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Arkansas Rice Research Studies 1992

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CULTURAL PRACTICES RESEARCH

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 1992*, Arkansas Agricultural Experiment Station Research Series 425. 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.

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

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

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PROFILES OF ARKANSAS RICE PRODUCERS

J.C. Headley and Benjamin Klugh, Jr.

ABSTRACT

Over 5,000 farms in Arkansas produce rice. The rice producers are under continuous pressure from rising costs and low product prices. So that university scientists and members of the Arkansas Rice Research and Promotion Board could better serve the industry, producers were surveyed in 1991 to provide detailed information about them and their businesses. The typical producer is 49 years old and a high school graduate, has gross farm sales of $100,000-250,000 and belongs to a cooperative and a general farm organization.

INTRODUCTION

The purpose of this study was to provide a description of Arkansas rice producers reflecting their attitudes toward agricultural policies, demographic characteristics and the nature of their farm business. The objectives of the study were:

1. To develop estimates of the type and size of farms producing rice.
2. To develop estimates of farm operator characteristics such as age, education, community activity, etc.
3. To develop descriptive estimates of farmer attitudes toward farm organizations, farmer-owned cooperatives and research and promotion boards.

PROCEDURES

A survey of a sample of Arkansas rice producers was conducted in 1991 by personnel of the Arkansas Agricultural Statistics office. The sample consisted of all farmers voting in the 1991 referendum on check-off policy and a sample of non-voting farmers chosen at random.

The four-page survey was conducted by mail with telephone follow-up in two cycles. There were 3,559 surveys mailed on the first mailing and 3,135 surveys on the second mailing. A total of 1,237 usable surveys were completed for a 46% response rate. After each mailing, a sample of the non-respondents was conducted by telephone. Means, standard deviations and percentages were calculated for all questions. The data were expanded to provide state estimates. Frequency distributions for questions concerning who makes decisions and type of ownership were compared to distributions for other surveys done by Arkansas Agricultural Statistics, and no differences were noted.

RESULTS

The typical respondent was 49 years old and a high school graduate, had a farm size of 500-2000 acres, lived in Crop Reporting District 6, voted in the referendum in 1991, was a member of a cooperative and a farm organization and had never requested a refund of check-off funds. Three-fourths of the producers raised less than 500 acres of rice with 45% having less than 250 acres.

A strong majority of producers favor government programs with more support for price supports and marketing loans rather than for deficiency payments. Older producers tend to be stronger in support of government programs. Those who have requested refunds of their check-off funds tend to be less favorable toward government programs as are owners of smaller farms. Cooperative members are more supportive of marketing loan programs than those who are not members of a cooperative.

There is a significant difference in knowledge of the check-off program depending on farm location, farm size, whether the producer voted in the referendum, gross value of sales and education. This should help to target information activities by the research and promotion board.

The University of Arkansas research agenda is generally supported. Producers seem to agree with the 55% allocation of check-off funds to research. The research areas chosen most often by producers as meriting support are the areas that have been receiving the most funding. Producers who have requested refunds tend to be most negative toward both research and promotion activities of the Arkansas board. Demographic characteristics didn't prove to be statistically significant in explaining producers' preference for promotion and research. In general, producers are not as enthusiastic about the use of check-off funds to support promotion as they are about the use of funds for production and other research.

There are some demographic and economic characteristics that can be used to profile the 48% of producers who, on average, have historically requested refunds of their check-off funds. This group of producers tended to be younger, have gross farm sales of $100,000-$250,000 annually and not feel well represented by the Arkansas Rice Research and Promotion Board.

The results imply many challenges for farm organizations, community leaders, university extension and research faculty and policy makers. Typical rice producers operate businesses that are large and complex and that have been under economic pressure from low product prices and rising costs. The University of Arkansas and community and state agricultural leaders need vigorous programs aimed at improving management and production skills of producers and providing technology to remain competitive in the world rice market.

INTERNATIONAL AND INTERREGIONAL COMPETITIVENESS OF THE ARKANSAS RICE INDUSTRY

Gail L. Cramer, Kenneth B. Young and Eric J. Wailes

ABSTRACT

A North American Free Trade Agreement (NAFTA) study was completed in 1992 tc provide an assessment of the rice market in Mexico and an appraisal of the effect of NAFTA on U.S. rice exports to Mexico. The study also evaluated the effect of transportation improvements in Mexico on the competitiveness of U.S. rice imports. Implementation of NAFTA will include a scheduled phase out of the import tariff in Mexico for U.S. rice. This will provide an increased trade advantage for U.S. rice compared to rice imports from other countries.

INTRODUCTION

Rice production has been declining in Mexico since the mid 1980s because of increased crop competition on irrigated land and slow development of new rice production in dryland production areas. Rice consumption per capita has remained relatively low at about 12 lb/year, but total consumption has been increasing about 2%/year in accordance with average population growth. There are good prospects for increased per capita rice consumption in Mexico as a result of increased market availability of rice products, increased urbanization and rising personal income. Rice imports currently exceed the amount of domestic production and are expected to increase further because of the constraints on production and the effects of trade liberalization in Mexico.

PROCEDURES

Members of the study team visited Mexico in June 1992 to collect primary data for the study and to interview rice industry officials in Mexico. Secondary data were obtained from Mexican government sources and the USDA to evaluate production, consumption and trade trends.

RESULTS OF THE STUDY

The U.S. is projected to be a competitive rice exporter as a result of transportation improvements and rail rate adjustments in Mexico as well as the tariff reductions proposed in NAFTA. Rail transport costs will potentially decline up to 30% in Mexico and 10% in the U.S. to the border with larger unit shipments. As indicated by transport costs (Table 1), U.S. rice exports to Mexico travel further by rail than the rice of other competitors delivered at major ports in Mexico. Therefore, the rail cost savings would provide an increased competitive advantage to the U.S. over other rice exporters to Mexico. For example, the maximum potential rail cost savings would reduce the cost of imported U.S. rice delivered to Mexico City from Laredo, Texas, by $10.00/MT compared to only $6.20/MT for Thai rice unloaded at the Manzanillo Port and only $3.30/MT for Vietnamese rice unloaded at the Veracruz Port (Table 1).

A potential reduction in the import tariff for U.S. rice would have a substantial effect on the cost of U.S. rice in Mexico compared to that of competitors (Table 1). The approximate tariff for U.S. #2 milled rice was $62/MT in December 1992 with a Laredo border price of $310/MT. Since NAFTA would provide this tariff reduction only for U.S. rice and not for other export competitors, the border price of U.S. rice could be increased by up to the amount of the tariff reduction without changing the price spread with other competitor's prices for rice in Mexico. Thus, the tariff reduction would provide the opportunity for an increased price premium for high-quality U.S. rice, provided that the demand is there.

The major benefit of NAFTA to the U.S. depends on receiving the preferred tariff treatment for U.S. imports to Mexico that is not provided for other competing exporters. This special benefit would be canceled over the long term if the General Agreement on Tariffs and Trade (GATT) were adopted as all exporters would ultimately receive the same tariff treatment for exports to Mexico.

The U.S. has been exporting about half of its rice in terms of rough rice rather than milled rice to Mexico as the import tariff is less on rough rice and there is a profitable market for rice by-products in Mexico (Table 2). This situation is not expected to continue after NAFTA is implemented as the tariff preference for rough rice will be gradually eliminated and the value of rice by-products should also decline when U.S. feed grains are allowed to enter duty free. Other factors include the likelihood that the Mexican rail rates for rough rice relative to milled rice will increase because of the difference in product density and the probability of higher milling costs in Mexico.

SIGNIFICANCE OF FINDINGS

The major findings of the study are that there are important constraints on expanding rice and other grain crop production in Mexico and that imports will likely continue to increase. Rice demand has been increasing in accordance with the population growth rate. Per capita consumption may increase as a result of increased income and improved marketing. The implementation of NAFTA and ongoing rail transport improvements in Mexico will increase the competitiveness of U.S. rice in Mexico to take advantage of this growing rice market. The implementation of GATT will ultimately cancel the tariff advantage of NAFTA for the U.S. relative to other rice exporters in the long run. The current GATT round agreement would require only minimal tariff reduction through the end of the decade. But in the medium run with NAFTA in effect, the U.S. will be more competitive with other low-cost rice exporters, such as Vietnam, for the Mexican rice market.

Table 1. Effect of transportation cost in Mexico on the cost of Mexico City rice imports, 1992.

Cost Item (U.S. $/MT)	U.S. Milled #2/4B	Thai Milled /5B	Vietnam Milled/5B
Import cost at border[z]	$310 (Laredo)	$290 (Manzanillo)	$260 (Veracruz)
Unloading cost at port	0	14	14
Import tariff (20%)	62	58	52
Customs (2.5%)	8	7	6
Transport (Mexico City)	25	21	11
Total Cost	$405	$390	$343
Premium to Thai price	$15	0	-$47
-10% Mexico freight	-2.50	-2.10	-1.10
-20% Mexico freight	-5.00	-4.20	-2.20
-30% Mexico freight	-7.50	-6.30	-3.30
-10% U.S. freight[y]	-2.50	0	0

[z]Price quotes for December 1992.

[y]Approximate savings with using 90-car train compared with using less than 25-car train from Stuttgart, Arkansas, to Laredo border. Rate per MT assuming an average of 90 MT/car.

Table 2. An example of estimated 1992 import cost of milled, rough and brown rice from the U.S. to Mexico (U.S. $/MT)

Cost Factor/ By-Product Return	Milled Rice (4%)[z]	Paddy #2 55/70	Brown from Paddy #2 55/70
CIF (Mexican Border)	$310 x 1.0 MT = $310	$165 x 1.745 MT[y] = $288	$258 x 1.3615 MT[x] = $351
Import tariff (%)	62 (20%)	29 (10%)	70 (20%)
Customs (2.5%)	8	7	9
Transport ($28/MT)	28	49	38
Milling ($35/MT)	0	61	48
Subtotal	$408	$434	$516
Value of By-Products:			
Hulls (22% Paddy @ $51/MT)	0	($20)	0
Bran (8% Paddy @ $144/MT)	0	(20)	(20)
Brewers (15% Paddy @ $215/MT)	0	(56)	(56)
Retain 4% brokens[w]	0	15	15
Subtotal	0	(81)	(61)
Net import cost for milled rice (4%) equivalent	$408	$353	$455

Assumptions:

[z]One metric ton milled rice contains 2,115.84 lb head rice and 88.16 lb brokens (at 4%).

[y]1.745 MT rough rice	x 55%	= 2,115.29 lb head rice
	x 22%	= 846.12 lb hulls @ $51/MT
	x 8%	= 307.68 lb bran @ $144/MT
	x 15%	= 576.90 lb brokens @ $215/MT
[x]1.3615 MT brown rice	x 55%/78%	= 2,115.83 lb head rice
	x 8%/78%	= 307.90 lb bran @ $144/MT
	x 15%/78%	= 577.04 lb brokens @ $215/MT

[w]4% brokens retained in milled rice (not sold for brewers price).

THE ECONOMIC POTENTIAL OF RICE BRAN

Kenneth B. Young, Gail L. Cramer and Eric J. Wailes

ABSTRACT

Rice bran oil (RBO) contains special unsaponifiable ingredients that help to control cholesterol. These benefits are receiving greater publicity, causing increased demand for RBO. This market trend has encouraged the rice industry to consider commercial production of RBO in the U.S. Preliminary cost estimates of producing refined RBO, including the processing cost of stabilizing the bran, extracting the crude RBO and refining, are in the range of $0.37 to $0.44/lb. This is about half of the current wholesale price of imported refined RBO from Japan supplied to the U.S. market. The estimated cost of producing RBO is higher than current prices for corn and canola oil in the U.S., but RBO has been commanding a premium price in the retail market.

INTRODUCTION

Stabilized rice bran has been supplied since 1989 as a food ingredient for the manufacture of bakery products, breakfast cereals and other food products sold in supermarkets. The major driving force to use stabilized rice bran was the perceived health benefit that it reduced cholesterol in a manner equivalent to oat bran. More recently it has been determined that the active agent in rice bran to reduce cholesterol is contained in the oil. There is currently major interest in rice bran oil production.

This study assesses the cost of processing rice bran to produce a refined oil and evaluates the potential to market rice bran oil in comparison with other healthy vegetable oils such as corn and canola oil.

Various scientific studies conducted over the past 20 years have presented increasing evidence that typical American dietary patterns are associated with the incidence of chronic diseases that are the leading causes of death and disability (Connor and Connor, 1986). There is particular interest in the relationship between diet and cholesterol as coronary heart disease is the number one killer of both men and women in the U.S., claiming more than half a million lives each year.

There has been much controversy over the last few years as to what factors in the diet affect serum cholesterol and the relationship of cholesterol level to incidence of heart disease. Originally, the main concern was to maintain total serum cholesterol within a safe level of about 240 mg/1000 kcal. Later it was determined that the ratio of different cholesterol levels in the blood was at least as important as the total cholesterol level (TC). Low density lipoprotein cholesterol (LDL-C) was considered harmful, and high density lipoprotein cholesterol (HDL-C) was considered beneficial.

Numerous studies have demonstrated that diets enriched in saturated fat were responsible for raising TC and LDL-C and those enriched in unsaturated fat reduced LDL-C. The Food and Drug Administration (FDA) has recently changed dietary guidelines to limit total fat intake to 30% of calories and saturated fat to 10% of calories in the diet.

The FDA has permitted canola oil to be labeled as the lowest in saturated fat as it contains less than 6% saturated fat. As a result, canola oil has gained in popularity with consumers compared to other vegetable oils. Rice bran oil contains about 20% saturated fat.

