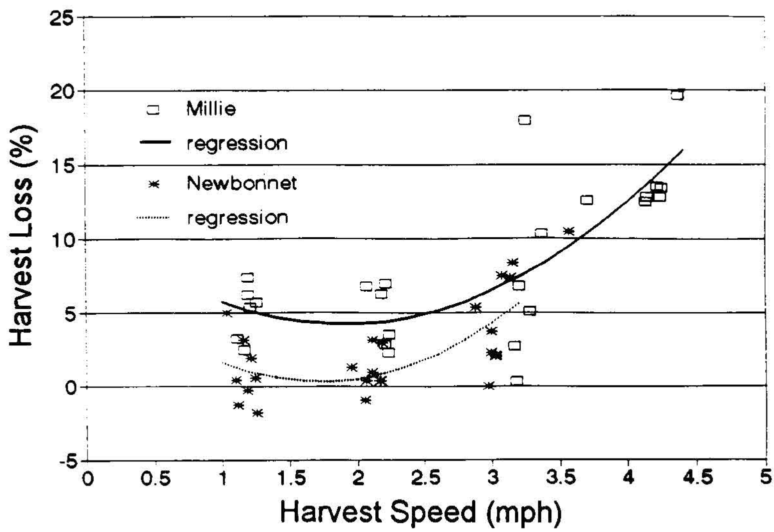

Fig. 1. Harvest loss of a Case/IH 1680 combine using a Shelbourne Reynolds stripper header at the indicated speeds relative to a Case/IH 1680 combine using a conventional header continually harvesting at 1 mph in 'Newbonnet' and 'Millie' rice.

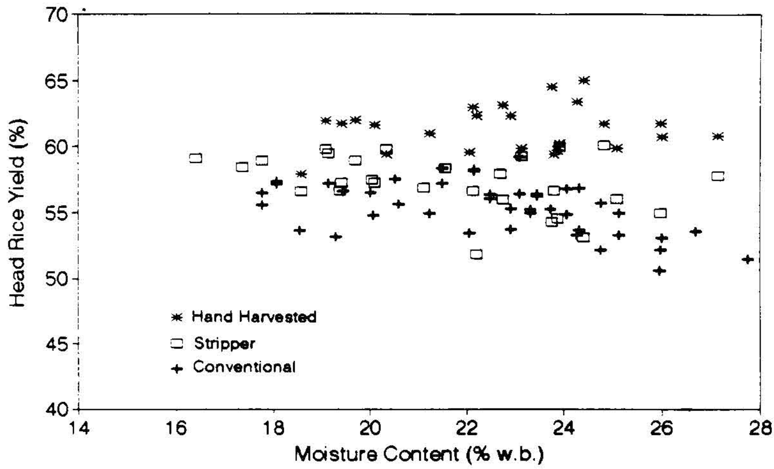

Fig. 2. Effects of grain moisture content at harvest on head rice yields of hand-, stripper combine- and conventional combine-harvested 'Newbonnet' samples.

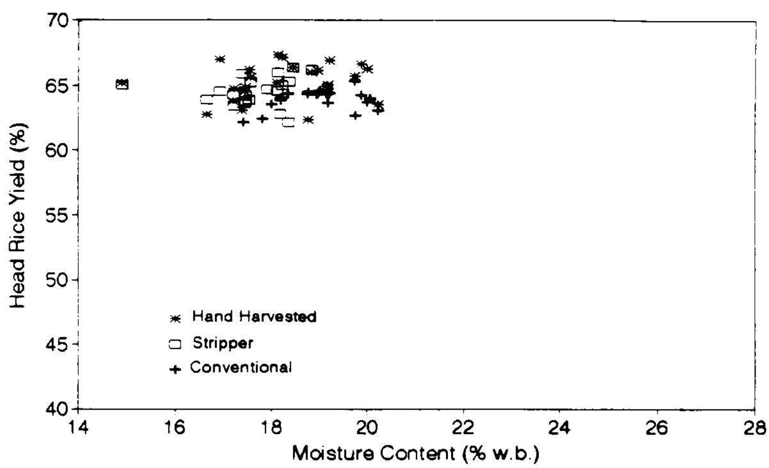

Fig. 3. Effects of grain moisture content at harvest on head rice yields of hand-, stripper combine-, conventional combine-harvested Millie samples.

COMBINE FUEL CONSUMPTION FOR HARVESTING RICE, WHEAT AND SOYBEAN

**T.J. Siebenmorgen, K.E. Bennett,
A. Mauromoustakos and E. Vories**

ABSTRACT

Fuel consumption tests were conducted on a Case IH 1680 axial-flow combine in two varieties of rice and wheat and one variety of soybean. Two different headers, a Shelbourne Reynolds SR6000 stripper header and a Case IH 1010 rigid cutterbar header, were tested.

Combine fuel consumption increased linearly with increasing speed. Combine fuel consumption using a stripper header was significantly less than that when using a conventional header at a given field speed. In addition, a unit increase in harvesting speed caused a larger increase in rate of combine fuel consumption with a conventional header than with a stripper header. A varietal difference in combine fuel consumption existed in rice, but differences were not significant in wheat. Combine fuel consumption, in terms of gallons of fuel consumed per hour, was highest in rice and lowest in wheat for equivalent harvesting speeds.

INTRODUCTION

Advances in harvesting methods have led to improvements in modern harvesting equipment. Two recent advancements have been the axial-flow threshing rotor and the stripper header. Little research, however, has been published that quantifies the performance or energy requirements of this modern harvesting technology.

Andrews et al. (1993) reported the effects of several combine operating parameters on harvest loss and quality in rice. A Case IH 1680 axial flow combine harvesting with a conventional cutterbar header was tested. They determined that feedrate, material other than grain to grain ratio, moisture content, rotor speed and concave clearance significantly affected harvest loss.

Arnold and Lake (1964) and Kepner et al. (1982) have indicated that the conventional combine cylinder accounts for approximately 80% of total harvester power requirements. Harrison (1991) determined that concave clearance, crop moisture content, rotor speed and feed rate significantly affected rotor power requirements of an axial-flow combine harvesting barley. The rotor power requirements ranged from 34 to 114 hp, depending on experimental combinations.

These studies, however, did not report combine fuel use during harvesting. Since fuel expense represents a significant portion of harvesting costs, quantifying combine fuel use for different headers in different crops and crop varieties is justified.

PROCEDURE

A Case IH 1680 four-wheel-drive axial-flow combine was used for testing. The combine was powered by a six-cylinder turbocharged diesel engine (Model 6TA-830). A Fluidyne 1250 precision fuel transducer was installed on the combine. The unit consisted of a four-piston positive displacement fuel transducer that provided measurement of fuel consumption, elapsed time and fuel temperature. A Shelbourne Reynolds SR6000 stripper header was tested in rice and wheat; a Case IH 1010 conventional rigid cutterbar header was tested in rice, wheat and soybean.

The experiment determined combine fuel consumption per hour (CFC) at various harvesting speeds: rice, 1 to 4 mph; wheat, 2 to 8 mph; and soybean, 2 to 5 mph (Table 1). These ranges represent typical harvesting speeds for the specified crops. Wheat, rice and soybean tests were conducted in June, September and October, respectively, of 1992 in commercial fields in northeastern Arkansas. Two varieties of long-grain rice ('Newbonnet' and 'Millie') and wheat ('Cardinal' and 'Saluda') and one cultivar of soybean ('Hutcheson') were tested.

Fields were divided into "blocks" prior to testing; each experimental replication was conducted within a single block. A test run consisted of harvesting a header width at a given randomized speed over a distance of usually 1000 ft. The grain harvested from a test run was weighed in a weigh wagon after each run. Fuel consumption, elapsed test time, test run length and fuel temperature were also recorded.

The experiment followed a complete randomized block design with several test replications for each header/crop/variety experimental combination. Test replications in rice were made within a single bay, the area between adjacent levees; test replications in wheat and soybean were made in marked sections of a field. Four or more replications were typically made for each experimental combination. The combine air conditioning system was not operated, and the four-wheel-drive system was disengaged during tests in wheat and soybean; however, the four-wheel-drive system was continuously engaged during all rice harvesting tests. Rotor speed, fan speed and concave clearance were held constant for each experimental combination and are listed in Table 1.

RESULTS AND DISCUSSION

The best predictive model for combine fuel consumption during harvesting was created using the PROC GLM procedure of SAS (SAS, 1989) and included a significant (P = 0.05) linear effect for the harvesting speed variable. The model for predicting combine fuel consumption (*CFC*) is:

$$CFC = \beta_0 + \beta_1 \times Speed \qquad [1]$$

where: β_0 and β_1 = regression coefficients
Speed = combine speed.

The coefficient of multiple determination, R^2, for the entire model was 0.94. Crop density was considered as a covariate in equation 1 and found to be insignificant in accounting for differences in CFC.

Figure 1 illustrates the linear effect of harvesting speed on CFC in fields of Newbonnet and Millie rice. Harvesting with a conventional header required significantly more fuel than harvesting with a stripper header for equivalent harvesting speeds. For instance, average CFC using a conventional header was 1.6 gal/hour higher than using a stripper header at 3 mph while harvesting Millie rice. A unit increase in harvesting speed caused a larger incremental change CFC using a conventional compared to a stripper header. For example, increasing harvesting speed from 1 to 3 mph in Millie produced an average increase in CFC of 3.1 and 2.1 gal/hour using a conventional and stripper header, respectively. A varietal difference in CFC also existed. Harvesting Newbonnet at 3 mph with a stripper header required approximately 0.6 gal/hour more fuel than harvesting Millie; however, Table 2 reveals that the average grain yield in Newbonnet fields was approximately 1160 lb/acre higher than in Millie fields.

Figure 2 illustrates CFC in fields containing Cardinal and Saluda wheat. Combine fuel consumption at high harvesting speeds was significantly higher when using a conventional rather than a stripper header. For instance, CFC using a conventional header at 5 mph was approximately 1.1 gal/hour higher than when using a stripper header. The rate of change in CFC with increasing speed was also greater with the conventional header. For example, increasing harvesting speed from 2.5 to 5 mph in Cardinal fields showed an average increase in CFC of 2.5 and 1.6 gal/hour using a conventional and stripper header, respectively. There were no statistical differences in CFC between the two wheat varieties.

Figure 3 illustrates CFC in soybean. Combine fuel consumption increased linearly with increasing harvesting speed. Increasing harvesting speed from 2.5 to 5 mph yielded an average increase in CFC from 6.9 to 9.9 gal/hour.

Statistical analysis in PROC GLM indicated that significant differences in CFC occurred among the three different crops for equivalent harvesting speeds and header types. Generally, CFC, in terms of volume of fuel per unit time, was highest in rice and lowest in wheat for the given crop yields and test conditions. Combine fuel consumption while harvesting Hutcheson soybean with a conventional header at 5 mph was approximately 0.8 gal/hour higher than harvesting Cardinal wheat. The rate of CFC at 3 mph using a conventional header in Cardinal wheat and Hutcheson soybean was approximately 2.9 and 2.6 gal/hour, respectively, less than when harvesting Newbonnet rice. Similarly, CFC at 3 mph with a stripper header was approximately 1.7 gal/hour higher in Newbonnet rice than in Cardinal wheat. One of the primary reasons for the differences in CFC is the difference in volume of grain harvested per unit time between the three different crops. Table 2 illustrates that the average crop yield of rice was approximately 4000 and 5000 lb/acre higher than wheat and soybean, respectively. Differences in CFC may also be explained by the different crop and harvesting conditions. For instance, the four-wheel-drive system was engaged during all tests in rice since wet soil conditions often exist but was not used in wheat and soybean crops.

CONCLUSIONS

Combine fuel consumption increased linearly with increasing harvesting speed for each header type/crop/variety experimental combination. Differences in CFC among crop varieties were significant in rice but not significant in wheat. Combine fuel consumption was greater in Newbonnet than in Millie, although Newbonnet had a significantly higher average grain yield. Harvesting wheat and rice at high harvesting speeds with a conventional header required significantly more fuel than harvesting with a stripper header. A unit increase in harvesting speed produced a significantly larger average increase in CFC using a conventional header than using a stripper header for each variety of wheat and rice. Combine fuel consumption, in terms of volume of fuel per unit time, using either the conventional or stripper header, was highest in rice and lowest in wheat for equivalent harvesting speeds.

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Table 1. Combine rotor speed, fan speed, concave clearance and harvest speed settings for the indicated crops when using a Shelbourne Reynolds SR6000 stripper header (stripper) and a Case IH 1010 rigid cutterbar header (conventional).

Crop	Header	Harvest Speed	Rotor Speed	Fan Speed	Concave Clearance
		mph	rpm	rpm	mm
Rice	stripper	1 to 4	550	900	3
	conventional	1 to 3	850	800	31
Wheat	stripper	2 to 8	580	1030	3
	conventional	2 to 6	800	800	31
Soybean	conventional	2 to 5	400	400	31

Table 2. Moisture content and crop yield data for indicated crops during harvesting tests.

Crop	Variety	Average Moisture Content	Average Crop Yield
		% w.b.	lb/acre[z]
Rice	Newbonnet	21.6	8,470
	Millie	17.5	7,480
Wheat	Cardinal	12.1	3,760
	Saluda	11.9	3,650
Soybean	Hutcheson	12.7	2,800

[z]Crop yield data are expressed by standardizing to a 12.5% moisture content (% w.b.).

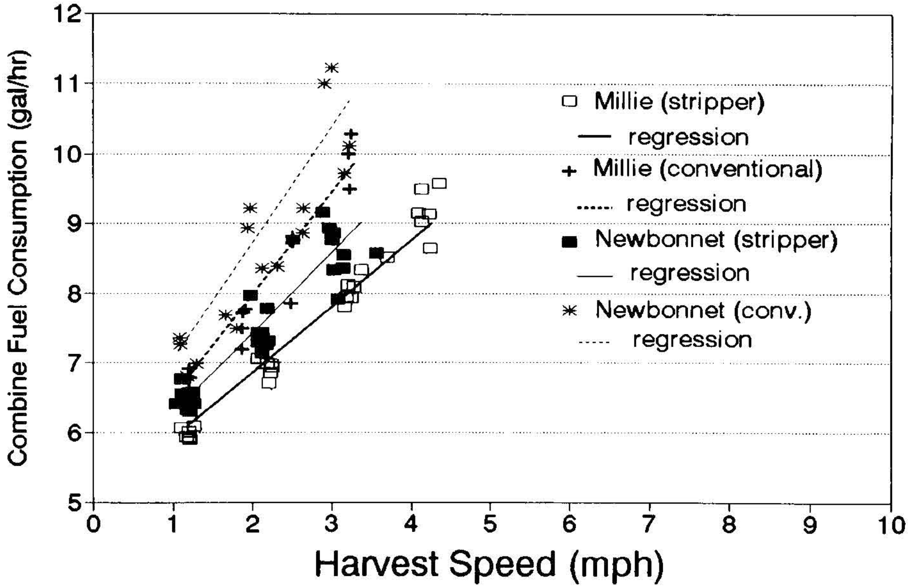

Fig. 1. Fuel consumption of a Case IH 1680 combine with a Shelbourne Reynolds SR6000 stripper header (stripper) and Case IH 1010 rigid cutterbar header (conventional) at various speeds in 'Newbonnet' and 'Millie' rice.

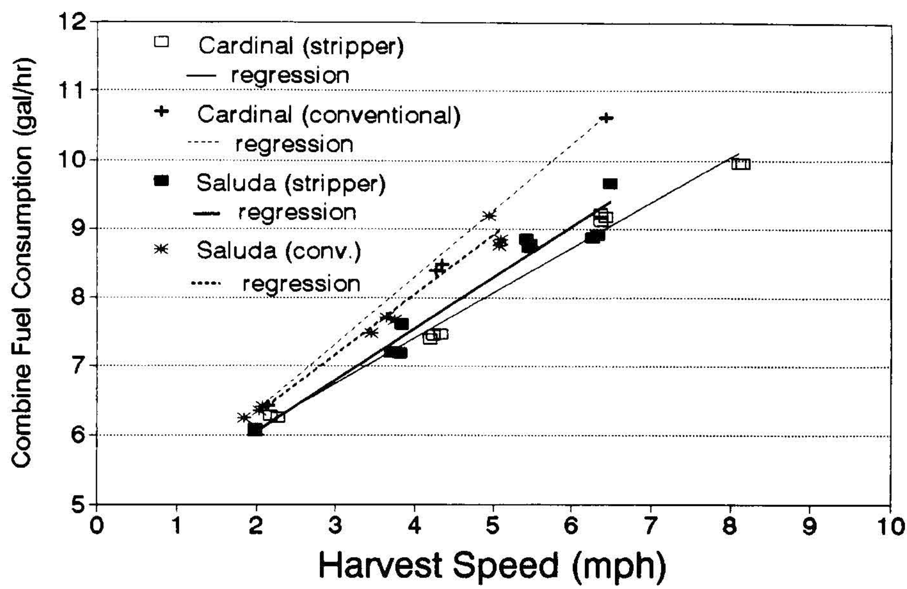

Fig. 2. Fuel consumption of a Case IH 1680 combine with a Shelbourne Reynolds SR6000 stripper header (stripper) and a Case IH 1010 rigid cutterbar header (conventional) at various speeds in 'Cardinal' and 'Saluda' wheat.

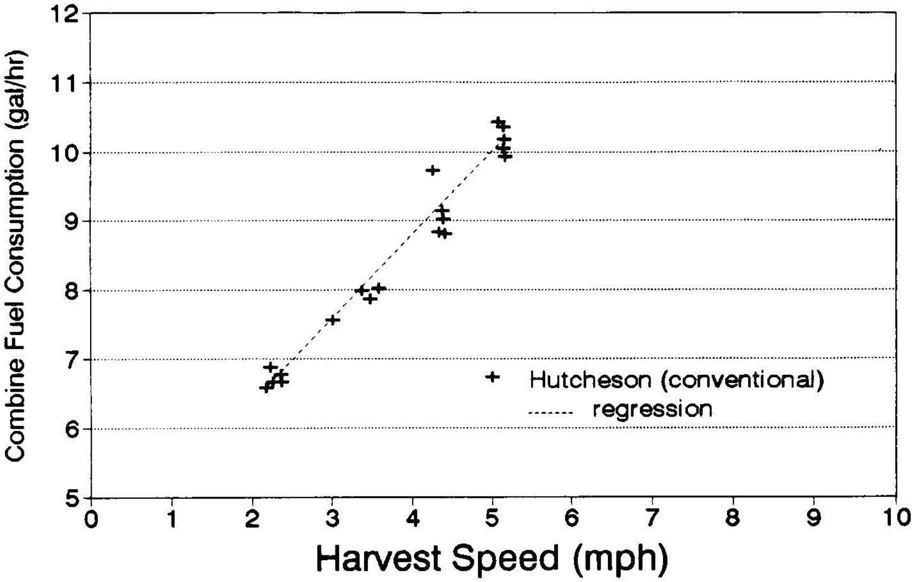

Fig. 3. Fuel consumption of a Case IH 1680 combine with a Case IH 1010 rigid cutterbar header (conventional) at various speeds in 'Hutcheson' soybean.

EFFECT OF RICE MOISTURE CONTENT AT HARVEST ON ECONOMIC RETURN

T.J. Siebenmorgen, R. Lu, T.A. Costello and Edward O. Fryar, Jr.

ABSTRACT

Economic analyses were conducted to assess the impact of rice harvest moisture content (MC) on economic return to the producer. The primary factors considered included percent total milled rice (PMR), percent head rice (PHR), grain yield (GY) and drying costs. Rice harvest MC had a significant impact on the final gross income to a producer. The optimal harvest MC was influenced by GY loss rate and, to a lesser degree, drying charge schedule. The relative price ratio of broken to head rice also affected the optimal harvest MC. Significant losses in gross income could be incurred if rice is harvested at MCs lower than 15% or higher than 22%.

INTRODUCTION

The primary factors that determine the economic return to a producer (the value of harvested rice less certain specified costs such as harvest, storage and drying costs) are grain yield (GY); milling quality, including percent milled rice (PMR) and percent head rice (PHR); and drying costs. Studies (e.g., Lu et al., 1992; Siebenmorgen et al., 1992) have shown that GY, PMR and PHR are a function of average rice MC. Grain yield, PMR and PHR will decrease and drying costs will increase as rice harvest MC increases above the optimal range. Also, when rice is harvested below the optimal range, PHR may decrease rapidly with decrease in MC. In addition, when harvesting is delayed, GY losses will be incurred as a result of plants lodging and grain shattering. Weather is the single most important factor influencing rice MC throughout the harvest season and, therefore, will affect the time of harvest. Rain and/or dew occurring during the late harvest season may cause rice kernels to fissure, resulting in PHR reductions. Harvesting is also constrained by factors such as total crop acreage, field conditions, harvesting capacity, drying method and the availability of drying and storage facilities.

The objective of this research was to assess the impacts of rice MC at harvest and/or time of harvest on economic return to a producer.

PROCEDURE

Economic analyses were performed for 'Newbonnet' long-grain rice harvested in 1988 and 1989 at Stuttgart, Arkansas. The rice MCs for given harvest dates were determined through the simulation model developed by Lu and Siebenmorgen (1993a,b). Hourly weather data, including air temperature, relative humidity, solar radiation, wind velocity and rain amount and duration, were used to simulate rice MC throughout the harvest seasons. The moisture content at 1:00 pm on each harvest date was used in estimating GY, PMR and PHR for that harvest date. The GY, PMR and PHR were estimated using the equations of Lu et al. (1992).

Based on a survey of commercial drying costs in Arkansas, two drying charge schedules, viz., incremental and flat rate schedule, were used in the economic analysis. The drying costs incurred under the incremental rate schedule were calculated at $0.25/bu for MC 19%, $0.30/bu for 19% < MC < 24%., and $0.50 for MC 24%. The drying costs incurred under the flat rate schedule were calculated at $0.30/bu. The price paid for head rice was calculated at $0.1143/lb. The price of broken rice was considered to be one half that of head rice. The gross income ($/acre), which is equal to the total value of rice per unit area minus drying costs, was calculated for each harvest date. Two grain loss rates were used to demonstrate their effects on the gross income to a producer. In the first case, the grain rate was assumed to be zero, which represented an ideal crop and environmental condition. In the second case, the grain loss rate was 0.661% of the potential maximum grain yield per day. This loss rate was obtained from a study conducted in Texas. A detailed description of the economic analysis procedure is given in Lu et al. (1993).

RESULTS AND DISCUSSION

Predicted values of PMR, PHR, GY and MC throughout the entire harvest season of 1988 are shown in Fig. 1. The PMR approached maximum at approximately 18% MC and thereafter remained constant. The PHR increased considerably as rice MC decreased until about 18%. Thereafter, environmental conditions showed significant influences on PHR. Rain and MC fluctuations caused significant reductions in PHR when rice MC was lower than 15%. The GY increased progressively as rice MC decreased until 22% and thereafter decreased linearly with harvest date as a result of lodging and shattering losses.

Figure 2 shows the effects of the two different drying charge schedules on costs ($/acre) for drying rice harvested at different MCs. The drying costs were significantly influenced by harvest MC and drying charge schedule. Under the incremental rate schedule, drying costs increased dramatically when rice was harvested above 24% MC, and the maximum drying cost was incurred when rice was harvested at 24% MC. However, with the flat rate schedule, the change in drying costs over the harvest MC range was not as great as in the incremental rate schedule.

Figure 3 shows the effects of the two drying charge schedules on the gross income to a producer. The gross income shown in the figure was calculated on the basis that $P_B = 0.5P_H$, where P_B is the price of broken rice and P_H is the price of head rice. The overall trends in gross income with time of harvest were similar under the two drying charge schedules. Drying charge schedules had dramatic impacts on gross income when rice was harvested above 24% MC. Significant losses in gross income were incurred with both drying charge schedules when rice was harvested above 22% MC, due to lower PMRs, PHRs and GYs and higher drying costs. Under the incremental charge schedule, the gross income was nearly constant when rice was harvested between 17% and 22%. The maximum gross income was obtained when rice was harvested at slightly less than 19% MC. Under the flat rate schedule, the maximum gross income was obtained when rice was harvested between 19% and 22% MC. There was potential advantage for the producer under the flat rate schedule if rice was harvested at a high MC, as compared to the incremental rate schedule. Figure 3 also shows that there was a great risk in gross income loss when rice was harvested at MCs lower than 15%; this is because rain and MC fluctuations would cause significant PHR reductions. Harvesting at MCs higher than 22% could also lead to significant gross income losses due to high drying costs and reduced GY and milling yields. However, it should be mentioned that the results shown here may not be generalized. This is because drying costs and charge schedules vary considerably, depending on location and drying company.

Results of these analyses also showed that a change in broken rice price had some effect on the optimal harvest MC.

Grain yield losses are influenced by many factors such as variety, crop and environmental/weather conditions. Figure 4 shows the effects of the GY loss rate on the gross income to a producer when the drying costs were calculated using the incremental rate schedule. The gross income was significantly influenced by the GY loss rate. The optimal harvest MC was between 15% and 19% when no losses in GY (a = 0) were incurred. The optimal harvest MC was slightly lower than 19% when the GY loss rate was 0.00661/day (a = 1). Similar results were also obtained when the flat rate for drying charges was applied. These results indicate that the optimal harvest MC is significantly influenced by the GY loss rate. A higher GY loss rate means that rice should be harvested at somewhat higher MCs to obtain the maximum gross income.

SIGNIFICANCE OF THE WORK

The results of this study showed that economic return to a rice producer is significantly influenced by rice MC, drying charge schedule, relative price schedule for broken rice and grain yield loss rate. Optimal harvest decisions can be developed with the consideration of specific constraining factors, including crop acreage, harvesting capacity, drying methods and the availability of drying and storage facilities. This research provides the basis for further harvesting simulations, and the research results are being incorporated into a rice harvest expert system to assist rice producers in making harvest decisions.