Current research (Nicolosi et al., 1990, 1992) indicates that saturated fat in the diet may be offset by the unsaponifiable components contained in some vegetable oils, including tocotrienols and oryzanols. Rice bran oil contains up to 4.4% of these unsaponifiable components, which is several fold greater than most other vegetable oils.

The purpose of this study is to evaluate the potential of rice bran oil to compete in the vegetable oil market in light of current scientific findings regarding its value in reducing cholesterol and to estimate the supply cost of refined rice bran oil to compare with the cost of other vegetable oils.

PROCEDURES

The study procedure for this research included a review of scientific literature on the health benefits of rice bran oil compared to other healthy vegetable oils and the collection of vegetable oil processing data from industry sources to estimate the cost of processing rice bran oil.

RESULTS OF THE STUDY

Current scientific evidence indicates that rice bran oil may perform better than the two leading healthy vegetable oils—corn and canola oil—in terms of providing the highest ratio of HDL-C to LDL-C while reducing total cholesterol to a level similar to that of canola oil (Table 1). Rice bran oil provided these superior results in spite of having higher saturated fat than corn or canola oil. Corn oil performed the next best to rice bran oil as it had the second highest ratio of HDL-C to LDL-C and provided the lowest overall total cholesterol level (Table 1). It was evident from this research report by Nicolosi and coworkers (Nicolosi et al., 1990, 1992) that some special unsaponifiable components in rice bran oil accounted for the favorable result as they offset the negative effect of the increased saturated fat when using rice bran oil. Other scientific studies have reported similar results (e.g., Yoshino et al., 1989).

One problem reported with using rice bran oil is the significant variation in the levels of unsaponifiables in different samples that affect the performance in reducing serum cholesterol. Up to 50% of these total components can be lost in conventional alkali refining and up to 90% of some individual components such as oryzanol and tocotrienols. There is a need to improve processing methods to optimize recovery of these important components in the oil. Physical refining is considered to be better than conventional alkali refining for the recovery of these components, but there are some technical problems in physically refining rice bran oil because of the high content of gums.

The potential amount of crude rice bran oil that could be extracted annually is estimated at 75,000 tons in the southern states and 93,000 tons overall in the U.S., given the current level of rough rice production of 155 million cwt. This compares with current annual utilization of 113,000 tons of peanut oil, 6,556,000 tons of soybean oil, 805,000 tons of corn oil and 316,000 tons of canola oil (Table 2). Current wholesale bulk prices are about $757/ton for crude peanut oil, $415/ton for crude soybean oil, $450/ton for corn oil and $396/ton for canola oil. About 80% of the canola oil consumed in the U.S. is currently imported as crude oil or in the form of canola seed.

Preliminary estimates have been made in this study of the cost of stabilizing rice bran, extracting crude rice bran oil and refining rice bran oil with the alkali refining process. Estimates are derived from previous work by Fellers (1991). Stabilization of rice bran is considered necessary because of the rapid deterioration of oil quality if the bran is not extracted immediately after milling. Stabilization cost is estimated at

$30.50/ton of bran output, extraction cost of crude rice bran oil is estimated at $509 to $621/ton of crude oil output, and the cost of refined rice bran oil is estimated at $736 to $882/ton of refined oil output, depending on the amount of transport and handling between points of bran stabilization, crude oil extraction and refining. This estimated cost is significantly above the current wholesale price of corn and canola oil. Therefore, the consumer would likely have to pay a price premium for refined rice bran oil to justify the activity unless there is a profitable market for the by-product, defatted rice bran, to offset the high cost of processing the oil.

SIGNIFICANCE OF FINDINGS

There is convincing evidence from the research of Nicolosi and other scientists that rice bran oil is valuable in controlling cholesterol and that it can perform better than other healthy vegetable oils, such as corn and canola oil. However, the estimated processing cost from our preliminary analysis appears to be significantly higher than the wholesale price of corn and canola oil. Therefore, the potential for rice bran oil will depend on whether consumers will be willing to pay a higher price for this product to justify the high processing cost.

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Table 1. Response of total cholesterol, LDL, HDL and total glycerides (blood fat) to use of selected vegetable oils in the diet.

	Type of Diet			
Fat Use/Response	Average American	Rice Bran Oil	Corn Oil	Canola Oil
Quantity of Fat in Diet:				
Total fat in diet	36%	30%	30%	30%
Veg. oil (% of diet)	mixed[z]	20%[y]	20%[y]	20%[y]
% saturated fat in diet	15%	10%	8.5%	7.4%
% monounsaturated fat in diet	15%	10%	6.8%	14.3%
% polyunsaturated fat in diet	6%	10%	14.7%	8.3%
Supplemental cholesterol in diet[x]	0.1%	0.1%	0.1%	0.1%
Response to Diet:				
Total cholesterol (TC)	312 ± 131	237 ± 106	224 ± 87	234 ± 114
LDL cholesterol[w]	247 ± 145	172 ± 128	168 ± 106	184 ± 128
HDL cholesterol[v]	65 ± 21	64 ± 31	56 ± 27	50 ± 22
Total glycerides	28 ± 11	21 ± 6	17 ± 6	21 ± 10
Ratio of HDL/LDL[u]	26.3%	37.2%	33.3%	27.2%
Ratio of HDL/TC[t]	20.8%	27.0%	25.0%	21.4%

Source: Nicolosi et al., 1992.

[z]The average American diet was assumed to have 36% total fat including 15% saturated fat, 15% monosaturated fat and 6% polyunsaturated fat from different fat sources including 40% olive oil, 16% corn oil, 38% coconut oil and 5% safflower oil.

[y]Test diets contained 20% RBO, corn oil or canola oil plus 10% other fat content composed of 8% olive oil, 62% coconut oil and 19% safflower oil.

[x]Additional cholesterol was included in all diets to induce a cholesterol response.

[w]LDL cholesterol is considered harmful.

[v]HDL cholesterol is considered beneficial.

[u]A high HDL/LDL ratio is beneficial.

[t]A high HDL/TC ratio is beneficial.

Table 2. Vegetable oil supply, disappearance and price, 1989-1991

Vegetable Oil	1989	1990	1991	1989-91 Average
Peanut oil:				
Supply (1,000 tons)	118	124	142	128
Disappearance (1,000 tons)	106	111	122	113
Price ($/ton crude)	$840	$910	$520	$757
Soybean oil:				
Supply (1,000 tons)	7,370	7,285	7,800	7,485
Disappearance (1,000 tons)	6,718	6,350	6,600	6,556
Price ($/ton crude)	$446	$420	$380	$415
Corn oil:				
Supply (1,000 tons)	779	902	940	874
Disappearance (1,000 tons)	716	825	875	805
Price ($/ton crude)	$496	$404	n.a.	$450
Canola oil:				
Supply (1,000 tons)	315	338	386	346
Disappearance (1,000 tons)	290	307	350	316
Price ($/ton crude)	$427	$401	$361	$396

Source: USDA-ERS, 1992.

BREEDING, GENETICS and PHYSIOLOGY

'LAGRUE', A NEW LONG-GRAIN RICE VARIETY

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

ABSTRACT

'LaGrue', a new short-season, high-yielding, long-grain rice variety, derived from the cross of 'Bonnet 73'/'Nova 76'//'Bonnet 73/3'/'Newrex' made at Stuttgart, Arkansas, in 1985, has been approved for release to qualified seed growers for the summer of 1993. The major advantage of LaGrue is its high yield potential. Its major disadvantage is its average milling yields similar to those of 'Alan', 'Lemont' and 'Laccasine'. LaGrue is similar in maturity to 'Lebonnet', has straw 6 in. shorter than 'Tebonnet' and has stiff straw similar to that of 'Newbonnet'. LaGrue is susceptible to rice blast, moderately tolerant to sheath blight and susceptible to kernel smut.

INTRODUCTION

LaGrue, a new short-season, high-yielding, long-grain rice variety, developed in the cooperative rice improvement program at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas, has been released to qualified seed growers for the 1993 growing season. LaGrue is the first variety released to be totally developed in the Stuttgart program since the inclusion of Rice Research and Promotion Board Grant Funds, which originated from the grower check-off. It is also the first variety to be developed with the use of the winter nursery in Puerto Rico. LaGrue has excellent yield potential and should offer a new alternative to rice producers.

PROCEDURES

LaGrue originated from the cross Bonnet 73/Nova 76//Bonnet 73/3/Newrex made at RREC in 1985. The long-grain variety Bonnet 73 was described by Johnston et al. (1973), the high amylose variety Newrex was described by Bollich et al. (1980), and the medium-grain variety Nova 76 was described by Johnston et al. (1979). During the three years prior to its release, LaGrue was widely tested in the Arkansas Rice Performance Trials (ARPT) and the Cooperative Regional Uniform Rice Nursery (URN) in Arkansas and other rice-growing states under the designation RU9001096 (RU number indicates Cooperative Regional Uniform Rice Nursery; 90 indicates year entered; 01 indicates Stuttgart, Arkansas, as its origin; 096 is its entry number). LaGrue was first tested under the designation STG87P38-111, indicating that it was first bulk harvested from the 1987 Stuttgart F_4 panicle row number P38-111 (planted from a panicle from Puerto Rico in row 111, range 38).

In 1991 the ARPT was conducted with four replications per location at five locations in Arkansas: RREC; Northeast Research and Extension Center, Keiser (NEREC); Pine Tree Experiment Station, Colt (PTES); Southeast Branch Experiment Station, Rohwer (SEBS); and Cotton Branch Experiment Station, Marianna (CBES). In 1992 the ARPT was grown at RREC, NEREC, PTES, SEBS and near Tupelo, in Jackson County, Arkansas (JC), with three replications per location. The 1990 data presented are from the Elite Test grown at RREC, CBES, PTES, NEREC and near Corning, Clay County, Arkansas (NA), with two replications per location. The URN was grown at RREC; Stoneville, Mississippi; Beaumont, Texas; and Crowley, Louisiana, 1990-1992. Data presented from these tests include plant height, maturity, lodging, kernel weight, head and total milling yields, grain yield and disease reactions. Disease ratings, which are indications of potential damage under conditions favorable for development of specific diseases, are reported on a scale of 0 = least susceptible to 9 = most susceptible. Relative straw strength is based on field tests using the scale 0 = very strong straw to 9 = very weak straw. Although cultural practices varied somewhat among locations, in general the tests were grown under conditions of high productivity.

RESULTS AND DISCUSSION

Data, presented by year, are given in Tables 1-3 for LaGrue and other high-yielding varieties. LaGrue had numerically (but not statistically) higher yields than these check varieties in the very-short-season group of the Elite Test with 6834 lb/acres (Table 1). In subsequent years, with a refinement of heading date information, LaGrue was included in the short-season maturity group. LaGrue is similar in maturity to Lebonnet and 'Gulfmont'. In the 1991 and 1992 short-season ARPT, LaGrue competed very favorably with both long- and medium-grain varieties (Tables 2 and 3). LaGrue produced 8724 lb/acre (194 bu/acre) average grain yield to exceed all other varieties in the short-season ARPT in 1992 compared to Lemont, 'Cypress', 'Mars', 'Orion' and 'Bengal' at 8124 (181), 7884 (175), 7941 (176), 8512 (189) and 8475 (188) lb/acres (bu/acres), respectively (Table 3). For comparison, in the 1992 midseason ARPT Newbonnet, 'Katy' and Lacassine had yields of 7351 (163), 7227 (160) and 7972 (177) lb/acres (bu/acres), respectively. LaGrue performed favorably in the URN in 1990 and 1991. In 1990 across four locations, averaging 7364 lb/acres (164 bu/acres) compared to 6985 lb/acres (155 bu/acres) for L202. The 1991-1992 four-location average in the URN of 6779 lb/acres (151 bu/acres) for LaGrue compared favorably with the medium-grain rice varieties Mars, Orion and Bengal, which yielded 6511 (145), 6731 (150) and 7432 (165) lb/acre (bu/acre), respectively.

LaGrue is susceptible to the blast fungus (*Pyricularia oryzae* Cavara), rating a 6, 5, 7 and 6 for the races IG-1, IH-1, IC-17 and IB-49, respectively (Table 4). LaGrue is moderately susceptible to sheath blight (*Rhizoctonia solani* Kuhn), rating a 6 like Newbonnet, 'Millie', Alan and Bengal. LaGrue, like Alan and Newbonnet, is susceptible to kernel smut, rating a 6.

Milling yields (percent whole kernel/percent total milled) at 12% moisture for LaGrue, Lemont, Cypress, Lacassine, Newbonnet and Katy were 62/72, 61/74, 66/73, 61/73, 66/73 and 66/72, respectively, in the 1992 ARPT. The kernel weight of LaGrue is 19.8 mg compared to Tebonnet, Cypress and Lemont at 18.3, 18.3 and 20.1 mg, respectively. The endosperm of LaGrue is nonglutinous and nonaromatic with a light brown pericarp. Results from the Cooperative Regional Rice Quality Laboratory at Beaumont, Texas, indicate that LaGrue has typical U.S. long-grain cooking quality characteristics as described by Webb et al. (1985). LaGrue has an average apparent starch amylose content of 22% and an intermediate gelatinization temperature (70-75° C), as indicated by an average alkali spreading score of 3.0.

SIGNIFICANCE OF FINDINGS

The release of the variety LaGrue offers producers a new high-yielding short-season alternative to the semi-dwarf varieties Gulfmont and Cypress. It has a very high yield potential, out-yielding all of the checks in the ARPT this season. The major disadvantage of LaGrue is the somewhat below-average head rice milling yield, which is similar to that of Alan and Lemont. LaGrue maintains the relatively good levels of sheath blight tolerance found in the Arkansas varieties with a rating of 6. LaGrue is moderately susceptible to blast and kernel smut.