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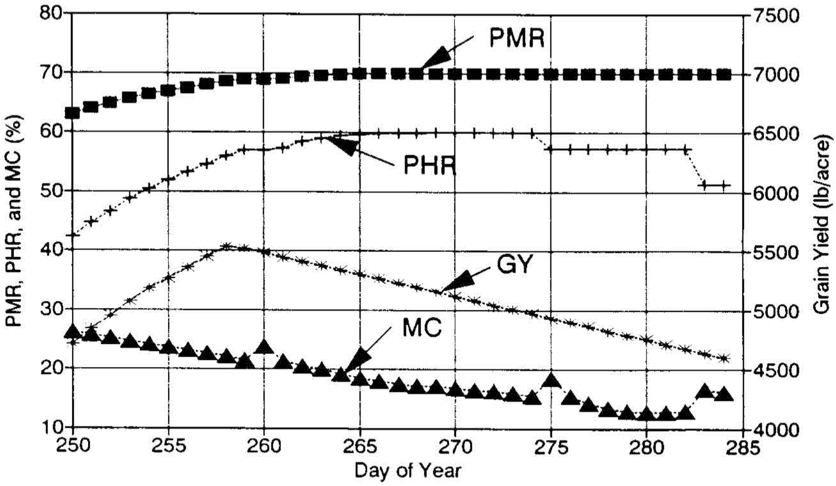

Fig. 1. Predicted values of percent milled rice (PMR), percent head rice (PHR), field yield (FY) and moisture content (MC) as a function of time of harvest for 'Newbonnet' variety in the 1988 harvest season.

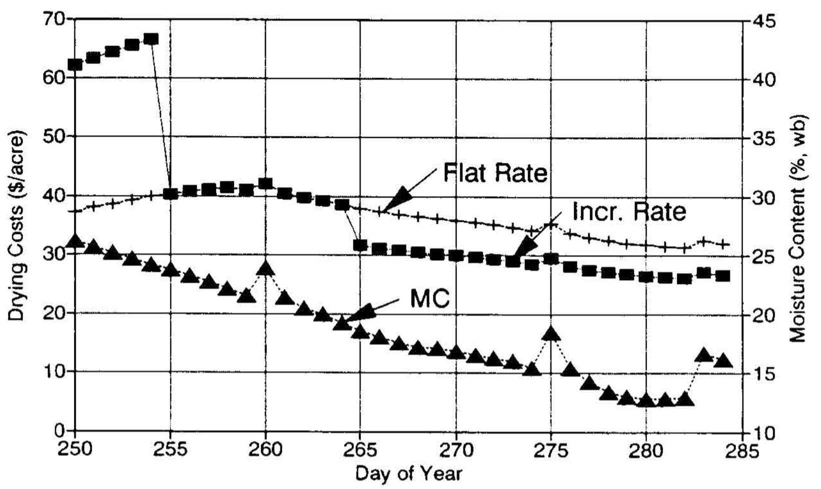

Fig. 2. Effects of time of harvest on moisture content (MC) and associated drying costs incurred under the incremental and flat rate schedules for the 1988 harvest season.

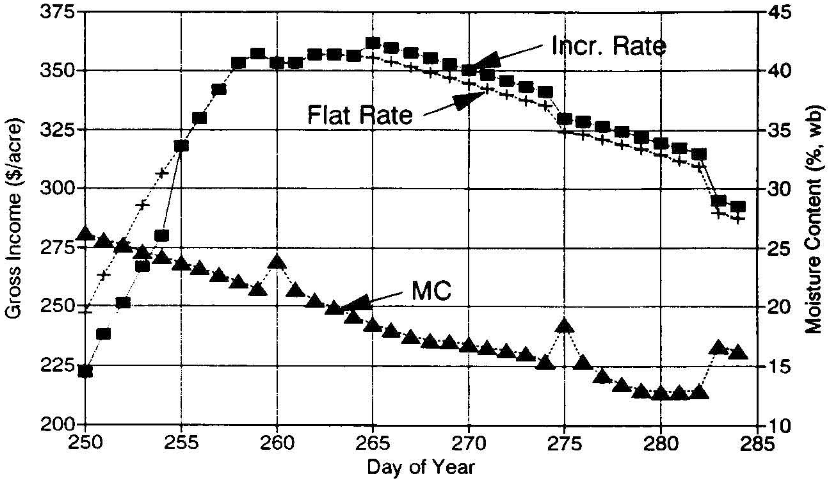

Fig. 3. Effects of drying charge schedules on gross income to a producer for the 1988 harvest season.

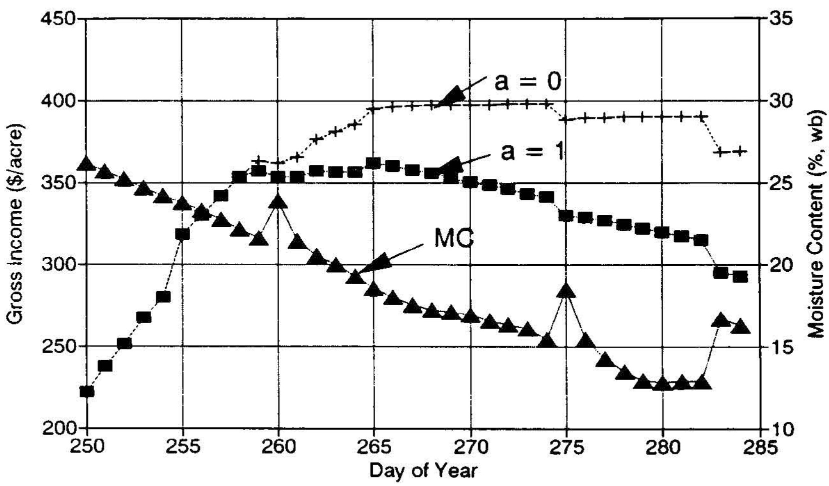

Fig. 4. Effects of two field loss rates (no loss -- a=0; and loss at 0.00661/day -- a=1) on gross income to a producer for the 1988 harvest season.

DRYING RATES AND HEAD RICE YIELD REDUCTION AS AFFECTED BY DRYING PARAMETERS

T.J. Siebenmorgen and C.W. Schulman

ABSTRACT

Two long-grain varieties of rice, 'Newbonnet' and 'Millie', harvested in 1992, were dried for various lengths of time at four relative humidity/temperature combinations to assess the effects of drying conditions on head rice yield (HRY). The four combinations represented two equilibrium moisture contents (EMCs), 8.6% and 6.3%. Preliminary observations indicate that drying rates were governed by the equilibrium moisture content corresponding to the relative humidity/temperature air conditions. With increased drying time, little reduction in HRY was observed for rice dried at the higher EMC. For the lower EMC, significant reductions in HRY were observed with increasing drying time. For high moisture content Newbonnet, a critical drying time duration existed between 60 and 120 min in which a substantial decrease in HRY occurred followed by no further reduction in HRY.

INTRODUCTION

Rice is routinely harvested at a moisture content ranging from 18 to 24% wet basis[1] (WB) and must be dried by artificial means to a moisture content of approximately 12.5% to insure safe storage. Special consideration must be given to the air conditions used for drying in order to minimize fissure (stress crack) development within the rice kernel. During the dehulling and milling process, fissured kernels break more readily, resulting in a significant decrease in HRY. The economic importance of obtaining high HRYs cannot be overstated as the market value of head rice is typically twice that of brokens.

[1]Unless otherwise specified, all moisture contents mentioned herein are on a wet basis.

Due to its hygroscopic nature, rice will adsorb or desorb moisture, depending on the surrounding environment. If rice is not at its EMC for given air conditions, a vapor pressure differential exists between the kernel and the surrounding air, leading to moisture transfer between the rice and air. In conventional drying, air is heated to lower its relative humidity (RH), thus increasing the drying potential. As air passes over the rice, evaporation of water takes place until the rice kernels equilibrate with the drying air or the drying process is terminated. According to Kunze (1979), it is the moisture gradient created during the drying period that provides the potential for later fissuring. The magnitude of this gradient is due to the rate of moisture removal or drying rate. Although numerous studies have been conducted to determine the drying rates of rice, little information is available that quantifies the relationships between drying rates and HRY reduction. In addition, drying information expressing the relationship of critical time points in the drying process to optimal HRY is inadequate at this time.

The primary objective of this investigation was to quantify the fundamental relationships between drying rates and resultant HRY. It should be noted that the results discussed below are preliminary findings based on data from one harvest season and subsequent research is being conducted to confirm and expand results of the 1992 investigation.

PROCEDURES

Long-grain rice of the varieties, 'Millie' and 'Newbonnet', was obtained from two commercial rice fields in Northeast Arkansas. The harvest moisture content of Millie was approximately 18% while the moisture content of Newbonnet was approximately 24%. In addition to evaluating newly harvested rice, Newbonnet rice that was stored at 1 C for two months after harvest was used for the drying tests. At the time of drying, the initial moisture content of the stored Newbonnet was approximately 18%. Rice with moisture contents below 20% were classified as medium moisture content, while rice with moisture contents above 20% were identified as high moisture content. For purposes of analysis, the rice used was classified into three groups: high moisture content Newbonnet (HMCN), medium moisture content Newbonnet (MMCN) and medium moisture content Millie (MMCM).

The drying procedure used "conditioned" air that flowed into a sixteen-tray conditioning chamber where the rice samples were dried, each tray being 152 x 254 mm. Perforations in the bottom of the trays allowed air to pass through the rice thus permitting drying. A relative humidity and temperature control unit (Parameter Generation and Control 300 CFM Climate-Lab-AA) provided the required drying air conditions for each test.

Sixteen trays, each filled with a 550-g sample of rough rice, were used for each drying test. This correlated to an approximate height of 15 mm of rice within each tray. A sample tray was removed from the conditioning chamber every 15 min during the first two hours of drying and at 30-min intervals for the remaining two hours of the testing period. When a sample was removed, the moisture content of a 100-kernel sub-sample was immediately determined using a Shizouka Sieki Model CTR-800A Individual Kernel Moisture Meter. The samples were then allowed to "gently" dry in another conditioning chamber to a moisture content of approximately 12.5%. Again, a Parameter Generation and Control unit provided the chamber with air temperature and relative humidity conditions of 33.0 C and 67.8% RH necessary to achieve an EMC of 12.5%. The equilibrated samples were placed in a sealed plastic bag and held in a cold storage room at 1 C until milling. Prior to milling, the samples were allowed to come to room temperature. Two 150-g sub-samples from each of the original 550-g samples were milled for 30 sec using a McGill #2 Miller with a 1500-g weight placed 15 cm on the miller lever arm from the centerline of the milling chamber. From this, HRY was determined.

Four relative humidity/temperature drying air conditions were used to evaluate the drying rates and HRY effects of drying. Table 1 lists these drying conditions. A relative humidity/temperature combination of 33.0 C and 67.8% RH, representing an EMC of 12.5%, served as the control air condition for the experiment. This air condition is representative of typical daytime air conditions in Arkansas during the peak harvest month of September. Two of the drying air conditions, C (43.5 C, 38.2% RH) and D (54.3 C, 21.9% RH), represented conventional drying methods that would be obtained through fossil fuel combustion, while conditions A (41.0 C, 37% RH) and B (49.0 C, 20.0% RH) represented air conditions achieved through an alternate drying method as desiccant drying.

RESULTS AND DISCUSSION

Drying Rates

The drying curves for the HMCN are seen in Fig. 1. The shape of the curves is representative of the two other rice classifications, MMCN and MMCM. For each of the three classifications, the drying curves for drying conditions A and C (EMC = 8.6%) were similar but were distinct from the those for drying conditions B and D (EMC = 6.3%). Similarly, no differences were noted in drying curves for rice dried at conditions B and D. This suggests that the primary factor in determining the shape of the drying curves was the combination of temperature and relative humidity--that is, EMC--as opposed to either temperature or relative humidity alone.

Head Rice Yields

Table 2 presents the HRYs for selected times during the drying process for the three classifications of rice. Consider first the results for MMCM and MMCN. For both classifications, drying conditions A and C exhibited no significant reduction in HRY over the four hours. For conditions B and D however, there was a significant reduction in HRY over time and the rate of HRY reduction for condition D was greater than that for condition B. For MMCM, each additional minute of drying resulted in a decrease in HRY of 0.08%.

For HMCN, as was the case with the other two classifications, condition A exhibited no reduction in HRY. While condition C did exhibit a significant reduction, it was extremely small (0.007% per minute of drying). Condition B (up to 90 minutes) and condition D (up to 75 minutes) showed a reduction in HRY with time. Unlike MMCM and MMCN, however, the rates of reduction for these two conditions were not different from each other. More importantly, no significant reduction in HRY was noted after 105 minutes of drying for condition B and at 90 minutes for condition D. Figure 2 illustrates the HRYs obtained for HMCN at the four drying conditions.

SIGNIFICANCE OF FINDINGS

This preliminary study indicates that drying parameters for two varieties of rice were found to be dependent upon the rice EMC corresponding to given drying air conditions. It is the combination of a particular temperature and relative humidity condition of the drying air acting together in terms of EMC that is the governing factor for moisture removal from the kernel. These conditions cannot be considered independently when quantifying drying rates. In terms of HRY, rice dried at higher EMCs resulted in higher HRYs than rice dried at lower EMC levels. Rice dried at a higher EMC showed little, if any, reduction in HRY with increasing drying time. Furthermore, a critical drying duration existed where substantial decreases in HRY were observed for HMCN. In general, this duration occurred between 60 and 120 min into the drying process. Decreases in HRY were correlated to increased drying rates. Rice dried at the lower EMC level exhibited increased drying rates with resultant HRYs being lower than those samples dried at lower drying rates. This indicated that the rate of moisture removal from the kernel had a significant effect on resultant HRY.

The results of this preliminary investigation have provided a foundation from which current research is being extended to address the primary objective. Further modeling of the drying process and head rice analysis is being developed that includes additional predictors such as initial rice moisture content, variety, degree of milling and storage time.

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Table 1. Relative humidity/temperature conditions for drying treatments.

Drying Condition	Dry Bulb Temperature	Relative Humidity	Equilibrium Moisture Content
	C	%	% WB
Control	33.0	67.8	12.5
A	41.0	37.0	8.6
B	49.0	20.0	6.3
C	43.5	38.2	8.6
D	54.3	21.9	6.3

Table 2. Head rice yields after 0, 60, 120 and 240 minutes of drying.

Classification of Rice	Rice Drying Condition[z]	Drying Time, Minutes 0	60	120	240
High Moisture Content	A	53.4	51.1	51.6	52.2
Newbonnet	B	51.7	50.8	43.5	42.6
	C	52.5	52.0	51.8	49.7
	D	52.6	49.2	42.4	41.8
Medium Moisture Content	A	52.4	52.9	53.0	53.7
Newbonnet	B	52.6	47.8	48.1	46.7
	C	52.6	51.7	52.2	51.8
	D	51.9	49.8	40.3	36.4
Medium Moisture Content	A	62.4	59.7	60.9	64.3
Millie	B	60.1	58.6	57.5	52.9
	C	61.8	61.9	59.9	61.3
	D	62.1	55.2	55.2	42.1

[z]Drying Conditions are noted in Table 1.

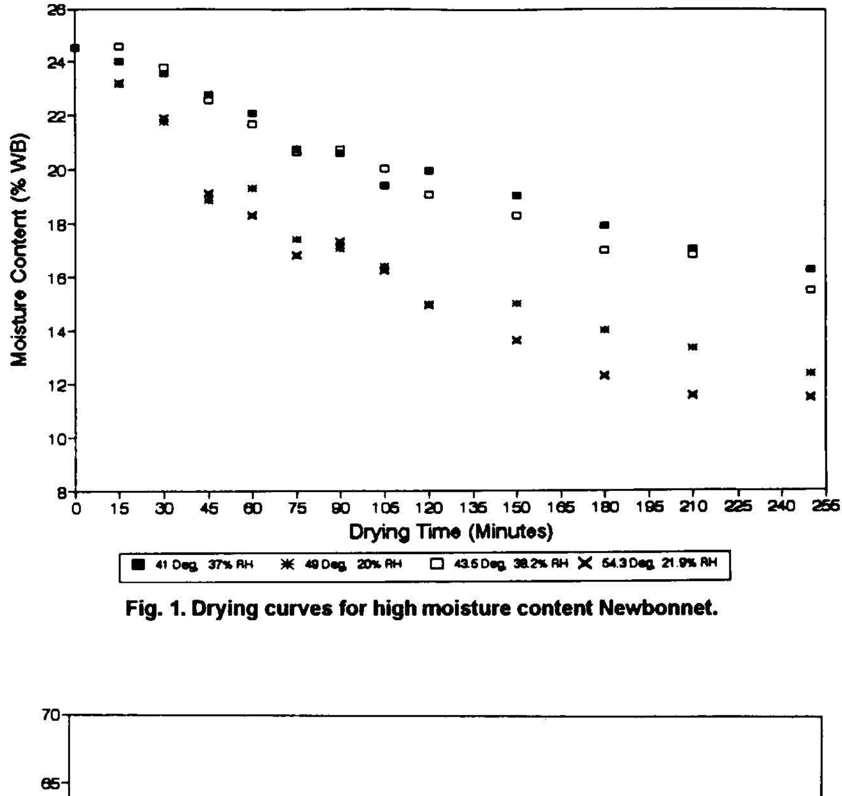

Fig. 1. Drying curves for high moisture content Newbonnet.

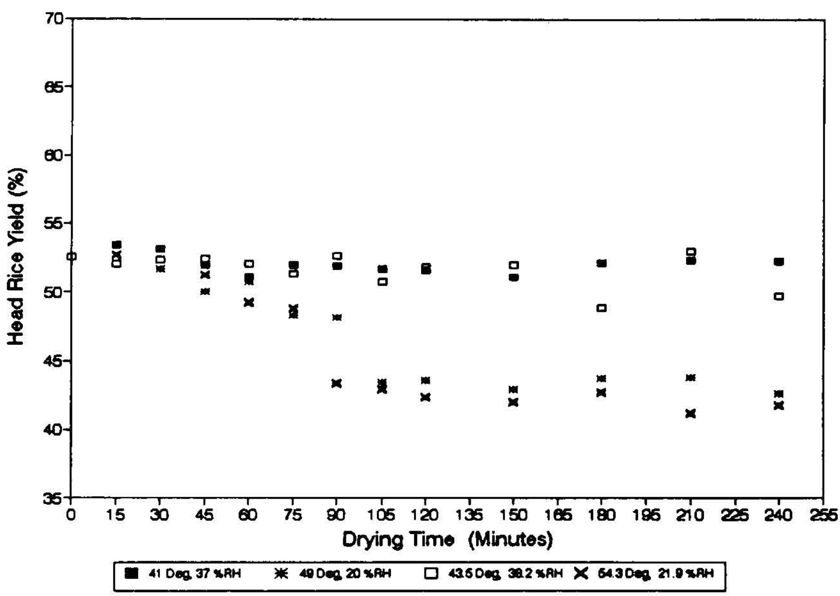

Fig. 2. Head rice yields for high moisture content Newbonnet.

A SPATIAL EQUILIBRIUM MODEL FOR POULTRY LITTER MANAGEMENT

Mark J. Cochran and Ramu Govindasamy

ABSTRACT

The purpose of this study was to document the market feasibility of transporting poultry litter to the Delta for use as a soil amendment in the production of rice, cotton and soybeans. Results indicate that, particularly for soils recently graded, the value of litter as a soil amendment exceeds the sum of the acquisition, transport, handling and spreading costs so that there exists a considerable potential for this industry to continue to develop.

INTRODUCTION

There is a growing interest in the feasibility of using poultry litter in the production of Delta row crops and, possibly, rice. Poultry production is mostly concentrated in the western region of the state while row crop production is concentrated in the east. Poultry litter has been proven to increase the productivity of recently graded soils while it is less productive on ungraded soils (Rainey et al., 1992; and Miller et al., 1991). The market feasibility of transporting litter to the eastern region depends on several factors. First, the farm-level derived demand must be estimated to determine how much farmers can afford to pay for the litter and still earn a profit. This will, in turn, depend on the yield response to the litter and on market prices. Profitable use of the litter would occur at a rate at which the marginal value of the yield response equals or exceeds the cost of the litter. Yield response will depend on depth of cut in land leveling and other soil characteristics, time since grading, crop produced and litter rate. The cost of the litter will be determined by the acquisition, transportation and handling costs. The transportation costs are a function of the mode of transportation, the distance between acquisition points and final destinations and the volume of material to be transported.

The objectives of this paper are to 1) establish the conditions for economical transport of litter from the poultry-producing regions to the Delta; and 2) determine the optimal rates of litter application given the source and destination of litter, the derived demand for litter for crop production in the Delta region and the cost of litter acquisition, transportation, spreading and handling.

THE MODEL

A spatial equilibrium model was developed using the field experiments on poultry litter as a soil amendment on cotton, rice and soybeans. A regional discontinuous non-linear optimization model was developed using the input from budgeting analysis to assess the cost and returns of using poultry litter. The litter-producing areas are divided into five source regions (Fayetteville, Batesville, Russellville, El Dorado and Hope).[1] The destination areas for crop production are divided into six regions (Stuttgart, Jonesboro, McGehee, Helena, Blytheville and Newport).[2] Table 1 displays the distance between source and destination regions. The optional litter rates used are 1000, 1500, 2000, 2500, 3000, 3500, 4000 and 4500 lb/acre. Two modes of transportation are truck and rail. Poultry litter production from the source region, crop prices, area under crop production and yields were estimated using Arkansas Agricultural Statistics (1991). The area under graded soils was estimated through a phone survey (1993) with the county Soil Conservation Service offices. The yields on graded soils compared to ungraded soils were estimated using the experimental data on crop responses to poultry litter. The cost of transportation by railroad was collected from Arkansas/Missouri Railroad Company; cost of truck transportation was estimated from Weaver and Souder (1990).

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[1]Fayetteville region includes Washington, Benton, Carroll, Madison and Sebastian Counties; Batesville region includes Izard, Stone, Independence and Cleburne Counties; Russellville region includes Pope, Logan, Franklin, Conway, Perry, Yell, Scott, Montgomery, Crawford and Johnson Counties; El Dorado region includes Union, Columbia, Ouachita, Cleveland and Lincoln Counties; and Hope region includes Nevada, Miller, Hempstead, Sevier, Pike, Howard, Polk and Lafayette Counties.

[2]Stuttgart region includes Monroe, Prairie, Lonoke, Arkansas and Jefferson Counties; Jonesboro region includes Clay, Greene, Craighead, Poinsett and Cross Counties; McGehee region includes Desha, Lincoln, Drew, Chicot and Ashley Counties; Helena region includes Phillips and Lee Counties; Blytheville region includes Mississippi, Crittenden and St. Francis Counties; and Newport region includes Lawrence, Jackson and Woodruff Counties.

The model consists of six components. First, the objective function maximizes the net revenue from the use of litter. Second, the revenue associated with the use of litter is derived from the increased crop yields due to litter applications. Third, the cost associated with litter use equals the sum of acquisition costs, spreading costs, handling costs, transportation costs and variable harvest costs. The model assumes that the price of litter is a function of demand for and supply of litter. The value of the marginal product of litter as a fertilizer in local pasture is the opportunity cost for transported litter. To determine the opportunity cost of litter in the source region, a linear programming model was constructed with an objective to maximize the forage income given the litter availability and soil productivity constraints (Buchberger, 1991). A survey conducted by Rutherford (1993) indicates that about 80% of the litter is used as a fertilizer to the adjacent pasture production and 20% of the litter in the source region is sold at an average price of $5/ton. Therefore, the cost of litter was introduced as follows. Twenty percent of the available litter can be sold at $5/ton, 30% of the litter can be sold at $13.81/ton, and 50% of the litter can be sold at $18.23/ton. The opportunity costs of $18.23 and $13.81 are the shadow prices representing value of marginal product of litter in local forage production. The fourth component of the model places a restriction on the availability of litter based on the litter production in each of the source regions. The fifth component deals with the maximum allowable use of litter in the destination region based on the acreage under graded soils and crop response to litter applications. The sixth component places restrictions on the availability of crop acreage under graded and ungraded soils.

RESULTS

The results are discussed in terms of three scenarios. First, the base scenario assumes that the cost of truck transportation is $0.10/ton/mile, cost of handling litter is $11.42/ton and the cost of spreading is $3.67/acre (Bosh and Napit, 1991). The base crop prices used are three-year state averages of $0.071/lb of rice, $0.606/lb of cotton and $5.858/bu of soybeans (Arkansas Agricultural Statistics, 1991). Second, the litter transportation cost sensitivity scenario analyzes the robustness of the optimal solutions to changes in the cost of transporting the poultry litter. Third, the crop prices sensitivity scenario analyzes the impact of changes in the crop prices on the optimal solutions.

Base Scenario

Table 2 provides the optimal quantities of litter transportation from each of the five source regions to each of the six destinations. It is optimal to transport the entire litter production from all the source regions except Fayetteville. That is, only about 66% of the litter is transported with an opportunity cost of $18.13/ton of litter. Several reasons can be attributed to this limited transportation of litter, such as the high opportunity cost of litter use in local pasture production and the transportation distance from Fayetteville. With an opportunity cost of $13.81/ton of litter, it is optimal to transport all the litter from all sources except Fayetteville. The results indicate that it is optimal to transport only 64% of the litter with an opportunity of $13.81/ton of litter. The reasons behind the limited transport of litter with an opportunity cost of $18.23 also holds at an opportunity of $13.81/ton of litter. Finally, with an opportunity cost of $5/ton of litter, it is optimal to transport the entire litter production from all the source regions to destinations. In terms of total supply from all the source regions to destination, the optimal solution indicates that only about 75% of the litter is being transported to all the destination regions.

Table 3 provides the optimal choice of crop mix, graded or ungraded soil type, rate of litter application and the acreage for the base scenario. As expected, it is optimal to apply litter for graded soils irrespective of the crops grown, given the distance between the source and destinations. The optimal application rates are about 3000 lb/acre for rice, 4000 lb/acre for cotton and 2000 lb/acre for soybeans. Depending on yield response to litter applications and distance from the source regions, it is sometimes optimal to apply 1000 lb of litter per ungraded acre of rice.

Transportation Cost Sensitivity Scenario:

In this scenario, the impact of changes in transportation cost is evaluated. From the base scenario value $.10/mile/ton, the transportation costs were increased to $.15/mile/ton and $.20/mile/ton. The results are presented in Tables 4 and 5. As expected, the increased transportation costs decreased the optimal amount of litter to transport. With a transportation cost of $0.15/mile/ton of litter and an opportunity cost of $18.23/ton of litter, it is optimal to transport the entire litter only from Batesville, Russellville and El Dorado. The results indicate that it is not optimal to transport any litter from Fayetteville or Hope. As a result, the unused litter with an opportunity cost of $18.23/ ton of litter increased from 34% to 61%. However, at an opportunity of $13.81/ton of litter, it is optimal to transport the entire litter from all source regions except Fayetteville. Although the same effect has been observed in the base scenario, in this scenario, the unused litter with an opportunity cost of $13.81 increased from 36% to 44%. The unused litter with an opportunity cost of $18.23/ton increased from 34% in the base scenario to 76% with a transport cost of $0.20/mile/ton of litter. Also with an opportunity cost of $13.81/ton of litter, the unused litter increased from 36% to 80% with a transport cost of $0.20/mile/ton.