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Table 1. Results from the 1990 Elite Test.

Variety	Yield (lb/acre)	Height (in.)	Days to 50% HD^z	Kernel Wt (mg)	Milling HR:TOT
LaGrue	6834	41	87	18.4	56-71
Millie	6792	39	86	18.8	60-72
Alan	6624	37	82	15.7	56-72
Tebonnet	6560	46	85	17.2	59-73
L.S.D. (0.05)	637	2	2	0.9	7-1

^{z}HD=heading; HD:TOT=ratio of head rice to total rice

Table 2. Results from the 1991 Arkansas Rice Performance Trials.

Variety	Yield (lb/acre)	Height (in.)	Days to 50% HD^z	Kernel Wt (mg)	Milling HR:TOT
LaGrue	7026	43	85	18.8	58-71
Tebonnet	6219	50	80	17.2	60-72
Mars (MG)^y	6945	46	87	17.7	67-72
Orion (MG)	7271	43	85	16.3	66-72
L.S.D. (0.05)	697	2	2	1.1	4-1

^{z}HD=heading; HD:TOT=ratio of head rice to total rice
^{y}MG=medium grain

Table 3. Results from the 1992 Arkansas Rice Performance Trials.

Variety	Yield (lb/acre)	Height (in.)	Days to 50% HD^z	Kernel Wt (mg)	Milling HR:TOT
LaGrue	8724	44	84		62-72
Lemont	8124	35	88		61-74
Cypress	7884	35	86		66-73
Mars	7941	47	86		66-73
Orion	8512	42	84		64-72
Rico I	7768	43	87		63-73
Bengal	8475	35	86		64-74
L.S.D. (0.05)	576	2	2		6-1

^{z}HD=heading; HD:TOT=ratio of head rice to total rice.

Table 4. Reaction of rice varieties to diseases.

Variety	Sheath Blight	Kernel Smut	Straighthead	Rice Blast Race IG-1	IH-1	IC-17	IB-49
Adair	5	4	7	7	4	6	5
Alan	6	6	5	4	5	7	8
Bengal	6	3	7	2	2	4	8
Cypress	7	--	4	1	1	6	6
Katy	5	--	5	1	1	1	2
Lacassine	8	3	4	1	1	6	6
LaGrue	6	6	5	6	5	7	6
Lemont	8	3	4	1	1	6	5
Mars	5	1	7	2	2	3	8
Millie	6	4	7	7	7	7	7
Newbonnet	6	6	4	1	1	8	8
Orion	5	2	5	5	5	4	7
Tebonnet	7	3	7	4	1	6	7

'ADAIR': A NEW, VERY-SHORT-SEASON, LONG-GRAIN RICE VARIETY

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ABSTRACT

The University of Arkansas Agricultural Experiment Station will release a new very-short-season, long-grain rice variety named 'Adair' to seed growers for the 1994 season. The new rice variety was named in memory of Dr. Charles Roy Adair, a pioneering USDA/ARS rice breeder located at the Rice Branch Experiment Station, Stuttgart, Arkansas, from 1931 to 1953. The major advantage of Adair is its high yielding ability and early maturity (similar to 'Alan'). Adair also offers a moderate level of field resistance to blast, similar to that of 'Millie' and 'Tebonnet', and Adair also has good sheath blight tolerance, similar to that of 'Katy'. The major disadvantage for Adair is its low percentage head rice yield.

INTRODUCTION

The primary objective of the Arkansas rice breeding program is to develop and release new and improved rice varieties adapted to Arkansas. The development of a new rice variety is a 10-to-12-year process. For example, the cross for the new blast-resistant variety Katy was made at Stuttgart, Arkansas, in 1979, with release occurring in 1989. A new rice variety begins with the crossing of two parents, selection and purification during early generations and testing for adaptation across the Arkansas rice belt. This report describes the new, very-short-season, long-grain rice variety, Adair, which will be released to seed growers for the 1994 season.

PROCEDURES

Adair was derived from the cross L201/RU7402003 made at the University of California, Davis, in 1978. Early generations were grown and selections made at Stuttgart. The experimental designation for evaluation at Stuttgart was STG85L9-112, which resulted from a bulk of F_7 seed from the 1985 panicle row L9-112. Adair was tested in the preliminary yield trials in 1986, the Stuttgart Initial Tests in 1987 and 1988, the Elite Test in 1989 and the Arkansas Rice Performance Trials (ARPT) and Cooperative Uniform Regional Rice Nursery (URN) in 1990-1992. In the latter, Adair was tested as the experimental line RU9001007. In 1991, 1200 panicle rows were grown and rogued for offtypes. Approximately 1000 rows were selected and bulked together to produce breeder seed, which was used to plant the 9-acre foundation seed field in 1992. In 1992, 1200 panicle rows, which had been selected from 120 of the best panicle rows in 1991, were grown as family blocks and rogued to produce the 1994 breeder seed. Disease reactions are rated on a scale of 1 to 9. A rating of 1 indicates the highest level of resistance, and a rating of 9 indicates extreme susceptibility.

RESULTS AND DISCUSSION

Adair is a high-yielding, very-short-season, long-grain rice cultivar, similar in maturity to Alan (Table 1). Adair is approximately 3 in. taller than Alan and 7 in. shorter than Tebonnet, with a lodging resistance rating between those of Alan and Tebonnet. Adair should be fertilized with 120 lb N applied as a three-way split (60-30-30). The major advantage of Adair is its high yielding ability. Rough rice yields of Adair have consistently topped the ARPT during its three years of testing (1990-1992). The major disadvantage of Adair is its average to below-average head rice yields, similar to those of 'L202', which are most likely due to large kernel size. Tests conducted at Stuttgart in 1992 indicate that optimum harvest moisture content for Adair is in the range of 18 to 20%.

Data from the URN tests (1990 to 1992), which are conducted in Arkansas, Louisiana, Mississippi and Texas, showed Adair with an average rough rice grain yield of 6924 lb/acre, compared to 5930 and 5905 lb/acre for Alan and 'Maybelle', respectively. Head rice and total milling yields for Adair, Alan and Maybelle averaged 54/69, 57/70 and 57/71, respectively (percent whole kernel/percent total milled). Adair has typical U.S. southern long-grain cooking quality.

Adair is moderately susceptible to rice blast (*Pyricularia oryzae* Cav.) races IG-1, IH-1, IC-17 and IB-49, with ratings of 7, 4, 6 and 5, respectively (Table 2). Adair, like Millie and Tebonnet, has shown greater field resistance to blast than the other very-short-season cultivars currently available to producers. Adair is moderately tolerant to sheath blight (*Rhizoctonia solani* Kuhn) with a rating of 5, making it one of the most sheath-blight-tolerant varieties in the very-short-season group. Adair, like Millie and Tebonnet, rates 7 for straighthead, indicating that grain yield of Adair can be severely reduced under straighthead conditions. Stem rot, kernel smut and brown spot do not appear to be problems for Adair. Adair has the potential for moderately high levels of peck, especially when planted early or in isolated areas.

SIGNIFICANCE OF FINDINGS

On 11 December 1992 the new very-short-season, long-grain rice variety Adair was released by the Arkansas Agricultural Experiment Station. It was named in memory of Dr. Charles Roy Adair, a pioneering USDA/ARS rice breeder located at the Rice Branch Experiment Station from 1931 to 1953. Dr. Adair released seven rice varieties to the Arkansas rice industry and built the foundation on which the Arkansas rice breeding program operates today. The major advantage of Adair is its high yielding ability and early maturity (similar to Alan). Adair also offers a moderate level of field resistance to blast and sheath blight tolerance that are currently lacking in other early-maturing rice varieties. A disadvantage for Adair is its low percentage head rice yield. However, the yield of head rice per acre indicates an advantage over Alan, which was grown on 19% of the Arkansas rice acreage in 1992.

Table 1. Agronomic data by year for 'Adair' and varieties of similar maturity from the Arkansas Rice Performance Trials, 1990-1992.

Variety	Yield (lb/acre)	Height (in.)	Days to 50% HD[z]	Kernel Wt (mg)	Milling HR:TOT
1990					
Adair	7380	42	81	18.8	55-70
Maybelle	6614	37	83	17.5	63-72
Tebonnet	6701	46	84	17.4	61-72
Alan	6796	38	81	15.8	62-71
Millie	6716	39	84	19.3	66-73
L.S.D. (0.05)	438	1	2	0.7	7-1
1991					
Adair	7065	42	79	20.4	58-70
Maybelle	6624	37	74	16.7	56-72
Tebonnet	6219	50	80	17.2	60-72
Alan	6563	40	80	16.0	62-71
Millie	6567	40	80	19.2	65-72
L202	6453	35			
Rosemont	6914	34	79	19.1	60-72
L.S.D. (0.05)	1086	1	3	0.9	5-2
1992					
Adair	7782	43	80	20.4	56-71
Maybelle	6902	38	75	17.8	58-71
Jackson	7262	39	81	17.3	60-73
Tebonnet	7138	50	82	18.3	62-72
Alan	7100	40	80	16.6	60-72
Millie	6613	40	81	19.3	65-72
Rosemont	7982	35	80	19.7	58-72
L202	7996	37	79	20.8	56-71
RT7015	7735	36	81	17.9	61-72
LSD (0.05)	583	2	1	0.8	3-1

[z]HD = heading; HR:TOT =ratio of head rice to total rice.

Table 2. Disease and straighthead reactions for 'Adair' and other very-short-season varieties.

Variety	Sheath Blight	Straight-head	Stem Rot	Kernel Smut	Brown Spot	Rice Blast Race IG-1	IH-1	IC-17	IB-49
Adair	5	7	3	4	3	7	4	6	5
Maybelle	7	3		5	4	7	7	7	8
Jackson	7	4			4	7	4	5	7
Tebonnet	7	7	5	3	4	4	1	6	7
Alan	6	5		6	5	4	5	7	8
Millie	6	7		4	3	7	7	7	7
Rosemont	8	4		6		8	7	8	8
L202	7	5		4	7	5	3	8	6
RT7015	8	5				8	8	8	8
Texmont	8	7				8	8	8	8

GENETIC, PHYSIOLOGICAL AND BIOCHEMICAL ENHANCEMENT OF EXOTIC RICE GERMPLASM

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ABSTRACT

In 1992, the Rice Germplasm Program focused on evaluation of allelopathy for control of ducksalad and barnyardgrass, germplasm resistance in rice to herbicides used for control of red rice, salt tolerance and genetic resistance to straighthead. Continued evidence of allelopathy to ducksalad was observed with the suppression activity extending up to 6 in. from the base of the rice plant. Some varieties or accessions reduced up to 84% of the ducksalad in the area of activity. Screening of 5,500 additional accessions was conducted for allelopathy to barnyardgrass. Approximately 400 varieties were evaluated for resistance to the herbicides glyphosate (Roundup) and sulfosate (Touchdown). Six varieties have apparent resistance to glyphosate at the 0.5X and 1.0X rate when applied prior to or shortly after flooding. Straighthead evaluations for 32 varieties or advanced breeding lines were conducted at three locations. Straighthead studies were conducted to determine genetic mechanisms involved in its control. One-hundred-four varieties from Japan were evaluated for maturity, plant height, lodging and milling quality. The earliest-maturing varieties headed 56 days after emergence. Taste tests will be conducted in both Japan and the U.S. on these varieties. One-hundred-six short-statured accessions from the USDA/ARS rice collection were evaluated for response to the growth regulator, gibberellic acid (GA_3). Seven accessions had an emergence index for treated seed that was almost twice as large as that for untreated seed. In the enhancement phase of the program, individual F_2 populations were grown and evaluated from crosses involving straighthead resistance and ducksalad allelopathy. Additional crosses were made with accessions that had demonstrated glyphosate resistance and ducksalad allelopathy.

INTRODUCTION

The USDA/ARS Rice Germplasm collection contains 16,134 varieties, or accessions, from 99 countries. The collection is the primary genetic base for all variety development in rice in the U.S. This program is designed to evaluate rice germplasm in the USDA/ARS collection and enhance desirable germplasm so it can be utilized in variety development programs. Two evaluation and enhancement projects that were emphasized in 1992 were allelopathy (ability of a rice plant to suppress adjacent weed growth and development) in rice to weed species such as ducksalad, barnyardgrass and sprangletop and tolerance of rice germplasm to herbicides such as Roundup and Touchdown.

Annual losses due to weeds in rice in the U.S. have been estimated at 17% of the potential production, or almost one million metric tons, valued at $205 million. More than 50 weed species infest direct-seeded rice in the U.S. Ducksalad is one of the most frequently reported aquatic weeds in rice, and barnyardgrass is the major weed that infests dry-seeded rice in the southern rice-producing states, including Arkansas. Effective weed control programs for rice include preventive, cultural, mechanical, chemical and biological practices. The most recent and perhaps least exploited is the biological method. In recent years weed control through allelopathy has received increased attention. For example, it was estimated in 1977 that the development of new technology from allelopathics would benefit U.S. agriculture by 2% of its total production, or about $2 billion annually.

Allelopathy recently has been defined as any direct or indirect harmful effect by one plant on another through the production of chemical compounds released into the environment. Allelopathy is postulated to be one mechanism by which weeds affect crop growth; it occurs widely in natural plant communities. Allelopathic potential of weeds through the release of toxic substances into the environment either through root exudation or from decaying plant material has been demonstrated in about 90 species. In addition to the existence of allelopathy in weeds, several workers have reported that crops such as rye (*Selecale cereals* L.), wheat (*Triticum aestivum* L.), sunflower (*Helianthus annuus* L.) and oats (*Avena sativa* L.) possess allelopathic activity or have weed-suppressing properties. It has been postulated that "wild types" of existing crops may have possessed high allelopathic activity, a characteristic that was reduced or lost as they were hybridized and selected for other characteristics.

PROCEDURES

Investigations of the effect of allelopathy on weed species such as ducksalad, barnyardgrass and sprangletop were conducted on a Crowley silt loam soil at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas. Allelopathy to ducksalad was evaluated in both rows and hill plots. The rows (4.5 ft in length) were approximately 21 in. apart, and the hill plots were about 30 in. apart. Between 15 and 20 barnyardgrass seed were seeded in each hill at the time the rice was seeded. Two types of measurements for allelopathy were recorded at mid-season: (1) the radial area of activity, in inches, from the base of the plant and (2) the percentage of ducksalad control within the area of activity. Also, agronomic characteristics such as plant height, lodging, grain type, heading date and seed coat color were recorded. Approximately 5,500 varieties were evaluated in hill plots for allelopathic activity in rice to barnyardgrass and sprangletop.

Approximately 400 accessions were evaluated for resistance to the herbicides Roundup and Touchdown. Three spray dates and three spray rates were tested. The spray rates were 0.5X, 1.0X and 2.0X (0.38, 0.75 and 1.5 lb active ingredient/acre) applied one day prior to flood, two weeks later and four weeks later. Cultivars were included in the test as checks. Plant height, maturity, lodging, grain yield and grain type were recorded at maturity.

About 14,000 of the 16,134 varieties in the USDA/ARS rice germplasm collection have been screened for salinity tolerance in a hydroponic system at Fayetteville, Arkansas. Ten seeds of each variety were placed directly into a saline nutrient solution with an electrical conductivity of 10 to 11 ds/m. The seedlings were rated based on germination, amount of growth and survival at the end of the seedling development period.

Straighthead (SH) evaluations of 50 varieties and segregating populations were conducted at RREC. MSMA at three levels of arsenic, 4 lb, 6 lb and 8 lb, was applied preplant incorporated to induce straighthead symptoms. Thirty-two cultivars were evaluated for straighthead resistance at Stuttgart, Marianna and Pine Tree, Arkansas. MSMA at a 6-lb/acre rate of arsenic was applied preplant incorporated at each location. Straighthead ratings on a scale of 0-9 (0 = no SH, 9 = no panicles produced) were taken at grain maturity.

A total of 104 Japanese varieties were evaluated at RREC for earliness, plant height, lodging, grain and milling yield and general adaptability to southern U.S. rice growing conditions. Also, taste tests are being conducted in both Japan and the U.S. on all the Japanese varieties and the U.S. varieties that were included as checks. One-hundred-six short-statured varieties from the USDA/ARS rice germplasm collection were treated with gibberellic acid (GA_3) to determine their response to GA_3. An emergence index, which is a weighted stand count that gives greater credit to seedlings that emerge early, was calculated for each variety.

RESULTS AND DISCUSSION

Allelopathy

Results from previous germplasm evaluation tests were used to select 420 rice varieties or accessions that had demonstrated allelopathic activity to ducksalad. Data from eight varieties that showed the greatest allelopathic activity to ducksalad in 1992 and two U.S. check cultivars, 'Rexmont' and 'Newbonnet', are presented in Table 1. In previous tests rice varieties from India demonstrated apparent allelopathy to barnyardgrass. About 5,500 rice varieties from 63 countries were evaluated for allelopathy to barnyardgrass in 1992. Preliminary data showed that 3,665 of these varieties do not have allelopathy to barnyardgrass. The remaining 1,835 varieties will be further evaluated in 1993. Also, a natural infestation of sprangletop demonstrated that 4,442 varieties did not have allelopathy to sprangletop. The remaining 1,058 accessions will be evaluated further in replicated tests in 1993.

Herbicide tolerance

Seven varieties of the 400 tested had a higher level of tolerance to Roundup. The mean percentage yield increase of the seven tolerant varieties as compared to the checks across two rates and two times of application are presented in Table 2. The data indicate that rice germplasm available from the USDA/ARS collection can tolerate a 1.0X rate of Roundup prior to flooding. Also, responses to Roundup within a variety can differ due to spray rate and date. Five of the 400 varieties demonstrated a higher level of tolerance to Touchdown at a 1.0X rate. Also, these five were among the top 20 varieties that demonstrated tolerance to Roundup.

Japanese varieties

The earliest-maturing varieties that originated in Japan were evaluated for plant height, lodging, grain yield, milling yield and maturity (Table 3). PI 234981, PI 281633 and PI 282403 required only 56, 57 and 57 days from seedling emergence to 50% heading, respectively. Plant heights of the early-maturing Japanese accessions ranged from 31 to 46 in. Grain yields for Japanese varieties ranged from 89 to 218 bu/acre, demonstrating that high grain yields are possible with very-short-season germplasm from Japan. Some total and head rice yields exceeded those of the U.S. check varieties (Table 3).

Gibberellic acid (GA_3)

Of the 240 short-statured varieties from the USDA/ARS rice collection evaluated for treatment with GA_3, data are shown for the seven that demonstrated the greatest response (Table 4). These seven varieties will be evaluated in 1993 to determine if they possess the sd_1 semidwarf gene or other genes controlling semidwarfism in rice.

SIGNIFICANCE OF FINDINGS

The identification and enhancement of rice germplasm possessing allelopathic properties to major aquatic and dry-land weed species can revolutionize weed control in rice by reducing or eliminating the need for certain herbicides. The identification and enhancement of rice germplasm that is tolerant to glyphosate (Roundup) or sulfosate (Touchdown) that controls red rice in commercial rice could facilitate the use of a single application of a biodegradable herbicide for general weed control. Also, the development of germplasm that permits reduced use of herbicides or pesticides may result in improved water quality, less environmental contamination and greater profits to the rice producer. Rice germplasm from Japan confirmed that high yields can be obtained with very-short-season, short-statured germplasm.

Table 1. Descriptive data for eight germplasm accessions that demonstrated allelopathic activity to ducksalad.

Accession Number	Radial Activity Mean[z] (in.)	Percent Weed Control	Plant Height (in.)	Grain Type[y]	Days to Heading	Seed Coat Color[x]
PI 229268	5	81	49	L	101	Lt.Br.
PI 338511	5	80	33	M	104	Lt.Br.
PI 408642	5	76	39	M	139	Lt.Br.
PI 321179	4	80	40	L	93	Lt.Br.
PI 338550	4	77	35	M	91	Lt.Br.
PI 161028	4	76	59	L	105	White
CI 7071	4	74	56	M	90	Lt.Br.
PI 282120	4	75	55	M	109	Brown
Rexmont (check)	0	0	46	M	88	Lt.Br.
Newbonnet (check)	0	0	41	L	97	Lt.Br.

[z]Radius, in inches, from the base of the rice plant where ducksalad was controlled

[y]Grain Type: S = short, M = Medium, and L = Long

[x]Seed Coat color: Lt.Br. = Light Brown

Table 2. Rice accessions that demonstrated tolerance to glyphosate (Roundup) at two spray dates and two spray rates and two check cultivars.

	Grain yield			
	Date 1		Date 2	
Accession	0.5X	1.0X	0.5X	1.0X
	g/4.5 ft			
PI 353692	102	89	76	119
PI 399662	248	66	200	129
PI 433838	143	65	222	79
PI 400706	152	18	113	14
PI 388320	135	2	148	33
PI 414715	165	42	226	154
PI 414714	119	27	171	185
Newbonnet	0	0	0	0
Lemont	0	0	0	0

Table 3. Rice varieties originating from Japan evaluated for days to heading, plant height, lodging and grain and milling yield.

Accession Number	Days to Heading[z]	Plant Height	Lodging[y]	Yield	Milling Total	Milling Head
		in.		bu/ac	%	
PI 202977	61	34	9	149	70.0	65.0
PI 224651	61	39	8	162	70.5	64.8
PI 224817	61	36	9	131	67.8	60.8
PI 226161	67	44	9	93	58.0	50.3
PI 226207	70	46	2	89	57.8	30.5
PI 234981	56	40	9	94	69.5	59.5
PI 281633	57	40	9	136	71.3	66.0
PI 282403	57	38	9	112	71.3	63.8
PI 291637	64	40	9	120	71.8	65.8
PI 341933	62	31	7	166	72.8	67.0
PI 362099	70	40	7	218	72.5	68.3
S201 (check)	84.0	37	1	141	71.5	60.3
S101 (check)	77.0	40	3	200	69.8	64.0
Mean	65.0	39	7	139	68.8	60.5
CV(%)	1.5	5.3	15.5	15.2	2.2	4.0
LSD (0.05)	2	3		30	2.1	3.5

[z]Days to heading = days from seedling emergence to 50% of the panicles emerged

[y]Lodging: Scale of 1 to 9, where 1 = 0-10% of the plants are lodged and 9 = 81-100% of the plants are lodged

Table 4. Emergence index and plant height of short-statured rice lines treated with gibberellic acid (GA_3).

Accession Number	Days to Heading[z]	Emergence Index[y]		Plant Height	
		Treated	Untreated	Treated	Untreated
				---------- in ----------	
CI 9978	83	122	64 S[x]	29	27 NS[x]
PI 331469	86	107	57 S	31	30 NS
PI 346923	83	142	78 S	26	25 NS
PI 348795	77	102	56 S	30	30 NS
PI 403597	78	123	75 S	30	30 NS
PI 345786	90	140	88 S	32	32 NS
PI 350373	101	109	64 S	26	26 NS

[z]Days to heading: = days from seedling emergence to 50% of the panicles emerged

[y]Emergence Index: Weighing stand counts where higher credit is given to an earlier date and higher number of seedlings

[x]S=Treated vs Untreated are significantly different and NS=Treated vs Untreated are not significantly different

BREEDING AND EVALUATION FOR IMPROVED RICE VARIETIES THROUGH RICE BIOTECHNOLOGY

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ABSTRACT

Anther culture has been used to a limited extent to develop new rice cultivars. Anther culture techniques are being utilized to develop rice varieties with improved blast resistance. An increased number of doubled haploid plants have been derived from the anther culture program at the Rice Research and Extension Center (RREC) in Stuttgart, Arkansas. These lines are in different stages of development in the greenhouse. Five out of 13 doubled haploid lines developed in 1991-1992 were resistant to the rice blast fungus when treated with a bulk of the four races that are prevalent in Arkansas: IB-49, IC-17, IH-1 and IG-1. These lines will be further tested in 1993.

INTRODUCTION

Anther culture has been used to develop rice (*Oryza sativa* L.) cultivars in China and was utilized in the development of the long-grain rice cultivar 'Texmont', developed by the Texas Agriculture Experiment Station and USDA/ARS. In general, use of anther culture for the development of new rice cultivars has been limited in the past. Our program is using anther culture techniques to develop rice cultivars with improved 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 for the improvement of blast resistance in varieties.

PROCEDURES

Anthers were collected from tillers from 1031 selected F_2 space plants that were grown in the field in 1992. Approximately 10 to 30 F_2 space plants were selected from each of 30 crosses involving Katy or other highly blast-resistant parents. Anthers from as many as three tillers were selected on some plants.

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. The tillers were wrapped in foil and chilled for four to seven days at 7°C. Panicles from the chilled tillers, with the flag and second leaf sheath intact, were sterilized in a 50% chlorox solution for 30 minutes and then rinsed in sterile deionized water. Anthers were dissected by cutting off the top of the florets (lemma and palea) just above the anthers and sliding tweezers gently up the floret to excise the anthers. The anthers were plated on two calli initiation media, one containing sucrose and the other containing maltose at approximately 50 anthers/plate. The plated anthers were sealed with parafilm and incubated in the dark at 27°C until callus formation occurred. 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 on the regeneration media were incubated at 27°C under continuous cool-white fluorescent lighting. Development of green spots, roots, albino and green plant regeneration were recorded.

The initiation medium was N6 Callus Initiation Medium (Chu, 1978) supplemented with 60.0 g/l sugar (sucrose or maltose) and 2,4-dichlorophenoxyacetic acid, adjusted to pH 5.8. Agarose type II was added to make a solid media prior to autoclaving for 25 min at 15 PSI. The calli regeneration media consisted of Murashige-Skoog medium (1962) supplemented with 40.0 g/l sugar (sucrose or maltose), 0.5 mg/l 1-naphthylaceitc 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.

Anther culture lines developed from this will be tested for blast resistance and then increased and entered into the traditional testing program.

RESULTS AND DISCUSSION

Table 1 lists preliminary findings on the number of plants per cross producing calli and transferred to regeneration media. Some calli were produced from every cross combination plated; however, there was considerable variation in the number of plants per cross producing calli. For crosses 9130, 91662 and 91664, only 10% of the plants had tillers that produced calli and were transferred to regeneration media. Crosses 9128, 9129, 91672, 91709, 91713, 91722, 91737 and 91738 produced calli on 80% or more of the plants from which tillers were selected. Twenty-eight of the crosses had calli that produced green spots. Green spots are the first sign of viable calli from which plantlets are produced. Data are still being collected on these populations. Plantlets have been transferred to test tubes from 13 of these crosses, and at this time we have 55 plants surviving in the greenhouse derived from 12 crosses. There are additional plantlets that will be ready for transferring to test tubes and to the greenhouse in the future.

In 1992 13 anther culture lines were grown in the field as a seed increase and for further agronomic evaluation from a bulk of seed off each anther culture-derived doubled haploid plant. Some of these lines appeared to be segregating for plant type and maturity. Panicles from these lines will be selected and planted in adjacent rows in 1993. These lines have been tested for blast resistance. Five of the 13 lines tested rated a 3 (0=immune 9=maximum disease) or less when inoculated with a bulk of the blast isolates IB-49, IC-17, IH-1 and IG-1. Additional testing will be conducted in 1993.