Output Price Sensitivity Scenario

In this scenario, the impact of changes in the output crop prices on the optimal solutions is analyzed. Specifically, the crop prices were increased by 20% and decreased by 20% compared to the base prices. The results are presented in Tables 5 and 6. The impact of increased crop prices was similar to that of decreased transportation costs. Unlike the base scenario, with 20% increase in crop prices, the optimal solution indicates that the entire litter production from all the source regions should be transported to the destinations. The intuition behind this result is that higher crop prices have shifted the derived demand for litter upward. With a 20% decrease in crop prices, it is optimal to transport the entire litter supply only from Batesville to destinations at an opportunity cost of $18.23/ton of litter. That is, the unused litter increases from 36% in the case of base scenario to 92% with 20% decrease in crop prices. The impact of 20% decrease in crop prices seems to have a bigger impact on the optimal quantity of litter transported than the increase in the transportation cost to $0.20/mile/ton. With a 20% decrease in crop prices, the optimal solution indicates that none of the ungraded soils should be amended with poultry litter.

POLICY IMPLICATIONS

These results suggest that it is economical to transport significant portions of the litter produced from regions with high concentrations of poultry production to areas of major row crop production on graded soils. In fact, in many cases the value of the marginal product of litter as a soil amendment in row crop production exceeds the sum of transportation costs and the value of the marginal product as a fertilizer in local forage production so that the entire available supply could be transported from some source regions. An industry is currently developing to transport litter for use as a soil amendment in rice production, and it has been estimated that 30,000 tons of litter were transported last year (Winrock International, 1993). These results suggest that there is tremendous potential for growth in this industry and that as the industry continues to develop, even larger quantities of litter can be predicted to be transported in the future. However, it should be noted that litter must be acquired by paying poultry producers more than the litter is worth as a fertilizer on local pastures. Poultry production areas closer to graded row crop production are the best candidates for sources of litter.

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Table 1. Distance between the source regions and destinations (miles).

	Sources				
Destination	Fayetteville	Batesville	Russellville	El Dorado	Hope
Stuttgart	252	108	127	126	157
Jonesboro	253	74	179	239	245
McGehee	297	188	183	99	146
Helena	305	135	191	191	222
Blytheville	306	127	230	285	298
Newport	220	29	133	204	183

Table 2. Base scenario results from discontinuous non-linear optimization.[z]

Source[y]/Destination/Mode of transport of Litter	Optimal Quantity (million pounds)	% of Available Supply
Step Function 1 (Supply 1): Litter Opportunity Cost: $5/ton		
1) Fayetteville.Jonesboro.Truck	127	100
2) Batesville.Jonesboro.Truck	30	100
3) Russellville.Newport.Truck	94	100
4) El Dorado.McGehee.Truck	25	100
5) Hope.Stuttgart.Truck	101	100
Step Function 2 (Supply 2): Litter Opportunity Cost: $13.81/ton		
1) Fayetteville.Jonesboro.Truck	37	19
2) Batesville.Jonesboro.Truck	39	88
3) Batesville.Newport.Truck	6	12
4) Russellville.Stuttgart.Truck	71	50
5) Russellville.Helena.Truck	70	50
6) El Dorado.McGehee.Truck	37	100
7) Hope.McGehee.Truck	151	100
Step Function 3 (Supply 3): Litter Opportunity Cost: $18.23/ton		
1) Batesville.Newport.Truck	74	100
2) Russellville.Blytheville.Truck	104	44
3) Russellville.Newport.Truck	131	56
4) El Dorado.McGehee.Truck	61	100
5) Hope.Stuttgart.Truck	232	92
6) Hope.McGehee.Truck	21	8

[z]Truck transportation cost at $0.10/ton/mile, crop prices at $0.071/lb, $0.606/lb and $5.858/bu for rice, cotton and soybean, respectively.

[y]Litter availability (million pounds) at each of the source regions are: Fayetteville 634, Batesville 149, Russellville 470, El Dorado 123 and Hope 505.

Table 3. Optimal choice of crop, soil, litter rate and acreage for base scenario

Destination/Crop/Litter Rate (lb/acre)	Optimal Acreage (Ungraded Soil)	Optimal Acreage[z] (Graded Soil)
1) Stuttgart.Rice.(1000)3500[z]	329570	11600
2) Stuttgart.Cotton.4000	0	3500
3) Stuttgart.Soybean.3000	0	6500
4) Jonesboro.Rice.3500	0	50500
5) Jonesboro.Cotton.4000	0	4000
6) Jonesboro.Soybean.2000	0	19500
7) McGehee.Rice.(1000)3500	127300	28000
8) McGehee.Cotton.(1500)4000	16869	11000
9) Helena.Rice.3500	0	20000
10) Blytheville.Rice.3500	0	11550
11) Blytheville.Cotton.3500	0	17500
12) Blytheville.Soybean.2000	0	1250
13) Newport.Rice.(1000)3500	163100	37800
14) Newport.Soybean.2000	0	4700

[z]Figures inside parentheses are optimal litter rates for ungraded soils.

Table 4. Optimal choice of crop, soil, litter rate and acreage for sensitivity scenario.

Transportation Cost	$0.15/ton/mile		$0.20/ton/mile	
Destination/Crop/Litter Rate (lb)	Acreage Ungraded	Acreage[z] Graded	Acreage Ungraded	Acreage Graded
1) Stuttgart.Rice.(1000)3500	250410	11600	0	11600
2) Stuttgart.Cotton.4000	0	3500	0	3500
3) Stuttgart.Soybean.2500	0	6500	0	6500
4) Jonesboro.Rice.3500	0	50500	0	0
5 Jonesboro.Rice.3000	0	0	0	50500
6) Jonesboro.Cotton.3500	0	4000	0	4000
7) Jonesboro.Soybean.2000	0	19500	0	0
8) Jonesboro.Soybean.1500	0	0	0	19500
9) McGehee.Rice.(1000)3500	127300	28000	0	28000
10) McGehee.Cotton.4000	0	11000	0	11000
11) Helena.Rice.3000	0	20000	0	20000
12) Blytheville.Rice.3000	0	11550	0	0
13) Blytheville.Rice.2500	0	0	0	11550
14) Blytheville.Cotton.3500	0	17500	0	17500
15) Blytheville.Soybean.1500	0	1250	0	0
16) Blytheville.Soybean.1000	0	0	0	1250
17) Newport.Rice.3500	0	37800	0	37800
18) Newport.Soybean.2000	0	4700	0	4700

[z]Figures inside parentheses are optimal litter rates for ungraded soils.

Table 5. Sensitivity scenario results from discontinuous non-linear optimization[z]

Source/Destination/Mode of litter transport (million lb)	Crop Prices		Transport Cost	
	20% Up	20% Down	$0.15/t/m	$0.20/t/m
Step Function 1 (Supply 1): Litter Opportunity Cost: $5/ton				
1) Fayetteville.Jonesboro.Truck	127	127	48	0
2) Fayetteville.Blytheville.Truck	0	0	79	0
3) Batesville.Jonesboro.Truck	0	0	30	0
4) Batesville.Blytheville.Truck	0	30	0	0
5) Batesville.Newport.Truck	30	30	0	30
6) Russellville.Stuttgart.Truck	0	11	0	0
7) Russellville.Jonesboro	0	0	34	0
8) Russellville.Helena.Truck	0	40	60	0
9) Russellville.Newport.Truck	94	0	0	94
10) Russellville.Blytheville.Truck	0	43	0	0
11) El Dorado.McGehee.Truck	25	25	25	25
12) Hope.McGhee.Truck	31	81	0	0
13) Hope.Stuttgart.Truck	0	0	0	71
14) Hope.Helena.Truck	70	20	0	11
Step Function 2 (Supply 2): Litter Opportunity Cost: $13.81/ton				
1) Fayetteville.Jonesboro.Truck	49	0	0	0
2) Fayetteville.Blytheville.Truck	113	0	0	0
3) Fayetteville.Newport.Truck	28	0	0	0
4) Batesville.Newport.Truck	44	0	0	0
5) Batesville.Jonesboro.Truck	0	19	44	0
6) Batesville.Blytheville.Truck	0	25	0	44
7) Russellville.Stuttgart.Truck	30	21	122	0
8) Russellville.Newport.Truck	111	120	0	0
9) Russellville.Jonesboro.Truck	0	0	0	141
10) Russellville.Blytheville.Truck	0	0	19	0
11) El Dorado.McGehee.Truck	37	37	37	37
12) Hope.Stuttgart.Truck	0	30	106	0
13) Hope.McGhee.Truck	151	0	46	0
Step Function 3 (Supply 3): Litter Opportunity Cost: $18.23/ton				
1) Fayetteville.Jonesboro.Truck	317	0	0	0
2) Batesville.Jonesboro.Truck	74	74	74	54
3) Batesville.Newport.Truck	0	0	0	18
4) Russellville.Stuttgart.Truck	235	0	94	0
5) Russellville.Helena.Truck	0	0	0	49
6) Russellville.Newport.Truck	0	0	142	0
7) Russellville.Blytheville.Truck	0	0	0	45
8) El Dorado.McGehee.Truck	61	0	61	61
9) Hope.Stuttgart.Truck	138	0	0	0
10) Hope.McGhee.Truck	114	0	0	0

[z]Scenario deals with 20% increase and 20% decrease in crop base prices at $0.071/lb, $0.606/lb and $5.858/bu for rice, cotton and soybean, respectively.

Table 6. Optimal choice of crop, soil, litter rate and acreage for sensitivity scenario.

Change in crop prices	20% Increase		20% Decrease	
Destination/Crop/Litter Rate (lb/acre)	Optimal Acreage Ungraded	Optimal[z] Acreage Graded	Optimal Acreage Ungraded	Optimal Acreage Graded
1) Stuttgart.Rice.(1000)3500[y]	329570	11600	0	0
2) Stuttgart.Rice.3000	0	0	0	11600
3) Stuttgart.Cotton.4000	0	3500	0	3500
4) Stuttgart.Soybean.3000	0	6500	0	0
5) Stuttgart.Soybean.2000	0	0	0	6500
6) Jonesboro.Rice.(1000)3500	324430	50500	0	50500
7) Jonesboro.Cotton.4500	0	4000	0	0
8) Jonesboro.Cotton.3500	0	0	0	4000
9) Jonesboro.Soybean.2500	0	19500	0	0
10) Jonesboro.Soybean.1500	0	0	0	19500
11) McGehee.Rice.(1000)3500	127300	28000	0	28000
12) McGehee.Cotton.(1500)4000	99926	11000	0	11000
13) Helena.Rice.3500	0	20000	0	0
14) Helena.Rice.3000	0	0	0	20000
15) Blytheville.Rice.3500	0	11550	0	0
16) Blytheville.Rice.3000	0	0	0	11550
17) Blytheville.Cotton.4000	0	17500	0	0
18) Blytheville.Cotton.3500	0	0	0	17500
19) Blytheville.Soybean.2000	0	1250	0	0
20) Blytheville.Soybean.1500	0	0	0	1250
21) Newport.Rice.(1000)3500	0	37800	0	0
22) Newport.Rice.3000	0	0	0	37800
23) Newport.Soybean.2500	0	4700	0	0
24) Newport.Soybean.2000	0	0	0	4700

[z]Optimal acreage represents the total optimal acreage applied with litter given endogenous litter prices. Truck transportation cost at $0.15 and $0.10/ton/mile, 20% increase and 20% decrease in crop base prices at $0.071/lb, $0.606/lb and $5.858/bu for rice, cotton and soybean, respectively.

[y]Figures in parenthesis are the optimal rates of litter application to ungraded soils whereas figures outside the parenthesis are the optimal rates of litter application to graded soils.

ECONOMICS OF NITROGEN FERTILIZATION OF 'ALAN' RICE IN ARKANSAS.

Lucas D. Parsch, Lihong Kan, Bobby R. Wells and Richard J. Norman

ABSTRACT

Data from nitrogen fertilization studies of 'Alan' rice grown in Arkansas between 1989-92 were analyzed from an economic perspective to determine the nitrogen (N) level and midseason application sequence that result in maximum net returns. Results for the cultivar Alan show that the economically optimal N level and midseason N application sequence differ from one site to another. At Stuttgart, Arkansas, net returns were maximized with a single pre-flood application of N. At Colt and Keiser, Arkansas, net returns were maximized with 2-way and 3-way split applications, respectively, using low and moderate levels of midseason N. Averaged across three locations, 118 lb/acre N resulted in maximum net returns for Alan using average rice prices and nitrogen costs. These optimal N application sequences do not change, and the corresponding optimal N levels remain relatively stable when subjected to broad fluctuations in rice price and N cost.

INTRODUCTION

One important management issue faced by the rice producer is determining the economically optimal N level and midseason N application sequence. In recent years, various studies have been conducted in Arkansas to determine the response of rice to alternative fertilization regimes, yet few of these studies have been analyzed for their economic implications. The purpose of this study was to analyze the optimal N fertilization strategy for the cultivar 'Alan' based on experimental data collected in Arkansas. Alan is a relatively new and popular long-grain rice cultivar that was grown on 28% of the total rice acreage in Arkansas in 1993. Results of the study should provide producers with strategic information on the N level and N timing sequence that maximizes net returns for Alan.

PROCEDURES

Experimental data from fertilization studies that evaluate yield response of Alan rice to nitrogen level, timing of nitrogen application and plant area measurements (Wells et al., 1991, 1992, 1993) were assembled and organized for use in the present study. The data were collected at three sites in Arkansas over the period 1989-1992: Stuttgart (Rice Research and Extension Center, Crowley silt loam, 1989-1992); Keiser (Northeast Research and Extension Center, Sharkey clay, 1989-1991); and Colt (Pine Tree Experiment Station, Calloway silt loam, 1989-1991). The experimental design was a split plot with early-season pre-flood N rates of 0, 40, 80, 120 or 160 lb/acre as the main plots and mid-season N rates of 0, 30, 60 or 90 lb/acre as the subplots. Using statistical procedures, a yield response surface of Alan was estimated for each of the three sites based on plot data of grain yield, nitrogen rate and timing of mid-season application. Data were pooled across years, and the effect of year was modeled as cumulative growing degree days base 50 F (GDD) between 1 May and 1 September to account for weather differences that may have influenced yield. Interaction terms were also included. Each estimated response surface predicts yield as a curvilinear (quadratic) function of total seasonal N. In each response surface, binary variables are used to explain the impact of four N timing treatments: (1) A single N application applied at preflood (PF); (2) a two-way split of N applied at PF and 30 lb/acre N applied at internode elongation (IE); (3) a three-way split applied at PF and 30 lb/acre N at each IE and 10 days after IE (IE10); and (4) a three-way split at PF and 45 lb/acre N at each IE and IE10.

Once each response surface was estimated, differential calculus was used to solve the profit-maximizing N level at a given site for each N application sequence. Profits, i.e., returns above cost of N fertilizer and N application, were computed for a base scenario using the 1987-1991 five-year average price of rice in Arkansas ($7.92/cwt indexed to 1991 dollars) and the 1987-1990 four-year average price N as urea ($0.185/lb N). Cost of aerial application of N as urea was the average for Arkansas in 1991 ($4.25/acre for material applications less than 100 lb/acre and $0.0924/lb N for urea applications greater than 100 lb/acre). Results of the base scenario were subsequently subjected to sensitivity analysis to determine whether the optimal N level and application sequence were stable when the price of rice and cost of nitrogen were allowed to vary.

RESULTS AND DISCUSSION

Results for the cultivar Alan based on data from three experimental sites over the period 1989-1992 are presented in Table 1 for average rice price and nitrogen cost. For each site, Table 1 shows the predicted level of total seasonal N that results in maximum net returns above nitrogen material cost and nitrogen application cost for each of the four application sequences. Table 1 also shows predicted yield, total cost of N materials and N application and the corresponding maximum net returns associated with each application sequence. The economically optimal N application sequence at each site is designated with (*) in the Predicted Net Returns column. For example, at Keiser, a total seasonal N application of 156 lb/acre distributed in a three-way split of 96-30-30 at PF-IE-IE10 results in larger returns above specified costs ($615.89/acre) than any of the other N application sequences. This same application sequence results in a predicted yield of 83.61 cwt/acre with cost of N totaling $46.28/acre. The three remaining application sequences (1, 2L, and 3H) result in net returns that--at best--fall short of the optimal (3M) sequence by $4.30/acre to $39.49/acre.

The results in Table 1 can be summarized as follows for Alan:

1. The optimal N application sequence varies by site. A single pre-flood application is optimal at Stuttgart, a 2-way split with 30 lb/acre midseason N is optimal at Colt, and a 3-way split with 60 lb/acre midseason N is optimal at Keiser.
2. The economically optimal total seasonal N level varies from one site to another, ranging from 97 lb/acre at Stuttgart to 156 lb/acre at Keiser. Averaged across the three sites, the optimal total seasonal N is 118 lb/acre.
3. Use of a non-optimal N application sequence at any specified site results in reduction in net returns that can be dramatic. The cost of attempting to maximize profits using the "wrong" application sequence ranged from $4.30/acre at Keiser to $47.62/acre at Colt.

The results in Table 1 are not independent of economic factors. Normally, a higher price of rice will necessitate higher levels of N in order to maximize returns. Conversely, higher prices of N will necessitate lower levels of N in order to maximize returns. Sensitivity analysis was conducted in order to determine how the results in Table 1 are affected when price of rice was allowed to vary between the 10-year high and low values for Arkansas and the cost of nitrogen was ranged between ±2 standard deviations of the four-year mean.

Summary results of the sensitivity analysis are presented in Table 2. The first row for each site repeats the optimal N application sequence and N level under average prices from Table 1. The second row at each site identifies the optimal application sequence and range of optimal N levels when prices and costs are allowed to vary. For example, at Keiser, the optimal N application sequence is a 3-way split with medium midseason N (3M) for all combinations of rice price and nitrogen cost specified above. However, optimal total seasonal N level does vary between 152 and 158 lb/acre under the same price and cost ranges.

Results in Table 2 can be summarized as follows for Alan:

1. At any given site, the optimal N application sequence is not affected by broad changes in price of rice or cost of nitrogen. Under the sensitivity analysis conducted here, the application sequence at all three sites was invariant to specified changes in economic factors.
2. Although changes in price of rice and cost of nitrogen affect the total seasonal N level that is optimal, these changes are relatively small. Optimal N level varied by as little as 6 lb/acre at Keiser to as much as 11 lb/acre at Stuttgart under the alternative economic scenarios. On a percentage basis, these ranges are only 4% to 11% of the optimal N level under average prices.

The results in Tables 1 and 2 do not account for differing levels of residual soil fertility, diseases and pests and other risks associated with rice production.

SIGNIFICANCE OF FINDINGS

Results of this study indicate that identifying the appropriate split application sequence for N on Alan rice may be of greater importance than finding the optimal total seasonal N-level. At each of three sites, use of the profit-maximizing N level in combination with a non-optimal N application sequence resulted in a dramatic reduction in net returns when compared to the profit-maximizing N level for the optimal N application sequence. Use of a non-optimal application sequence resulted in a reduction of net returns ranging between $4.30/acre at Keiser and $47.62/acre at Colt. These results demonstrate that the cost of applying N in the "wrong" number of split applications is high, even if the optimal N level (associated with that split) is employed. Once the optimal N application sequence is identified at any given site, it is fairly robust in that changes in price of rice or cost of N materials have little effect on it.

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Table 1. Predicted nitrogen level that maximizes net returns for four alternative nitrogen (N) application sequences, 'Alan' rice, Arkansas, 1989-92.

Site	Application Sequence[z]	Profit Maximizing Nitrogen Level N_{PF}	N_{IE}	N_{IE10}	Total N	Predicted Yield	Predicted N Cost	Predicted NR	NR Status
		lb/acre[y]	lb/acre[y]	lb/acre[y]	lb/acre[x]	lb/acre[w]	$/acre[v]	$/acre[u]	$/acre[t]
Stuttgart	1	97	0	0	97	6432	27.02	482.39*	0.00
	2L	83	30	0	113	6340	32.86	469.25	-13.14
	3M	68	30	30	128	6158	38.33	449.42	-32.97
	3H	59	45	45	149	6166	41.63	446.69	-35.70
Keiser	1	115	0	0	115	7680	31.88	576.40	-39.49
	2L	93	30	0	128	7806	36.93	581.27	-34.62
	3M	96	30	30	156	8361	46.28	615.89*	0.00
	4H	95	45	45	185	8374	51.6	611.59	-4.30
Colt	1	79	0	0	79	7349	21.93	560.09	-31.61
	2L	70	30	0	100	7839	29.14	591.70*	0.00
	3M	59	30	30	119	7455	35.99	554.44	-37.26
	4H	49	45	45	139	7360	38.62	544.08	-47.62

[z]Number of applications per season with low (L), medium (M), or high (H) midseason N.
[y]Level of nitrogen applied at preflood (PF), internode elongation (IE) and 10 days after internode elongation (IE10) for profit maximization for each split sequence.
[x]Level of total seasonal nitrogen applied for profit maximization for each split sequence.
[w]Predicted yield for the profit maximizing split sequence.
[v]Total cost of N materials (as urea) and aerial application.
[u]Predicted maximum net returns (NR) for each split application. Optimal split sequence at each site is designated with *.
[t]The difference in net returns for each split application and the optimal split application at each site.

Table 2. Optimal nitrogen application sequence and N level under alternative price scenarios, 'Alan' rice, Arkansas, 1989-1992.

Location	Price Scenario	Optimal Application Sequence	Optimal Total N (lb/acre)	N Split (PF-IE-IE10)
Stuttgart	Average Price[z]	1	97	97-0-0
	All Prices[y]	1	90-101	—
Keiser	Average Price[z]	3M	156	96-30-30
	All Prices[y]	3M	152-158	—
Colt	Average Price[z]	2L	100	70-30-0
	All Prices[y]	2L	95-102	—

[z]Optimal application sequence and N level using five-year (1987-1991) average price of rice and four-year (1987-1990) average price of nitrogen as urea.

[y]Range of optimal N-levels and optimal application sequence for rice price varying between the 10-year high and low price of rice, and nitrogen prices ranging between ±2 standard deviations of mean price of N.

ARKANSAS RICE MODEL 1994 INTERNATIONAL BASELINE PROJECTIONS

Eric J. Wailes, Gail L. Cramer, and Shenggen Fan

ABSTRACT

The international and interregional competitiveness of the United States rice industry is critical to the long-term economic survival of rice farmers and agribusiness firms located in Arkansas and other rice-producing regions. A global rice model is developed to simulate the rice economies of the United States and our major export competitors and importing countries. This model framework is used to develop a baseline projection of supply, consumption, trade and prices. The baseline projection will be used as a benchmark to evaluate domestic and international policy changes, impacts of new technology, resource constraints and consumption shifts. A 1994 baseline projection is reported for world production, consumption, net trade and prices, U.S. supply and utilization and Arkansas supply.

INTRODUCTION

The rationale for a baseline projection for the world rice economy is compelling. The baseline projection provides a benchmark against which it is possible to evaluate the consequences of new developments affecting world rice trade such as the recently agreed GATT accord, as well as regional (NAFTA) and unilateral reforms. Of primary interest for the U.S. rice industry is a framework for analysis of policy reforms to be developed in terms of the forthcoming 1995 omnibus farm legislation. The modeling framework allows for the analysis of longer-term impacts of production, consumption and technology shifts. An assessment of the trade position of the United States is evaluated based upon a continuation of current policies, consumption preferences and production practices.

PROCEDURES

A baseline projection of the global rice economy was developed for the period 1993-2003. The Arkansas Rice Model (ARM) is based on a multi-country econometric framework. This framework consists of over 500 statistically estimated equations. The model provides projections for a set of 16 major rice producing/trading countries and an aggregate rest-of-the-world region. Projections include national levels of production (area harvested and yields), consumption, net trade, stocks and prices. Estimates for these variables are based on a set of explanatory variables including exogenous macroeconomic factors such as income, population, inflation rate, technology development and, especially, government-determined policy variables that reflect the various mechanisms by which countries intervene in their rice sector economy. The baseline assumes that current policies are maintained. Macroeconomic data are based on WEFA (Wharton Econometric Forecasting Associates) and Project LINK (an international consortium of macroeconomic forecasters) projections. A baseline projection is not a forecast since, for example, the baseline presented here does not include the GATT agreement that was concluded in late 1993. This baseline will be used to evaluate the GATT agreement.

Countries or regions explicitly included in the model are the United States, Thailand, Pakistan, China, India, Burma, Vietnam, Japan, Korea, Australia, Indonesia, the European Community, Egypt, Iran, Iraq and Saudi Arabia. The United States is further disaggregated by states to provide projections of rice supply. All other countries are included in the rest-of-the-world (ROW) region. The individual countries that are currently included in the model account for over 82% of world rice production, 79% of consumption, 85% of world rice exports, 20% of world rice imports and 80% of world rice stocks.

RESULTS AND DISCUSSION

Growth in global rice production over the projection period will mainly come from yield increases, as area harvested is projected to increase only slightly to 147.9 million ha by 2003 from a 1992 base of 145 million ha (Table 1). The world average yield for rice was about 2.42 metric tons (mt)/ha in 1992 and is projected to be 2.74 mt/ha by 2003. Consequently, total production increases from 351 million metric tons (mmt) in 1992 to 405 mmt by 2003.

Total world consumption is projected to increase at the same rate as total production, from 354 mmt in 1992 to 407 mmt by 2003. Consumption growth is primarily driven by population growth. Income growth has mixed effects on rice consumption. For some Asian countries, rice has become an inferior (negatively related to higher incomes) product, while for other countries, including some industrialized market economies, it is still a normal product. Ending stocks are projected to increase from 43.6 mmt in 1993 and then decline to a level of 43.8 mmt by 2003.

World rice net trade is projected to increase only marginally from 11.6 mmt in 1992 to 14.6 mmt by 2003. Net trade as a percentage of total production increases slightly from 3.3% in 1992 to 3.6% by 2003. The international rice market is projected to remain thin.

Among the major net exporting countries, Thailand is projected to maintain its status as the dominant rice-exporting country (Table 2). Thailand's net exports in 1993 may reach 4.5 mmt and 5.0 mmt by 2003. Net exports from the United States are projected to remain level near 2.25 mmt. This implies a decline in the U.S. net export market share from 19% in 1992 to 15% by 2003. The most significant growth in exports is by Burma (Myanmar), which is projected to expand exports following the pattern of Vietnam over the past decade. Pakistan also is projected to expand exports; however China, Vietnam and India are all projected to have declining rice exports.