SIGNIFICANCE OF FINDINGS

Genetic factors are associated with the ability to utilize anther culture techniques, and certain lines will not produce plantlets. These data show the differences among the populations that we studied in 1992. Therefore, at present we must continue to utilize the traditional methods along with anther culture techniques for the selection of lines from the populations while we evaluate lines produced from anther culture to insure that we are not losing valuable material that will not culture.

Lines developed through anther culture have the potential to become varieties in a shorter period of time than those that progress through a traditional breeding program because they are homozygous (pure lines) and do not require the generations of inbreeding to become pure lines. The potential for quickly incorporating blast resistance into rice varieties of the future is increasing with the successful production of the doubled haploid plants emerging from this program.

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Table 1. Preliminary data from 1992-1993 anther culture program.

Cross	Total No. Plants/Cross	No. Plants/Cross Producing Calli	No. Plants/Cross Producing Green Spots	No. Plantlets/ Cross
9123	30	22	14	10
9124	7	3	2	
9127	18	8	6	
9128	23	19	13	
9129	10	9	8	5
9130	10	1		
9153	20	14	6	
9161	20	11	10	54
9172	10	6	3	
9175	15	11	6	3
9193	14	10	7	7
91643	19	4	1	
91647	21	7	3	
91658	15	4	3	5
91662	20	2		
91663	30	11	5	
91664	30	3	2	
91672	20	17	8	
91681	20	8	4	
91682	11	6	3	
91709	22	19	18	8
91713	20	18	17	5
91722	8	8	3	
91723	12	9	7	
91726	10	3	2	3
91736	17	8	4	1
91737	20	20	14	8
91738	20	8	4	
91739	20	16	9	3
91740	17	12	9	1

PHYSIOLOGICAL LIMITATIONS ON RICE YIELD

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

ABSTRACT

This research is directed at determining physiological limitations on rice grain yield during the grain-filling process. We examined sucrolytic enzyme activity and grain-filling in the endosperm of three rice lines: two parents and an F_1 hybrid. The hybrid and the Chinese parent, 'Qiguizao', had somewhat higher sucrose synthase activity than the 'Lemont' parent in this experiment. We did several defoliation tests and found that rice plants with no leaf blade area during the grain-filling period could still produce some filled grains. We compared grain, stem, sheath and leaf area changes between Lemont and 'Gui-chow', a high-yielding Chinese variety, and found a rapid decrease in stem and sheath weights for Gui-chow after anthesis followed by less drastic changes in weight. Sucrolytic enzyme activity for Gui-chow also decreased rapidly after anthesis. Lemont sheath and stem weights decreased gradually after anthesis throughout the grain-filling period, as did sucrolytic enzyme activity.

INTRODUCTION

Rice grain yields are determined to a large extent during the grain-filling period. The grain filling process is affected by external factors such as the amount of sunlight, but the process is also controlled genetically and biochemically. Most of the energy and material for filling the grain is provided to the grain in the form of sucrose. This is because sucrose is the main (>95%) form of carbohydrate translocated from sources (organs supplying carbohydrates) to sinks (organs receiving carbohydrates). The developing rice grain must take incoming sucrose and decompose it into its two constituent sugars. It has been demonstrated that the enzyme sucrose synthase is involved in the grain-filling process because the rates of sucrose metabolism required to fill the rice grain require sucrose synthase rather than the slower invertases.

Rice grains ordinarily develop rapidly from the time of anthesis (fertilization of the ovule) until grain maturity. In the field the upper, older grains of the panicle complete grain fill first, followed by the younger, lower grains (Counce et al., 1992). In particular, we are seeking ways that rice yields are limited during the grain-filling process. We hope to identify physiological limitations on rice grain-filling that can be manipulated by plant breeders to more effectively select for increased rice yield. In this project we are focusing attention on enzymes involved in the breakdown and production of sucrose. To do this, we examined several cultivars and breeding lines for differences in sucrose metabolism enzymes and in the utilization of stored carbohydrates to fill grains.

MATERIALS AND METHODS

Enzyme Analyses

Fresh rice tissues were ground in a mortar chilled with liquid nitrogen into a Hepes extraction buffer adjusted to pH 7.5, passed through a desalting column and assayed for sucrose synthase, pyrophosphate phosphofructokinase (PPi-PFK), acid and neutral invertases (AI and NI, respectively), adenosine triphosphate PFK (ATP-PFK) and uridine diphosphoglucose pyrophosphorylase (UDPG-PPiase). By the end of 1992, we were routinely assaying for all of the above enzymes except ATP-PFK and UDPG-PPiase. These two enzymes were occasionally assayed to confirm other results. All of these enzymes are involved in sucrose metabolism in plant cells.

Plant Culture

Plants were grown in the field, greenhouse and growth chamber at the University of Arkansas Northeast Research and Extension Center (NEREC), Keiser, Arkansas. Standard production practices were used in the field. In the greenhouse and growth chamber, plants were grown in a circular arrangement in pots and buckets of various sizes, depending upon the objective of the experiment.

The lines used in the experiments included SLG-1, a large-seeded breeding line; M15-117 and M15-123, closely related lines developed from selections of F-2 generation plants from a 'Bond' by Lemont cross made by Dr. Karen Moldenhauer; Gui-chow, a high-yielding Chinese rice variety; Lemont, which yields well in high-irradiance, sunny conditions during grain-filling (Tu et al., 1990); Qiguizao, a high-yielding Chinese rice variety that does well in low-irradiance, cloudy conditions during grain-filling; and 'Le/Qi', an F-1 hybrid of Lemont and Qiguizao. The M15-123 and M15-117 lines yielded 115 and 158 bu/acre, respectively, in a two-year test at NEREC (P.A. Counce, unpublished data). The striking yield difference between these two lines suggested that significant physiological factors might be involved in their productivity differences. The Le/Qi hybrid is produced by a chemical emasculation of the female parent in field production (Z.P. Tu, personal communication).

Lemont, Qiguizao and Le/Qi were seeded weekly in pots in the greenhouse in the fall of 1992. Plants were tagged at anthesis at the top of the panicle and subsequently sampled at 5, 10, 15 and 20 days after anthesis.

Field-grown Lemont and Gui-chow were compared for stem, sheath and grain weight changes and enzyme activities during the grain-filling period. Large, separate areas seeded with Lemont and Gui-chow were sampled weekly during the grain-filling period. Plants were divided into stems, sheaths, leaf blades and panicles. Sucrose metabolism enzymes in fresh stems and sheaths were assayed weekly as well.

Several defoliation studies were conducted in the greenhouse in which varying degrees of defoliation were imposed upon plants at various growth stages at and after panicle emergence. The defoliation treatments were done by severing selected leaves at the junction of the leaf blade and sheath.

RESULTS AND DISCUSSION

Lemont, Qiguizao and Le/Qi were compared for endosperm enzyme activities of these lines and to try to determine how the differences in grain-filling in different irradiance environments might be related to sucrose metabolism enzymes. Preliminary data presented in Table 1 suggest that the performance of Qiguizao and Le/Qi in low-irradiance conditions may be affected by sucrose metabolism. Further data are being collected. Initially, however, sucrose synthase activities of Qiguizao and Le/Qi appear to be somewhat higher than that for Lemont. Acid invertase activities were somewhat low and appeared to decrease with time. Neutral invertase activities were low enough to suggest that the enzyme was not active in these rice endosperm tissues.

Data from a field study of Lemont and Gui-chow indicated that stems and sheaths decreased in weight soon after anthesis, followed by less dramatic weight changes (data not shown). Total sucrolysis enzyme (sucrose synthase and invertase) activity in stems and sheaths of Gui-chow decreased from approximately 300 nmoles/g fresh weight per minute at anthesis to nearly zero 14 days later. Sucrolytic enzyme activity decreased steadily but not precipitously for Lemont after anthesis and was parallel to stem and sheath weight decreases. Sucrose phosphate synthetase (SPS) activity in stems and sheaths was found to be low during grain-filling compared to activity in leaves during this period. This enzyme is required for producing sucrose in source tissue.

Several striking responses to defoliation were found. When three lines of rice were completely defoliated just prior to anthesis, kernel weights were reduced less than 20% compared to the undefoliated controls (Table 2). Percentage filled grain was reduced by approximately 30% for M15-117 and M15-123 but only negligibly for SLG-1 (Table 2). In a related experiment, individual kernel weight differences were reduced 24% by complete defoliation and by nearly 10% when the three lower leaves were removed (Table 3). When the fourth leaf from the top and leaves below it were removed, kernel weights were virtually identical to those of the undefoliated control. Percentage filled grains, number of filled grains per panicle and grain weight per plant were reduced least compared to the control when the fourth leaf and below were removed, more when the top three leaves were removed and most with complete defoliation (Table 3). Sequential growth data revealed that M15-117 relied more on stored carbohydrates in the sheaths and stems than did the higher-yielding related line M15-123. An experiment with Alan rice in the field revealed a small decrease in grain yield per plant but virtually no difference in grain weight when all leaves were removed three weeks after anthesis. However, grain filling is nearly complete by this development stage. These defoliation data indicate that rice plants can produce some grains, with varying reductions in kernel weight, with no leaf blade area during the grain-filling period. This indicates that rice has some ability to fill rice grains from carbohydrates stored in stems and sheaths, and this appears to vary among cultivars.

SIGNIFICANCE OF FINDINGS

Preliminary data suggest that significant differences in endosperm sucrose metabolism enzyme activity of different rice lines may allow the identification of higher yielding rice lines. We can also hope that the enzyme basis for utilization of stored starch can be identified, located on the genome and transferred to improve rice yield and yield stability. Considerable time was spent in developing extraction and assay procedures for rice tissue during 1992. The procedures and protocols developed should allow for refinements and additional progress in 1993.

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Table 1. Endosperm enzyme activities of two rice parents ('Lemont' and 'QGZ') and an F1 hybrid (YZ1) grown in the greenhouse at Northeast Research and Extension Center, Keiser, Arkansas, in 1992.

Entry	DAA[z]	Protein	Sucrose Synthase	PPI-PFK	Acid Invertase	Neutral Invertase	Kernel Weight
		mg/g fresh wt	------------------------------	nmoles mg/protein/min	------------------------------	------------------------------	mg/grain
Lemont	5	10.36 ± 4[y]	46.6 ± 47.5	46.1	16.6 ± 24.5	5.2 ± 4.5	5.12 ± 2.33
	10	10.57 ± 1.15	60.7 ± 16.9	79.9	19.3 ± 22.5	3.0 ± 3.4	12.23 ± 1.89
	15	10.06 ± 2.01	25.3 ± 11.7	84.4 ± 57.9	8.1 ± 6.5	1.5 ± 0.7	16.30 ± 2.98
	20	7.76 ± 1.91	29.9 ± 8.5	66.6 ± 45.0	11.3 ± 8.2	1.5 ± 0.9	22.28 ± 0.52
YZ1	5	8.81 ± 2.08	96.1 ± 50.5	204.4	85.6 ± 35.6	7.0 ± 6.5	5.22 ± 0.91
	10	13.87 ± 3.24	56.5 ± 35.6	98.1 ± 65.4	8.4 ± 9.7	2.7 ± 2.9	7.18 ± 3.70
	15	8.04 ± 3.68	32.5 ± 18.8	48.2 ± 19.1	42.9 ± 51.2	1.5 ± 1.6	14.59 ± 4.28
	20	9.14	18.5	18.1	2.3	0	18.80 ± 2.34
QGZ	5	4.27	83.6	649.8	38.8	16.9	3.20 ± 0.99
	10	8.22 ± 2.63	154.7 ± 61.7	223.3 ± 59.1	12.1 ± 14.5	4.8 ± 4.7	5.80 ± 2.79
	15	6.88	43.6	31.2	13.5	1.6	10.93 ± 2.18
	20						11.72 ± 0.87

[z]DAA = Days after anthesis

[y]Value = Mean ± standard error except in cases when only one value was obtained.

Table 2. Response of three rice lines to defoliation in the greenhouse, January through June of 1992, Northeast Research and Extension Center, Keiser, Arkansas.

	Final Kernel Weight			Percentage Filled Kernels[z]		
Treatment	M15-117	M15-123	SLG-1[y]	M15-117	M15-123	SLG-1
	----------mg/kernel[x]----------			------------%------------		
Defoliated	21.2	21.7	52.2	57.2	64.2	36.8
Control	24.2	24.8	57.6	79.7	91.6	35.1

[z](Filled seeds/(filled + unfilled seeds)) X 100 = % of filled kernels/panicle

[y]From a separate experiment. Note that SLG-1 has very large grains.

[x]Oven-dried to bound moisture only.

Table 3. Response of rice to varying levels of defoliation at anthesis, greenhouse study, Northeast Research and Extension Center, Keiser, Arkansas, 1992.

Treatment	Kernel Weight	Percentage Filled Grains	Filled Grains per panicle	Grain Weight per plant
	mg/grain[z]	%	no.	g/plant
Complete defoliation	53.1 ± 2.8	46.1 ± 12.6	17.4 ± 3.3	0.92 ± 0.18
4th leaf and below removed	68.9 ± 3.1	57.5 ± 2.8	21.9 ± 2.0	1.49 ± 0.03
3rd leaf and above removed	63.0 ± 0.6	55.1 ± 3.4	22.3 ± 1.8	1.35 ± 0.13
Control (no defoliation)	69.6 ± 1.1	61.2 ± 2.5	24.3 ± 2.7	1.56 ± 0.25

[z]Corrected to 12% moisture.