The baseline projection without the GATT agreement (which is expected to provide minimum access into previously closed rice markets such as Japan and Korea of more than 1 mmt by 2003) shows that relatively strong growth in imports is projected to occur in Iran and Saudi Arabia. Most of the net import growth, however, is dispersed throughout the globe and reflected in the Rest of World designation (Table 2). The net trade projection for each country or region identified in Table 2 is based on a more detailed supply and utilization framework that is available in a more comprehensive report (Wailes et al., 1994).

The international rice price (Thailand FOB 5%) is projected to increase from \$264/mt in 1992 to \$378 in 1993 due to the poor harvest in Japan and relatively tighter supplies (Table 2). The price is projected to average \$355/mt during the period from 1994 to 1998. After 1998, the international price is projected to increase in nominal terms steadily from \$388/mt in 1998 to \$434/mt by 2003. In real terms, it is projected to increase only slightly.

Baseline projections for the United States rice sector are based upon a continuation of current government programs (Table 3). U.S. rice production is heavily influenced by government programs. The acreage reduction program is set in response to the stocks to utilization ratio. The acreage reduction program is set to achieve a desired stocks to use ratio between 0.165 and 0.20. The program participation rate is projected to decline from 96% in 1993 to 91% by 2003 due to a real decline in the nominally fixed target price. Total rice area harvested in the United States is 2.83 million acres in 1993, and it is projected to increase to 3.23 million acres by 2003. This increase mainly comes from more area planted as non-program acres. Yield is projected to increase from 5510 lb/acre in 1993 to 5937 lb/acre by 2003. As a result, rice production in the United States increases from 156.1 million cwt in 1993 to 191.9 million cwt by 2003.

Domestic food consumption of rice is projected to increase substantially, from 68.8 million cwt in 1992 to 90.6 million cwt by 2003, mainly due to income and population effects. Seed use is projected to be flat during the projection period, around 4.1 million cwt. Brewing use is projected to increase from 15.1 million cwt in 1992 to 18.1 million cwt by 2003.

Exports are projected to remain at a level of approximately 80 million cwt; imports are projected to increase from 6.1 million cwt in 1992 to 11.4 million cwt by 2003. Ending stocks are projected to increase to 38 million cwt in 1994 and gradually decline to 31.2 million cwt by 2003.

Farm price is projected to be $8.64/cwt in 1993, dropping to $6.96 in 1994 and increasing to $9.29 by 2003. Export price is projected to be $21.03/cwt in 1993, dropping to $19.34/cwt in 1994 and increasing to $22.92/cwt by 2003.

The baseline projection for Arkansas reflects that government program participation is projected to decline in 1994 to 93%, increasing to 95% from 1996 to 1999, and then gradually declining to 93% by 2003 (Table 4). Total area planted to rice is projected to increase substantially to about 1.5 million acres by 1994, and then decline and settle at approximately at 1.4 million acres. Arkansas rice yield is projected to grow from 5050 lb/acre in 1993 to 5646 lb/acre by 2003. Production is projected to increase to 76.9 million cwt in 1994, drop to 69.1 million cwt in 1995, and then gradually increase to 79 million cwt by 2003. Baseline projections have been developed for other major rice producing states but are not shown.

SIGNIFICANCE OF FINDINGS

The major findings of the development of the Arkansas Rice Model is the measurement of interactions among broad sets of exogenous and endogenous variables on the global rice economy. The model framework solves for a global equilibrium in world rice trade, production and consumption at prices that clear the market. The development of this baseline framework is significant because it provides a comprehensive framework within which evaluations of changes in domestic and international rice policies can be conducted. This framework lends itself as well to assessments of impacts of new technology, resource constraints and consumption shifts. Annual revised baseline projections will be developed from the model so that analysis of policy changes and market competitiveness can be made in a timely and comprehensive manner.

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Table 1. Estimated world total rice supply and utilization, 1992-2003.

Variable/Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Area Harvested	(Mil. ha)	145.1	145.1	146.5	146.3	146.5	146.7	146.7	146.9	147.1	147.3	147.6	147.9
Yield	(tons/ha)	2.42	2.40	2.45	2.48	2.52	2.55	2.58	2.61	2.64	2.67	2.71	2.74
Production	(mmt)	351.1	347.5	359.7	363.1	368.9	373.9	378.4	383.4	388.6	393.8	399.1	404.7
Consumption	(mmt)	354.4	355.2	356.3	361.9	366.8	372.1	378.1	384.1	389.9	395.5	401.6	407.2
Net Export	(mmt)	11.64	13.28	13.05	13.03	13.26	13.47	13.61	13.78	13.97	14.19	14.40	14.64
Net Import	(mmt)	11.64	13.28	13.05	13.03	13.26	13.47	13.61	13.78	13.97	14.18	14.40	14.64
Residual	(mmt)	0	0	0	0	0	0	0	0	0	0	0	0
Ending Stocks	(mmt)	51.4	43.6	47.0	48.2	50.4	52.2	52.4	51.8	50.5	48.8	46.3	43.8

Source: USDA and Arkansas Rice Model projections.

Table 2. Estimated world rice net trade and world price, 1992-2003.

Variable/Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
EXPORTERS	(1,000 mt)	11644	13277	13050	13031	13256	13470	13612	13784	13966	14185	14399	14643
United States	(1,000 mt)	2248	2347	2243	2272	2194	2244	2297	2297	2280	2273	2254	2233
Thailand	(1,000 mt)	4300	4494	4832	4735	4828	4895	4890	4930	4966	5004	5047	5049
Pakistan	(1,000 mt)	900	1300	1161	1205	1248	1291	1332	1372	1411	1437	1468	1497
Burma	(1,000 mt)	275	400	521	613	702	800	908	1030	1166	1316	1481	1661
Vietnam	(1,000 mt)	1900	2000	1878	1877	1875	1873	1869	1865	1860	1854	1846	1838
China	(1,000 mt)	1015	1350	1028	991	1107	1075	1008	949	909	888	843	857
India	(1,000 mt)	340	800	690	631	571	529	500	479	464	451	440	429
Australia	(1,000 mt	490	454	478	479	481	482	484	487	491	496	502	507
Egypt	(1,000 mt)	176	133	219	229	250	282	322	373	419	466	517	572
IMPORTERS	(1,000 mt)	11644	13277	13050	13031	13256	13470	13611	13783	13966	14184	14399	14643
Japan	(1,000 mt)	20	1500	500	20	20	20	20	20	20	20	20	20
Indonesia	(1,000 mt)	590	-250	0	0	0	0	0	0	0	0	0	0
Iraq	(1,000 mt)	508	550	496	501	508	515	521	526	531	535	538	540
Iran	(1,000 mt)	765	750	576	549	555	587	639	706	786	876	973	1076
Saudi Arabia	(1,000 mt)	652	750	708	737	767	799	832	866	901	938	977	1016
Total EC-12	(1,000 mt)	234	450	370	381	383	380	375	368	360	351	341	331
South Korea	(1,000 mt)	0	0	0	0	0	0	0	0	0	0	0	0
Rest of World	(1,000 mt)	8875	9527	10400	10843	11023	11169	11226	11297	11368	11464	11550	11660
RESIDUALS	(1,000 mt)	0	0	0	0	0	0	0	0	0	0	0	0
THAIFOB, 5%	(US$/mt)	264	378	328	335	358	352	372	388	405	415	428	434

Source: USDA and Arkansas Rice Model projections.

Table 3. Estimated United States supply, utilization and prices, 1992-2003.

Variable/Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
PROGRAM												
Participation rate	0.95	0.96	0.90	0.95	0.93	0.92	0.94	0.93	0.92	0.92	0.91	0.91
ARP rate	0.00	0.05	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50/85 participation rate	0.38	0.49	0.35	0.39	0.37	0.38	0.42	0.41	0.42	0.42	0.43	0.43
Idled acres rate	0.24	0.35	0.25	0.32	0.29	0.28	0.32	0.30	0.29	0.29	0.29	0.28
Flex rate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
YIELD												
Actual (lb/acre)	5741	5510	5709	5732	5760	5785	5811	5837	5862	5887	5912	5937
Program (lb/acre)	4849	4852	4852	4852	4852	4852	4852	4852	4852	4852	4852	4852
HARVESTED ACREAGE												
Non-program ('000)	313	422	551	320	444	484	367	430	447	471	484	498
Program ('000)	2817	2411	2757	2632	2651	2788	2766	2771	2760	2753	2743	2734
Total ('000)	3130	2833	3308	2951	3094	3272	3133	3201	3207	3224	3227	3232
SUPPLY (m cwt)	213.2	202.3	219.1	214.8	215.7	227.3	228.1	229.9	230.9	232.5	233.7	234.8
Production (m cwt)	179.7	156.1	188.8	169.2	178.2	189.3	182.1	186.8	188.0	189.8	190.8	191.9
Beg. Stocks (m cwt)	27.4	39.4	22.9	38.0	29.3	29.5	37.1	33.6	33.0	32.3	32.0	31.6
Imports (m cwt)	6.1	7.0	7.4	7.7	8.1	8.5	8.9	9.4	9.8	10.3	10.9	11.4
DOMESTIC USE	96.7	98.6	103.0	106.2	108.9	110.9	113.1	115.0	116.8	118.5	120.1	121.8
Food (m cwt)	68.8	70.5	74.9	77.3	79.4	81.3	83.1	84.7	86.3	87.7	89.1	90.6
Seed (m cwt)	3.8	4.1	3.7	3.9	4.1	3.9	4.0	4.0	4.1	4.1	4.1	4.2
Brewers (m cwt)	15.1	15.0	15.5	16.0	16.4	16.7	17.0	17.2	17.5	17.7	17.9	18.1
Residual (m cwt)	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
EXPORTS (m cwt)	77.0	81.0	78.1	79.4	77.3	79.3	81.4	81.8	81.7	82.0	82.0	81.8
TOTAL USE (m cwt)	173.7	179.6	181.1	185.5	186.2	190.2	194.5	196.8	198.5	200.5	202.1	203.7
END STOCKS (m cwt)	39.4	22.9	38.0	29.3	29.5	37.1	33.6	33.0	32.3	32.0	31.6	31.2
PRICES												
Target Price ($/cwt)	10.71	10.71	10.71	10.71	10.71	10.71	10.71	10.71	10.71	10.71	10.71	10.71
Farm Price ($/cwt)	5.90	8.64	6.96	7.86	8.13	7.45	8.03	8.31	8.61	8.83	9.09	9.29
Export Price ($/cwt)	15.15	21.03	19.34	19.56	20.36	20.15	20.81	21.36	21.94	22.27	22.72	22.92

Source: USDA and Arkansas Rice Model projections.

Table 4. Estimated Arkansas rice supply, 1992-2003.

Variable/Year		1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Program													
Participation Rate		0.98	0.98	0.93	0.97	0.95	0.95	0.96	0.95	0.95	0.94	0.94	0.93
50/85 Part. Rate		0.21	0.33	0.20	0.24	0.22	0.23	0.27	0.26	0.27	0.27	0.28	0.29
Idled Acres	%	0.26	0.33	0.23	0.31	0.27	0.27	0.30	0.28	0.27	0.27	0.26	0.26
Yields	(lb/acre)	5500	5050	5262	5335	5374	5412	5452	5491	5530	5569	5608	5647
Acreage Harvested													
Non-program	('000)	145.6	259.7	268.6	148.4	199.7	216.7	158.4	183.7	186.0	193.7	195.8	198.5
Program	('000)	1234.4	970.3	1193.6	1147.0	1151.6	1214.8	1211.9	1213.3	1209.9	1207.4	1203.9	1200.1
Total	('000)	1380.0	1230.0	1462.2	1295.5	1351.3	1431.5	1370.3	1397.0	1395.9	1401.1	1399.6	1398.5
Production	(m cwt)	75.9	62.1	76.9	69.1	72.6	77.5	74.7	76.7	77.2	78.0	78.5	79.0

Source: USDA and Arkansas Rice Model projections.

ESTIMATED PROCESSING COST AND POTENTIAL MARKET VALUE OF RICE BRAN OIL

Kenneth B. Young, Eric J. Wailes and Gail L. Cramer

ABSTRACT

Scientists have reported that rice bran oil (RBO) may help to reduce cholesterol and that RBO is superior to other cooking oils for some food preparations. The U.S. rice industry is currently developing facilities to process RBO, but there is little information available on the economics of RBO processing. This study evaluates the use of alternative RBO processing methods, including those developed in Japan, to estimate the cost under U.S. operating conditions. Estimated cost of refined RBO ranges from $0.30 to $0.42/lb, depending on the method of bran conditioning, extraction temperature and refining method. This cost for RBO is estimated to be higher than the price of the common vegetable oils but less than that of other more-specialized oils such as peanut oil. RBO has specialized, high-value uses, including the production of fried snack foods with a long shelf life. By-products of RBO refining also have specialized, high-value uses.

INTRODUCTION

Experience in processing rice bran oil (RBO) has been very limited in the U.S., and only one firm is known to have had any long-term commercial experience. Currently, several firms have announced plans to begin producing RBO on a commercial scale. In contrast to the U.S., RBO processing is a highly developed industry in Japan. The Japanese use specialized refining methods, and they produce high-valued pharmaceutical products as well as different grades of refined RBO that are currently exported to the U.S.