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

B.R. Wells, R.E. Baser 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 salinity and alkalinity tolerance of these accessions. This knowledge is required if rice varieties tolerant to salinity or alkalinity are to be developed from this collection. Therefore, we developed a hydroponic system to allow us to rapidly screen this collection for salinity tolerance. We have screened 14,000 accessions and from that group have identified 15 that exhibit a high degree of tolerance; however, seed from seven of those had sufficiently low germination to make the evaluation suspect. We have also screened the currently grown southern United States varieties and found an elevated level of salinity tolerance in 'Jasmine85' and 'V4716' (when screened in a solution with an electrical conductivity (EC) of 10.5 µmhos/cm). A soil-based system utilizing Calloway silt loam adjusted to a pH of 8.0 is being used to evaluate the collection for alkalinity tolerance based on symptoms for zinc (Zn) deficiency. This project is in the initial stages, and only 784 accessions have been evaluated, of which 16% did not exhibit any symptoms typical of Zn deficiency.

INTRODUCTION

A need for salt- and alkalinity-tolerant varieties of rice in the southern United States is becoming apparent with the decrease in good-quality ground water, accumulation of soluble salts in the soil and continuing rise in soil pH caused by use of waters containing excessive levels of calcium bicarbonates. Soil salinity is a major problem in many rice-producing areas of the world, and in some areas indigent varieties are reported to show more tolerance to saline conditions. Rice is very tolerant to salinity during seed germination; however, susceptibility to salinity increases as the plant progresses to the seedling stage. It then exhibits tolerance during tillering but again becomes susceptible at anthesis. The increased level of susceptibility during the seedling stage offers the opportunity to screen germplasm for tolerance to salinity by growing the plants for only a three- to four-week interval. Similarly, rice is 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 above 7.0. However, the problem is a reduction in availability, not a lack of Zn in the soil. Previous research (Wells et al., 1973) has shown the alkalinity problem to be most prevalent on silt loam soils with a pH above 7.3 and has shown that the problem can be corrected with additions of Zn fertilizers. If accessions can be located that are able to extract Zn from these alkaline soils, use of them would both reduce costs to the farmer and improve the environment by reducing applications 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 the point at which Zn could possibly become available in amounts excessive for plant uptake. Therefore, the purpose of this continuing study is to develop a hydroponic system to screen for salinity tolerance; to develop a soil-based system to screen for alkalinity tolerance; and to screen the USDA/ARS germplasm and the southern United States rice varieties for tolerance to salinity and alkalinity.

MATERIALS AND METHODS

The salinity screening study was conducted with a hydroponic system contained in a mobile home that had been renovated for this purpose by adding extra insulation, growth lights and temperature controls. Diurnal temperatures were maintained near optimum for maximum seedling growth (25-33°C day and 20-25°C night). Lighting was supplied by 300-watt quartz lights. The hydroponic solutions contained nutrient solution, as described by Yoshida et al. (1976) plus sufficient salt solution (mixture of NaCl and $CaCl_2$) to provide the desired salinity levels. The mean EC of the saline solution for screening of the USDA/ARS germplasm collection was 10.5 µmhos/cm whereas the southern United States varieties were screened in saline solutions with EC's of 0.8, 3.5, 5.5 and 10.5 µmhos/cm. These would be considered from low to very high levels of salinity in terms of plant tolerance.

Ten seeds of each variety/accession were placed on one layer of cotton matting, then covered with a second layer of matting and placed on the polyethylene support in the hydroponic solution. The nutrient solutions were changed weekly, and the seedlings were grown for three weeks prior to rating for salinity tolerance. Rating consisted of evaluating the seedlings for number of live and dead seedlings and number of germinated seed. In the USDA/ARS screening study, each accession was tested in duplicate. With the southern United States varieties, the treatments were replicated six times. Statistical analysis was conducted by the procedures of SAS, Inc.

The alkalinity screening study is being conducted in Calloway silt loam soil after adjustment of the pH to approximately 8.0 by addition of finely ground (<100 mesh) calcium carbonate. Ten seeds of each accession are seeded in flats and allowed to grow for eight weeks. Seedlings are evaluated at intervals during this period as being symptomatic or non-symptomatic of Zn deficiency. Therefore, the data include both symptoms and relative time of appearance of symptoms.

RESULTS AND DISCUSSION

We have completed salinity screening of 14,000 of the approximately 16,000 accessions of the USDA/ARS rice germplasm collection. Fifteen of these accessions have shown a high level of tolerance to salinity. However, seven of these accessions had germination less than 50%; thus the data are of doubtful value.

Detailed data from the southern United States varieties are given in Table 1. At the lowest salinity level (0.8 µmhos/cm), those varieties with the highest rating represent high seedling vigor as the salinity level was not sufficiently high to adversely affect growth of rice seedlings. At this salinity level, 'Mars', 'Orion', 'Lebonnet', 'Katy', 'Millie', 'Texmont', 'Lacassine' and V4716 appear to have the highest seedling vigor.

Those varieties exhibiting good vigor at the low salinity level continue to show higher ratings at the medium (3.5 µmhos/cm) and high (5.5 µmhos/cm) salinity level. However, when the salinity level was increased to 10.5 µmhos/cm, the relative ratings began to change. At this very high salinity level, only Jasmine85 and V4716 had statistically higher ratings than 'Newbonnet', which is considered very susceptible to salinity. Unfortunately, the major rice varieties currently being produced in the southern United States do not show any appreciable differences in tolerance to salinity. However, these ratings are from a hydroponic system, and response of the varieties when grown in soil might be different.

The alkalinity screening studies are just getting underway, and, to date, only 784 accessions have been through the complete screening program. Of these accessions, 16% did not exhibit any Zn deficiency symptoms. An additional 34% exhibited symptoms on less than 50%

of the seedlings within that accession. Based on these very preliminary results, it appears that the germplasm collection may contain a relatively large number of accessions with good tolerance to high-pH soils.

SIGNIFICANCE OF FINDINGS

This salinity screening study has located a few accessions with potentially high degrees of salinity tolerance. It is hoped that these apparently tolerant accessions can be incorporated into the southern rice breeding programs and eventually result in adapted, salt-tolerant rice varieties. Unfortunately, none of the present, widely grown southern rice varieties exhibited any appreciable degree of salinity tolerance. However, Orion, Mars, Katy and Millie indicate a trend toward increased salinity tolerance. Two minor varieties, Jasmine85 and V4716, showed potentially higher salinity tolerance.

The preliminary screening for tolerance to alkaline soils indicates that the germplasm collection potentially may have a relatively large number of accessions with good alkalinity tolerance. This offers excellent possibilities for use of these accessions to develop varieties with much more tolerance to alkalinity than is present in any of our currently grown varieties.

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Table 1. Salinity tolerance ratings for southern Unites States rice varieties as influenced by level of salinity.

Variety	Salinity Level			
	0.8	3.5	5.5	10.5
	μmhos/cm			
Newbonnet	5.2	5.9	3.8	3.2
Lemont	5.3	6.4	4.8	3.2
Tebonnet	5.3	7.5	4.8	3.0
Lebonnet	7.6	7.1	4.9	3.4
Mars	7.3	7.1	4.8	3.8
Orion	7.0	7.7	5.2	4.2
Gulfmont	5.5	6.8	4.9	2.8
L202	4.8	4.1	3.6	3.4
RT7015	5.3	6.4	4.7	3.7
Texmont	7.2	6.8	4.7	3.4
Lacassine	7.2	6.7	4.3	2.6
Rosemont	6.2	6.3	4.0	3.5
Dellmont	5.6	6.8	4.8	2.8
Jasmine85	6.4	6.2	5.1	4.9
Katy	7.4	7.4	4.6	4.0
Rico1	6.2	6.4	5.2	3.8
LaGrue	4.0	4.2	4.2	3.5
Adair	5.8	4.7	3.4	2.7
Maybelle	6.0	6.2	3.8	3.3
Alan	4.7	4.9	3.6	3.1
Millie	7.8	6.5	4.0	3.9
L201	4.0	6.2	3.5	3.6
V4716	8.1	8.2	6.4	4.5
RU9001194	5.8	6.1	4.5	2.9

LSD (0.05) = 1.2

CONTROL, BIOLOGY AND ECOLOGY OF PROPANIL-TOLERANT BARNYARDGRASS

R.J. Smith, Jr., R.E. Talbert and A.M. Baltazar

ABSTRACT

In field studies conducted during 1991 and 1992, propanil-resistant barnyardgrass was not controlled by emulsifiable or dry-flowable formulations of propanil. However, an emulsifiable formulation was more active than a dry-flowable formulation on resistant barnyardgrass, especially with high rates of 7 or 10 lb/acre, applied sequentially. Arrosolo did not control resistant barnyardgrass any better than did propanil. However, several other herbicide treatments effectively controlled resistant barnyardgrass. Facet, registered for use in rice in 1993, controlled propanil-resistant barnyardgrass when applied alone delayed preemergence or early postemergence or applied tank mixed with propanil, Bolero, Prowl or Arrosolo early postemergence. Tank mixture treatments of propanil and Bolero or Prowl controlled resistant barnyardgrass when applied early postemergence. Likewise, Arrosolo tank mixed with Bolero or Prowl was effective on resistant barnyardgrass. Bolero applied delayed preemergence controlled resistant barnyardgrass. Ordram granules applied after flooding following earlier treatments of propanil controlled resistant barnyardgrass, but Ordram granules applied into the flood without preflood propanil failed to control resistant barnyardgrass.

INTRODUCTION

Propanil, applied either sequentially alone or in combination with pendimethalin (Prowl), thiobencarb (Bolero) or molinate (Ordram) has been used consistently to control grasses and other weeds infesting rice. At least 3 to 5 lb/acre of propanil has been applied once or twice in each growing season for the last 30 years in Arkansas. Recently, several farmers in Poinsett County, Arkansas, have observed that barnyardgrass in their fields has survived propanil treatments. This is the first time that tolerance of barnyardgrass to propanil has been reported in Arkansas.

Development in weeds and crops of resistance to or tolerance of herbicides used continuously for the past 5 to 20 years has been observed and documented for triazines, sulfonylureas, imidazolinones and other herbicides. Resistance or tolerance is usually a result of morphological, physiological or genetic changes in the plant that enable it to survive herbicidal action.

Greenhouse studies conducted in 1990 showed that barnyardgrass collections from six farms in Poinsett County, Arkansas, were not controlled by propanil at rates as high as 10 lb/acre. Subsequent studies conducted in two growers' fields naturally infested with propanil-resistant barnyardgrass confirmed these results. In studies conducted in the greenhouse to compare efficacy of herbicide treatments, those that were identified as providing 80% or more control of propanil-resistant barnyardgrass included propanil tank-mixtures with quinclorac (Facet), Prowl or Bolero and fenoxaprop (Whip) applied alone. Facet, one of the promising compounds, is registered for use in rice in 1993. Additional studies are needed to develop commercially available alternative treatments, not only to expand growers' options, but also to avoid the incidence of another buildup of tolerance to existing herbicides. The use of adjuvants to enhance efficacy of propanil has yet to be explored, as well as the effect of environmental factors that may come into play in relation to efficacy of propanil.

Objectives of this research were: 1) to determine and compare efficacy of herbicide treatments for control of propanil-resistant barnyardgrass and 2) to determine efficacy of propanil formulations on propanil-resistant barnyardgrass.

PROCEDURES

Rice (cv. 'Newbonnet' or 'Tebonnet') was drill-seeded on Hillemann silt loam, Poinsett County, Arkansas, in May 1991 and 1992; four experiments were conducted in 1991 and two in 1992. Each experiment was arranged as a randomized complete block with four replications. Nitrogen and water management were as recommended by the DD50 program. Natural infestations of propanil-resistant barnyardgrass occurred. Herbicides were applied in 20 gal/acre at delayed preemergence (DPE) and postemergence (POE) at various times indicated as two-leaf (2-LF) or four-leaf (4-LF) stages or before flooding (BF) or after flooding (AF) timings. At DPE neither rice nor barnyardgrass had emerged; at the 2-LF stage rice and BYG had two leaves (4 and 2 in. tall); at the 4-LF stage or the BF timing, rice and BYG had four leaves

(8 and 4 in. tall); at the AF timing rice and BYG was tillered (16 and 14 in. tall). Rice injury ratings were recorded early or at midseason (16-20 or 48-58 days after the 2-LF applications). Barnyardgrass ratings were recorded after plants were well headed. Grain yields were taken, and all data were subjected to analysis of variance and significant means separated by LSD. Performance of herbicide programs was based on combined responses of rice injury, barnyardgrass control and grain yield.

RESULTS AND DISCUSSION

Neither emulsifiable nor dry flowable formulations of propanil applied sequentially at 10 lb/acre gave satisfactory control of resistant barnyardgrass (Table 1). However, emulsifiable propanil was more active than dry-flowable propanil. Propanil tank mixed with either bromoxynil (Buctril) or triclopyr (Grandstand) failed to control barnyardgrass satisfactorily (Table 2). Propanil tank mixtures that controlled 2-LF barnyardgrass included propanil (3-4 lb/acre) with Bolero (3 lb/acre), Prowl (1 lb/acre) or Facet (0.38 lb/acre). Propanil + Bolero each at 2 lb/acre applied sequentially at the 2-LF and BF timings controlled barnyardgrass. Facet at 0.38 lb/acre applied alone DPE or at the 2-LF stage controlled barnyardgrass. Tank mixtures of Facet (0.38 lb/acre) with propanil (3 lb/acre), Bolero (3 lb/acre), Prowl (1 lb/acre) or propanil + molinate (Arrosolo) (5.1 lb/acre) controlled 2-LF barnyardgrass. Although Arrosolo (6 lb/acre) alone failed to control barnyardgrass, tank mixtures of 5.1 lb/acre with Bolero (2 lb/acre) or Prowl (0.75 lb/acre) controlled barnyardgrass. Bolero at 4 lb/acre alone applied DPE controlled barnyardgrass. Fenoxaprop EW (Whip 360) at 0.06 lb/acre or fenoxaprop emulsifiable (Whip) at 0.15 lb/acre BF controlled 4-LF barnyardgrass. Both Whip formulations applied BF injured rice moderately soon after application, but rice recovered by midseason. Whip 360 at 0.06 lb/acre applied AF did not control barnyardgrass and injured rice moderately, which persisted to midseason. Ordram granules at 4 or 8 lb/acre applied AF controlled tillering barnyardgrass when propanil had been applied at the 2-LF and BF timings. The 8-lb/acre rate injured rice moderately while 4 lb/acre did not. Ordram granules at 4 lb/acre applied AF without previous propanil failed to control barnyardgrass.

SIGNIFICANCE OF FINDINGS

Many standard herbicide treatments controlled resistant barnyardgrass. Effective treatments included propanil tank mixed with Bolero, Prowl or Facet all applied POE; Bolero alone applied DPE; Facet alone applied DPE or POE or applied POE in tank mixtures with Bolero or Prowl; Arrosolo applied POE in tank mixtures with Bolero, Prowl or Facet; and Whip or Whip 360 applied BF. Because all of these herbicides are registered for use in rice, herbicide programs are available to farmers for controlling propanil-resistant barnyardgrass. Because herbicides with different chemistries control propanil-resistant barnyardgrass, alternative use of herbicides with various chemistries may help prevent buildup of resistance to these herbicides. For example, alternating Facet, Bolero and Prowl in programs for control of propanil-resistant barnyardgrass is suggested.

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Table 1. Effect of propanil on resistant barnyardgrass: Weed control, rice injury and rice grain yield—average three experiments in 1991 and 1992.

Treatment			Early	Grain
Herbicide/formulation[z]	Rate	Control	injury[y]	Yield
	lb/acre/application	%	%	lb/acre)
Propanil (EC)	5/5	44	10	5010
"	7/7	56	12	5180
"	10/10	66	15	6290
Propanil (DF)	5/5	36	2	4000
"	7/7	37	4	4250
"	10/10	48	10	4780
Propanil + Bolero (std)	4+3	87	10	6890
Untreated check	—	0	0	2550
LSD (0.05)	—	11	4	850

[z]EC = emulsifiable concentrate; DF = dry flowable; std = standard treatment
[y]Injury 16-20 days after treatment.

Table 2. Herbicide treatment for propanil-resistant barnyardgrass: Weed control, rice injury and rice grain yield—average of three experiments in 1991 and 1992.

Treatment				Injury[x]		Grain
Herbicide	Rate	Time applied[z]	Control[y]	Early	Late	Yield
	lb/acre		%	%	%	lb/acre
Propanil/Propanil	3/3	2 LF/BF	41	0	0	5480
"	6/6	"	52	11	0	5730
Propanil + Bolero	4+3	2 LF	82	10	0	7330
Propanil + Prowl	3+1	2 LF	62	10	0	7040
Arrosolo + Bolero	5.1+2	2 LF	87	10	0	6930
Arrosolo + Prowl	5.1+0.75	2 LF	74	10	0	7072
Arrosolo	6	2 LF	51	10	0	5390
Facet	0.38	DPE	89	18	0	7020
Facet	0.38	2 LF	94	14	0	7210
Facet + Bolero	0.38+3	2 LF	94	16	0	7480
Facet + Prowl	0.38+1	2 LF	94	14	0	7120
Facet + propanil	0.38+3	2 LF	97	17	0	7440
Facet + Arrosolo	0.38+5.1	2 LF	94	18	0	7110
Propanil + Bolero/ Propanil + Bolero	2+2/ 2+2	2 LF BF	77	11	0	6940
Whip 360	0.06	4 LF	91	13	2	7270
Whip	0.15	4 LF	90	15	6	7040
Whip 360	0.06	AF	65	38	27	5760
Propanil + Grandstand	3+0.38	2 LF	49	23	0	5820
Propanil + Buctril	3+0.38	2 LF	48	16	0	6160
Untreated check	—	—	0	0	0	3060
LSD (0.05)			10	4	2	700

[z]DPE = delayed preemergence; 2 LF = two-leaf stage; 4 LF = four-leaf stage; BF = before flood; AF = after flood. See text for stages of barnyardgrass and rice.

[y]Control ratings were recorded after barnyardgrass was >80% headed.

[x]Early injury ratings were recorded 16-20 days after treatment; late rice injury ratings were recorded 48-58 days after treatment.

CONSERVATION TILLAGE SYSTEMS AND STALE SEEDBED PRACTICES IN RICE IN ARKANSAS

Roy J. Smith, Jr.

ABSTRACT

Rice and soybeans grown in reduced- and no-tillage systems produced grain yields comparable to those for the same crops grown in conventional-tillage systems. However, costs of producing rice in reduced- and no-tillage systems were lower, therefore producing higher net returns. Standard herbicides controlled weeds equally well for rice grown in either reduced- and no-tillage systems or conventional-tillage systems. Ducksalad infestations were frequently lower in the reduced- and no-tillage systems. Net returns from no-till and conventional-till soybeans were similar. Glyphosate (Roundup) alone or tank mixed with V-53482 applied preplant burned down winter weeds in no-till rice and soybeans sufficiently to permit excellent stand establishment. Also, glyphosate tank mixed with Facet for rice or with Dual for soybeans burned down winter vegetation and controlled summer weeds residually to eliminate early herbicide treatments in both crops. Effective programs burn down winter vegetation to permit seeding and stand establishment of no-till rice and soybeans and to control weeds that infest the crops after seeding. Although available herbicide programs controlled weeds in no-till rice, they were frequently different for no-till than for conventional-till rice.

INTRODUCTION

Conventional tillage is a soil management system that depends on tillage to control all weeds and volunteer crop plants before seeding. Conservation tillage is a soil management system that leaves the soil surface resistant to erosion and conserves soil moisture. Conservation tillage methods include 1) zero or no tillage, 2) minimum or reduced tillage and 3) mulch tillage. No-tillage and reduced-tillage systems also may have less adverse impact on the environment, especially in areas where trace amounts of chemical pesticides have been detected in groundwater and surface water.

In Arkansas, mechanical operations used prior to seeding rice vary considerably both in timing and in number from farm to farm, and this variability is quite large even among farmers from the same county farming the same type of soil. For example, the number of mechanical operations prior to seeding rice can vary from a minimum of four to a maximum of eight, and the cost per acre of these operations varies from $26 to $60.

There is a need to investigate whether the number of mechanical operations normally performed prior to seeding rice can be reduced and what impact this reduction will have on weed control, grain yields and, ultimately, net profit. Research conducted in the Philippines and in Japan with rice has demonstrated that considerable savings in time, labor, capital and energy can be achieved in land preparation without loss in yields. Weed control programs for stale-seedbed rice may be different than for conventional-till rice because weeds infesting the two systems may be different. Hence, research is needed to compare efficacy of stale seedbed herbicide treatments for control of weeds in no-till systems for rice.

Objectives of this research were 1) to determine the long-term effects of conservation tillage systems on production and profitability of rice in Arkansas and 2) to develop and compare herbicide programs for stale seedbed production of rice.

PROCEDURES

Conservation Tillage Experiments

During the first year, soybeans were grown conventionally in rows spaced 32 in. In the second year, rice was drill-seeded in 7.5-in. rows. Two separate experiments were conducted with initiation of the first experiment in 1988 and the second experiment in 1989. Hence, rice was grown in the first and second experiments in 1989 and 1991 and 1990 and 1992, respectively. Likewise, soybeans were grown in the first experiment in 1990 and 1992 and in the second experiment in 1991.

Both experiments were located on Crowley silt loam with pH 5.8 and 0.9% organic matter at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas. 'Newbonnet' or 'Katy' rice was drill-seeded in late April or early May with crop emergence in May each year. 'Narow' or 'Hartz 7190' soybean was drill-seeded in June each year with emergence in the same month. Plots 100 by 26 ft were arranged in randomized complete blocks with four replications.

For rice, nitrogen fertilizer at 135 lb/acre was applied in a three-way split. Newbonnet was fertilized with 75 lb/acre applied before flooding, 30 lb/acre applied when internodes were 0.5 in. and 30 lb/acre applied 14 days later. Katy was fertilized with 65 lb N/acre before flooding, 35 lb N/acre when internodes were 0.5 in. and 35 lb N/acre 14 days later. Water management was conventional with flooding at early tillering and draining for straighthead control. Benomyl (Benlate) at 0.5 lb/acre was applied twice at midseason to Newbonnet for control of rice diseases, but Katy was not treated with fungicides.

Tillage treatments for rice and soybeans were as follows:

1. Conventional tillage, which included the following operations: one fall disking, one spring disking, one field cultivating, land planing twice and field cultivating again just before drill-seeding crops.
2. Reduced-tillage, which included spring disking once, land planing once and then field cultivating once just before drill-seeding crops.
3. Reduced-tillage, which consisted only of field cultivating three times just before drill-seeding crops.
4. Reduced-tillage, which consisted of field cultivating once just before drill-seeding crops.
5. No-tillage with glyphosate (Roundup) at 0.38 lb/acre applied two weeks before drill-seeding rice. A nonionic surfactant at 0.5% v/v was added to the herbicide.
6. No-tillage with glyphosate at 0.38 lb/acre + V-53482 (experimental herbicide) at 0.08 lb/acre applied two weeks before drill-seeding rice or soybeans in 1989, 1990 and 1991. In 1992, glyphosate at 0.38 lb/acre + quinclorac (Facet) at 0.38 lb/acre was applied two weeks before drill-seeding rice. However, in 1992 a tank mix of glyphosate and metolachlor (Dual) was applied preplant to soybeans. A crop oil concentrate at 1% v/v was added to these herbicide mixtures applied preplant to both crops.

Tillage was performed with standard commercial equipment, including disk-harrows, land levellers and field cultivators. Rice was seeded in 1989 with a commercial heavy-duty grain drill and in 1990, 1991 and 1992 with a commercial no-till grain drill. Soybeans were seeded with the no-till drill all three years. In the two no-till systems, burndown herbicide treatments were applied with a tractor plot sprayer in 20 gallons/acre spray mixture pressurized with CO_2.

In all treatments, weeds were controlled in rice with propanil at 3 or 4 lb/acre applied sequentially early postemergence or with propanil and thiobencarb (Bolero) each at 3 lb/acre, propanil at 4 lb/acre and pendimethalin (Prowl) at 0.75 lb/acre or propanil at 4 lb/acre and bromoxynil (Buctril) at 0.38 lb/acre, all applied postemergence in a tank mixture. Herbicides were applied to rice with a CO_2-pressurized backpack sprayer in 20 gallons/acre of spray mixture. In 1992, molinate (Ordram) granules at 3 lb/acre were applied aerially into the floodwater for control of escaped barnyardgrass.

In all treatments in soybeans, postemergence applications of quizalofop (Assure) or fluazifop-P (Fusilade 2000) controlled grass weeds while broadleaf weeds were controlled with a tank mixture of acifluorfen (Blazer) and bentazon (Basagran) or with Basagran alone.

Data collected in rice included weed control and crop injury ratings (0 = no control or crop injury; 100 = all weeds or crop plants killed), rough rice grain yield (lb/acre), total mill and head rice and bran yield (%), seed weight (g/1000 grains), days from emergence to 50% heading and seed viability (%). Data collected in soybeans included crop injury and weed control ratings and grain yield. A partial economic analysis was conducted to obtain net returns from each plot using standard costs of production inputs and the market value for rice grain. Average values of $0.14, $0.08 and $0.03/lb were used for head rice, broken kernels and bran, respectively. Also, an average deficiency payment of $0.04/lb was an added value. Average value for soybeans was $0.10/lb. All data were analyzed by analysis of variance with significant means separated by Duncans multiple range test (DMRT) ($P = 0.05$).

Stale seedbed experiments

Glyphosate alone or tank mixed with other herbicides was preplant applied (PA) on a stale seedbed to no-till rice on a Crowley silt loam. Soybeans grown in 1990 and 1991 were not tilled after harvesting, and no tillage was performed before seeding rice in 1991 and 1992. All herbicides were applied at 20 gallons/acre with a backpack sprayer. An adjuvant (X-77) at 1% v/v was added to all sprays PA and preemergence (PE). Each experiment contained three replications in a randomized complete block design. 'Tebonnet' or Katy was drill-seeded April or May with a no-till drill (John Deere 750) in 8 rows, 15 by 5 ft with 7.5-in. row spacing. Rice emerged 22 May 1991 and 14 May 1992 and was flooded early June. Nitrogen and water management were by the DD-50 program. Visual rice injury and weed control ratings (0-100 scale) and grain yields were recorded. Analysis of variance was conducted with significant (*P* = 0.05) means separated by DMRT or LSD.

RESULTS AND DISCUSSION

Conservation tillage experiments

In both crops, the no-tillage system with glyphosate applied alone or tank mixed with V-53482 or Facet/Dual burned down winter vegetation to provide a soil environment suitable for rice germination and stand establishment comparable to that in conventional tillage. The winter weed complex included annual bluegrass, horseweed, corn buttercup, little barley and dwarf dandelion. Glyphosate + V-53482 provided quicker and more complete burndown of winter vegetation than did glyphosate alone. For example, in 1990 glyphosate with surfactant burned down 75% of the vegetation by two weeks after application (at time of rice seeding) while glyphosate + V-53482 with crop oil burned down 95% of the vegetation during the same period. Preplant-applied Facet, tank mixed with glyphosate, controlled barnyardgrass residually to eliminate the need for the first propanil treatment.