This study evaluates the use of alternative methods to process rice bran prior to oil extraction plus alternative extraction temperatures and refining methods to process the RBO. Many of these methods were developed in Japan, and the processing data available from Japan were used to guide this study (Young et al., 1994 and 1991).

The growing demand for RBO in the U.S. is attributed to recent favorable research on the cholesterol control benefits of RBO. Research reported by Nicolosi et al. (1991, 1992) has demonstrated that the unsaponifiable components in RBO help to control cholesterol and seem to offset saturated fat in the diet. The most important unsaponifiable component in RBO is believed to be oryzanol. Current imported alkali-refined RBO with 200 ppm guaranteed minimum oryzanol content has a bulk wholesale price of about $0.80/lb, whereas the physically refined RBO with a guaranteed minimum of 10,000 ppm oryzanol is sold for about double the price. This study includes an evaluation of the market prospects for RBO as a health food product and for specialized food preparations.

PROCEDURES

Cost estimates for processing RBO are derived from previous studies of vegetable oil extraction and refining and from industry sources. Data were not available on the current distribution and marketing of RBO to fully assess the market potential. RBO is compared with other vegetable oils with similar health claims and food preparation characteristics to determine its approximate market value as a specialty oil. Processing costs for RBO are estimated for all processing stages, starting with the raw rice bran through refining activities (Figs. 1 and 2). Alternative processing methods compared included three bran treatments (stabilization, high-temperature conditioning and low-temperature conditioning) and two refining methods.

RESULTS OF THE STUDY

It was determined that RBO would probably be marketed as a specialty oil even if all the available rice bran in the U.S. were extracted, as the potential crude oil output is only about 93,000 tons/year. The status of current health research on RBO was reviewed in the study; however, the benefits of RBO are not yet proven to be superior to those of other vegetable oils for cholesterol control. Consequently, the FDA has not approved RBO as having any special health benefits. Until agencies such as the FDA endorse RBO as having special health benefits, there will likely to be a limited market for RBO as a health food product.

There are few studies on rice oil uses and qualities in food preparation in the U.S. (Young et al., 1994). The review of data from Japan on using RBO in food preparations indicates that RBO should have a definite niche market, particularly for packaged fried snack foods, as the shelf life of these products is superior to that of products prepared with other vegetable oils. RBO-prepared foods are strongly preferred in many Oriental countries such as Japan. RBO products may have a potential export market in Japan. RBO also has some unique characteristics that are desirable for producing semi-solid fat products such as margarine. RBO is considered comparable to peanut oil for stir frying applications. The niche market benefits of RBO are considered to be at least equivalent to refined peanut oil, which has a current recent average wholesale price of about $0.45/lb.

Estimated costs of processing RBO from raw rice bran are in the range of $0.30 to $0.42/lb at the refinery (Table 1). The least-cost option assumed that the raw bran was extracted almost immediately after milling with normal high-temperature solvent extraction. Cost was increased only slightly to $0.33/lb with raw bran extraction after low-temperature conditioning and low-temperature solvent extraction to help ensure better oil quality (Table 1). With bran stabilization, the cost of using low-temperature extraction and alkali refining was estimated at $0.42/lb versus $0.36/lb using normal high-temperature extraction. Less oil was extracted from the bran with low-temperature extraction, requiring more bran per ton of oil. Physical refining results in less refining loss when the RBO contains a high level of free fatty acids and the refined RBO has much higher oryzanol content. However, refinery operators contacted in this study were skeptical about using physical refineries available in the U.S. There is a limited potential supply of RBO to justify constructing a new physical refinery, whereas there is excess alkali refining capacity available.

The study assumed conservative values for RBO refining by-products such as defatted rice bran (DRB) and the soapstock. The soapstock from alkali refining is used to process oryzanol in Japan. The DRB may be extracted to provide high-value protein concentrates and food grade fiber concentrates that can have a higher market value than the RBO.

SIGNIFICANCE OF FINDINGS

The niche market for RBO appears to be much stronger in specialized food preparations than as a health food. There appear to be limited data on the food-preparation qualities of RBO in the U.S., and most of the data for this study were obtained from industry studies in Japan.

The methods used to condition bran for extraction, the extraction temperature and refining alternatives limit the type and quality of RBO by-products produced. For example, high-temperature treatment of the bran prior to extraction will denature the bran protein, making it difficult to extract protein concentrates from the DRB. More information is needed on the numerous processing options that are available for DRB and other RBO refining by-products.

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Table 1. Approximate processing costs of RBO with alternative methods of bran treatment, extraction and refining.

Activity	Option 1[a]	Option 2[b]	Option 3[c]	Option 4[d]	Option 5[e]
Raw bran[f]	$412 (5.9t)	$412 (5.9t)	$368 (5.3t)	$412 (5.9t)	$368 (5.3t)
Transport to stabilizer	0	0	0	0	0
Bran treatment[g]	18	18	37	141	126
Transport to extractor[h]	16	16	15	16	15
Extraction[i]	206	206	132	206	132
Gum removal[j]	30	30	30	30	30
Wax removal[k]	—	—	30	—	30
Transport to refinery[l]	30	30	30	30	30
Refining[m]	80	80	80	80	80
Winterization[n]	40	40	40	40	40
Subtotal	832	832	762	955	851
Refined yield (lb)	1,554 (77.7%)	1,454 (72.7%)	1,524 (76.2%)	1,454 (72.7%)	1,524 (76.2%)
By-product value	$ 347[o]	$ 347[p]	$ 308[q]	$ 347[r]	$ 308[s]
Subtotal	485	485	$ 454	608	543
Net cost per lb	0.31	0.33	0.30	0.42	0.36

Source: Authors.

[a]Raw Bran - L.T. Treatment - L.T. Extraction - Physical Refining.

[b]Raw Bran - L.T. Treatment - L.T. Extraction - Alkali Refining.

[c]Raw Bran - H.T. Treatment - H.T. Extraction - Alkali Refining.

[d]Stabilized Bran - L.T. Extraction - Alkali Refining.

[e]Stabilized Bran - H.T. Extraction - Alkali Refining.

[f]Bran required to extract 1 ton of CRBO @ $70/ton with 19% yield using high temperature extraction and 17% yield with L.T. extraction.

[g]L.T. treatment @ $3/ton, H.T. treatment @ $7/ton, stabilization @ $24/ton.

[h]$2.76/ton.

[i]L.T. extraction @ $35/t and H.T. extraction @ $25/t.

[j]Gum removal @ $0.015/lb

[k]Wax removal @ $0.015/lb

[l]Transport @ $0.015/lb

[m]Refining @ $0.04/lb

[n]Winterizing @ $0.02/lb

[o]4.88 ton defatted RB @ $70/ton + 20 lb gums @ $70/ton + 100 lb FFA @ $70/ton + 26 lb stearines @ $70/ton.

[p]4.88 tons defatted RB @ $70/ton + 20 lb gums @ $70/ton + 200 lb soapstock @ $30/ton + 26 lb stearines @ $70/ton.

[q]4.26 tons defatted bran @ $70/ton + 40 lb gums @ $70/ton + 100 lb wax @ $70/ton + 200 lb soapstock @ $30/ton + 36 lb stearines @ $70/ton.

[r]4.88 tons defatted RB @ $70/ton + 26 lb gums @ $70/ton + 200 lb soapstock @ $30/ton + 26 lb stearines @ $70/ton.

[s]4.26 tons defatted bran @ $70/ton + 40 lb gums @ $70/ton + 200 lb soapstock @ $30/ton + 36 lb stearines @ $70/ton + 200 lb wax @ $70/ton.

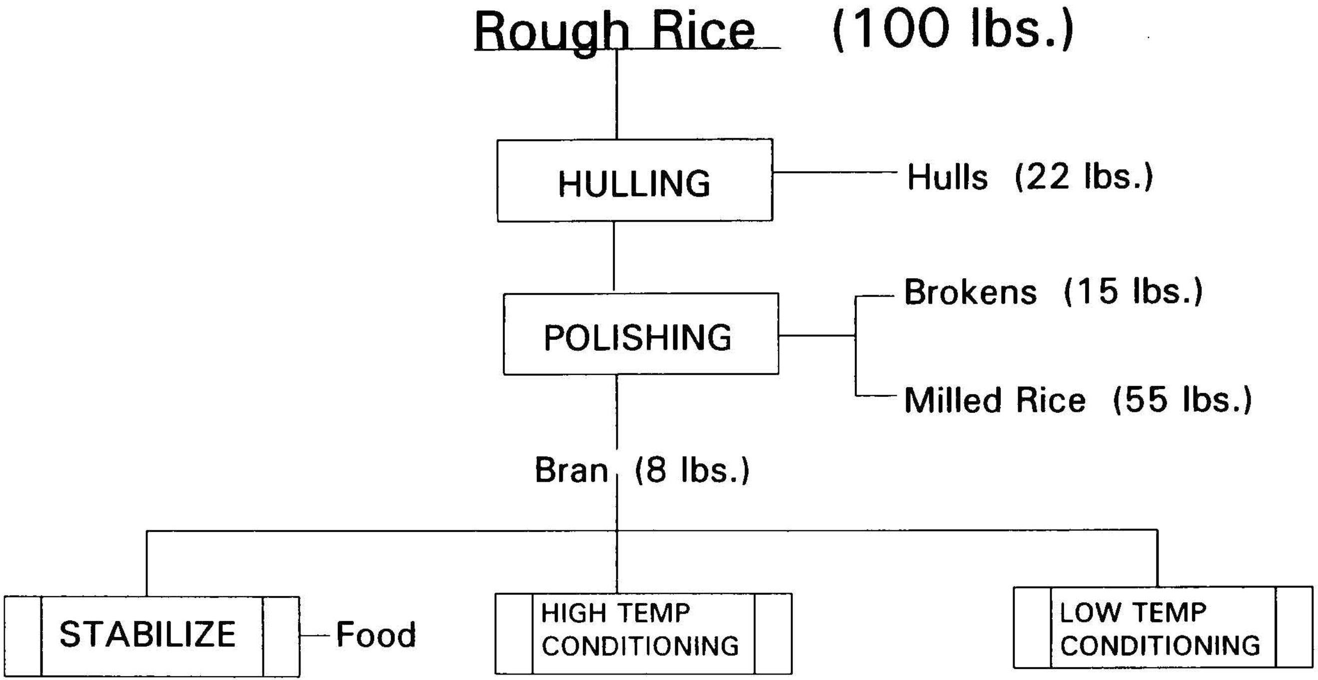

Fig. 1. Flow chart of rice milling by-products and bran treatment to facilitate oil extraction.

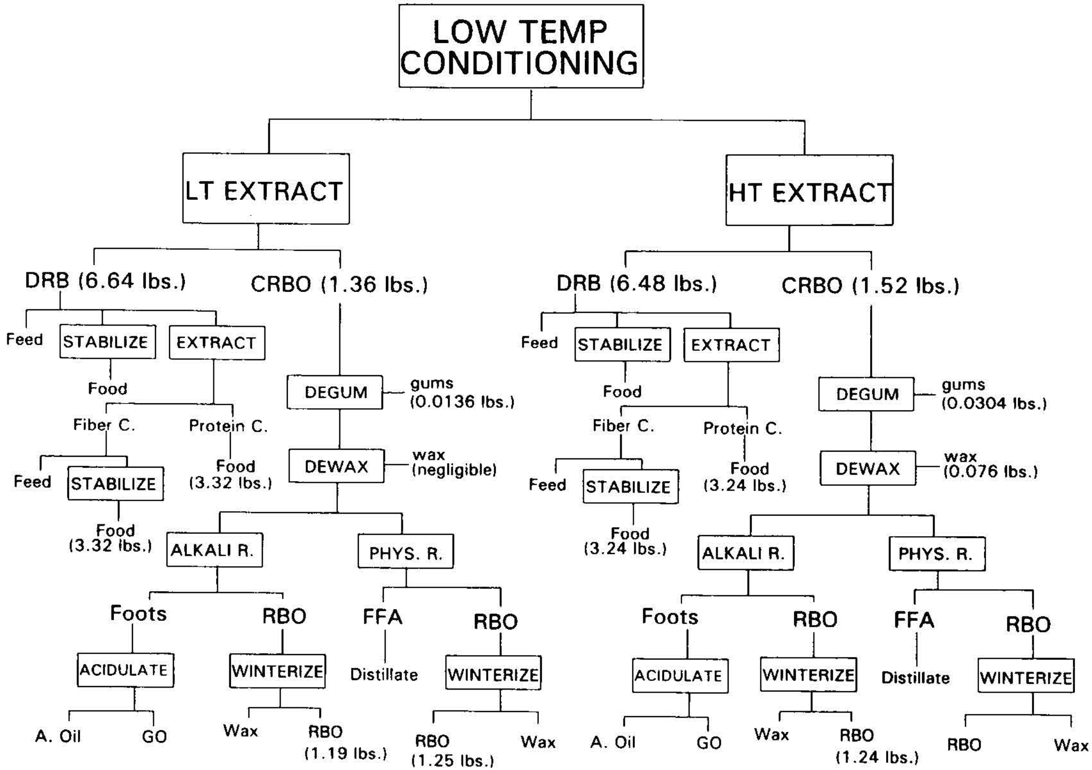

Fig. 2. Flow chart of bran extraction and RBO processing after low temperature bran conditioning.

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