Conventional herbicide treatments of propanil applied sequentially or tank-mixed with Bolero or Prowl controlled barnyardgrass, broadleaf signalgrass and large crabgrass in rice. Tank mixtures of propanil and Buctril controlled barnyardgrass and summer broadleaf weeds that frequently infested no-till rice. Ducksalad infestations were moderate to high in conventionally tilled plots while they were low in no-till plots. Ducksalad infestations in reduced-tillage systems were intermediate compared to those in conventional- and no-tillage systems.

Excellent rice stands were obtained in all years in all tillage treatments. Grain yields were not significantly different for the various tillage systems and ranged from 5500 to 5900 lb/acre, averaged for four years.

Net returns were significantly higher from reduced- and no-tillage systems than from conventionally tilled rice. Compared to conventional tillage, reduced- and no-tillage systems increased net returns from $62 to $76/acre. Reduced- and no-tillage systems reduced preplant costs for land preparation and herbicides by $13 to $20/acre compared with conventional tillage.

Tillage systems did not influence maturity of rice, total milled or head rice yields, 1000-grain weight or seed viability.

Conventional applications of herbicides (Assure or Fusilade 2000 for grasses and Blazer or Basagran for broadleaves and sedges) controlled weeds in conventionally tilled and no-till soybeans. However, in low-input reduced-tillage plots (treatment 4), weeds, including slender aster, horseweed and fall panicum, were present. Volunteer rice that infested no-till plots in 1991 was not controlled by grass-active herbicides.

For the three years, soybean yields averaged from 30 to 35 bu/acre for the different tillage systems. No-till plots yielded comparably to conventionally tilled plots. Only plots that received the low-input reduced tillage treatment (treatment 4) yielded significantly less than conventionally tilled soybeans (29 vs 35 bu/acre). Weeds present in the treatment at crop maturity probably reduced yields. Net returns were not significantly different for the tillage systems; they ranged from $25 to $51/acre for the reduced- and no-till systems compared with $28/acre for conventionally tilled soybeans. Compared to conventionally tilled soybeans, reduced- and no-till systems lowered the total costs of production by $23 to $31/acre.

Stale seedbed experiments

Preplant applied (PA) or preemerge applied (PE) glyphosate alone or tank mixed with Bolero, Prowl, Facet, Buctril, triclopyr (Grandstand), 2,4-D or 2,4-DB burned down winter weeds and permitted seeding and stand establishment of no-till rice. Only PE glyphosate + Grandstand injured rice. PA glyphosate + Facet controlled summer grasses residually for four but not for seven weeks. PE glyphosate tank mixed with Bolero, Prowl, Facet or Bolero + MON 13211 (experimental herbicide) controlled winter and summer weeds. MON 13211 injured rice moderately during early season, but rice recovered by midseason. Following PA glyphosate, herbicides that controlled summer weeds included PE Facet alone or tank mixed with Bolero or Prowl, or postemergence propanil tank mixed with Facet, Bolero, Prowl or Buctril. These treatments did not injure rice, and grain yields were improved in plots with good weed control.

SIGNIFICANCE OF FINDINGS

Reducing the number of tillage operations or no-tillage using glyphosate resulted in lower rice production costs, adequate weed control, comparable grain yields and higher net returns when compared with conventional tillage. In soybeans, conventional-, reduced- and no-tillage systems provided comparable stands, weed control, yields and net returns. Effective weed control and less land preparation and other production costs should make conservation tillage in Arkansas rice and soybeans feasible and perhaps more profitable than conventional tillage. Available herbicide programs control weeds effectively in no-till rice. However, herbicide programs may be slightly different for no-till than for conventional-till rice. Herbicide programs are required both to burn down winter vegetation to permit seeding and stand establishment of no-till rice and to control summer weeds that infest rice after seeding.

MANAGEMENT STRATEGIES FOR RICE PESTS: WEED CONTROL IN RICE (GRASS, RED RICE, BROADLEAF AND SEDGE CONTROL)

R.J. Smith, Jr. and C.B. Guy

ABSTRACT

Experiments were conducted to develop improved weed control technology for grass, broadleaf, sedge, aquatic and red rice weed complexes in rice. Existing herbicide programs controlled weeds effectively. New treatments such as Facet, Whip 360, Prowl and various new combinations of treatments of existing herbicides controlled grass weeds effectively with adequate selectivity to rice. Dry or liquid flowable formulations of propanil controlled grasses as effectively as emulsifiable concentrates. New treatments such as Londax tank mixed with propanil or Blazer controlled sedges or broadleaf weeds selectively in rice. The use of Select at ultralow spray volumes of 0.5 gpa with air-assist nozzles controlled red rice in soybeans at 1/2X rates compared with 1X rates when applied at spray volumes of 20 gpa with a conventional boom nozzle applicator. Rice germplasm lines with allelopathic properties suppressed growth of aquatic weeds, including ducksalad, redstem and waterhyssop comparably to standard herbicide treatments, including Londax, propanil or Basagran. Allelopathic rice suppressed aquatic weeds in dry- and water-seeded rice planted broadcast and in rows. Collego applied in an invert emulsion carrier controlled northern jointvetch and hemp sesbania and suppressed Indian jointvetch. Season-long competition of yellow nutsedge reduced grain yields of rice even at densities below 1 plant/ft^2.

INTRODUCTION

Weeds infesting rice cause significant yield reductions, resulting in monetary losses to rice growers. Barnyardgrass (BYG) and bearded sprangletop (BST), the two major grasses infesting rice, can reduce rice yields by as much as 80%. Red rice alone causes an estimated loss of $15 to $20 million annually to the rice crop in Arkansas. Broadleaf, sedge and aquatic weeds and red rice can reduce rice yields by 20% to 90%. Control programs for these weeds are available, but continued studies are conducted every cropping season to 1) improve existing technology, 2) adjust to changes in industry or regulation policies that determine commercial availability of herbicides and 3) 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. Studies include: 1) efficacy comparisons of standard and new herbicide treatments in various rates, times, combinations and methods of application; 2) integration of cultural practices with herbicides; 3) development of non-chemical control methods such as the search for rice germplasm lines with potential allelopathic activity against weeds; 4) development of microbial herbicides; and 5) weed competition.

PROCEDURES

Herbicide treatments were compared in replicated field experiments conducted in different soils and environments for control of weeds in rice and rotated crops. Standard and experimental 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, ≤30% injury to rice from which rice recovered in a reasonable period of time, with rice producing grain yields comparable to those of rice treated with standard herbicides. Six rice lines possessing potential allelopathic properties plus 'Rexmont' were compared with bensulfuron (Londax) for control of aquatic weeds in rice.

RESULTS AND DISCUSSION

Herbicide Programs for Grasses

Continued efficacy comparison studies of standard and experimental herbicides at different soil and environmental conditions showed that standard herbicides including Prowl, Bolero, propanil, Whip and Arrosolo provided adequate control of BYG and BST, the two major weeds infesting rice. These treatments should be applied to grasses not larger than the four-leaf stage. Prowl alone at 1 lb/acre applied delayed preemergence controlled BYG and BST effectively, and grain yields from rice so treated were comparable to those from rice treated with the best-performing standards, such as propanil + Bolero. Prowl alone is a very economical treatment for grass control in rice.

Propanil Formulations

A study on comparison of efficacy of dry flowable (DF) and emulsifiable concentrate (EC) formulations of propanil was repeated this year. Propanil in either formulation tank-mixed with Bolero or Prowl controlled two-leaf BYG and BST with consequent high rice yields. Although control of BYG and BST when propanil was applied alone in either formulation or when tank-mixed with Ordram was inferior to control with Bolero or Prowl tank mixtures, rice yields were high. Propanil in either formulation failed to control the two grasses when applied at the four-leaf grass stage.

Weed Control with Facet

Facet was evaluated again this year. At 0.38 to 0.5 lb/acre, it provided excellent control of BYG when applied by itself delayed preemergence to two-leaf grass or when tank-mixed with Bolero, Prowl, Arrosolo or propanil. It still failed to control BST when applied alone but provided excellent control of this weed when tank-mixed or applied sequentially with Arrosolo, Bolero, Prowl or propanil. Facet applied alone or tank mixed with propanil or Whip showed promise as salvage treatments for controlling large, tillering BYG plants selectively in rice. Facet tank mixed with propanil controlled tillering to jointing BYG that was up to 13-in. tall.

Red Rice Control

Clethodim (Select) was applied with conventional boom nozzles (CBN) in a spray volume of 20 gpa or air-assist nozzles (AAN) at 0.5 gpa for control of red rice in soybeans. The AAN treatments were applied with water, water + AgriDex or oil (Orchex 796F) as carriers. Select applied with CBN at the 1X rate or with AAN at 1/2X or 1X rates in all carriers controlled red rice comparably in soybeans. These treatments performed better than 1/2X rates applied conventionally. Generally, applications with CBN at the 1/2X rate or with the AAN at 1/4X or lower rates had reduced control.

In a water-seeded culture, rice seeded with pregerminated seed was injured less than rice seeded with dry seed by treatments of preplant incorporated (PPI) Ordram or preplant surface-applied Bolero either alone or combined. Ordram at 2 lb/acre PPI followed by Bolero at 2 lb/acre preplant injured rice less than higher sequential rates of 3/3 or 4/4 lb/acre. Ordram PPI or Bolero preplant either alone or combined controlled about 70% of the red rice.

Yellow Nutsedge and Broadleaf Weed Control

Londax + propanil applied before flooding controlled 3- to 6-in. yellow nutsedge plants at 0.3 to 0.6 oz/acre. For broadleaf weed control, Londax controlled northern jointvetch, hemp sesbania, eclipta and rice flatsedge at 0.45 to 1.0 oz/acre and palmleaf morningglory at 0.6 to 1.0 oz/acre. Tank mixes of Londax at 0.45 oz/acre and Blazer at 0.125 lb/acre controlled hemp sesbania and northern jointvetch.

Continuing evaluation studies with triclopyr (Grandstand) showed that tank-mixing it with propanil provided adequate control of broadleaf weeds when applied before or after flooding at 0.25 to 0.38 lb/acre of Grandstand. When applied alone, this rate should be 0.38 lb/acre.

For broadleaf weed control, propanil, Londax or Grandstand applied alone or propanil tank-mixed with either Londax or Buctril during early season controlled 12-in. northern jointvetch and hemp sesbania. When applied at midseason, propanil or Grandstand alone or propanil tank-mixed with Buctril controlled 20- to 24-in. hemp sesbania and northern jointvetch. The propanil tank mixtures were more effective than the single treatments, particularly when applied to larger weeds. Propanil, tank-mixed with Buctril, Grandstand, Basagran or Blazer, provided excellent control of broadleaf weeds.

Microbial Herbicide Studies

Collego and Coletru were studied for broadleaf weed control in rice. When Collego alone or tank-mixed with Coletru was applied in invert emulsions, northern jointvetch and hemp sesbania were controlled and Indian jointvetch was suppressed. However, Coletru applied as an invert emulsion controlled only hemp sesbania. Likewise, Collego applied in a carrier of only water controlled only northern jointvetch. Applying Collego in an invert emulsion carrier apparently broadens its activity to control hemp sesbania in addition to northern jointvetch.

Allelopathy Studies

Efficacy of allelopathic rice germplasm and bensulfuron (Londax) for control of aquatic weeds in rice were compared in a field experiment. Six allelopathic rice lines and Rexmont, a standard cultivar without allelopathic activity, were compared. Aquatic weeds, including ducksalad, purple ammannia and disc waterhyssop, germinated after the rice was flooded. Because significant differences in aquatic weed control did not occur between handweeding and herbicides (for control of unwanted weeds), the herbicides propanil + Basagran followed by Whip did not control aquatics residually. In the handweeding and herbicide treatments, all rice lines (PI 338065, 338123, 312777, 338046, 345920 and 373026) reduced dry weight of aquatic weeds from 93 to 99% with a control rating of 77 to 95% in 1991 and 86 to 98% in 1992, compared with Rexmont. Aquatic weeds in Rexmont produced 62 g/ft^2 of dry biomass. Londax at 0.1 lb/acre controlled all aquatic weeds in all rice lines.

A second field experiment compared the efficacy of allelopathic rice germplasm for control of aquatic weeds in water-seeded rice in 1992. The allelopathic activity of rice germplasm in water-seeded rice was compared to that of dry-seeded rice of earlier experiments. With water seeding, aquatic weeds, including ducksalad, purple ammannia and disc waterhyssop, germinated when rice germinated. Aquatic weeds produced 32 g/ft^2 in water-seeded Rexmont and produced 15 g/ft^2 in dry-seeded Rexmont. PI 256340 reduced dry weight of aquatic weeds 72% compared with Rexmont in dry- and water-seeded cultures. Visual ratings indicated that PI 256340 reduced growth of aquatic weeds 43 and 86% in water- and dry-seeded rice, respectively. Nine rice lines (PI 229272, 297816, 338065, 389680, 277414, 294400, 303683, 312777 and 338711) reduced dry weight of aquatic weeds 60 to 67% compared with Rexmont in water-seeded rice. These rice lines reduced weed dry weight 62 to 90% in the dry-seeded culture. The non-statistical comparison indicated that, although most allelopathic rice lines in water-seeded culture showed less activity than in dry-seeded culture, they reduced weed biomass in a water-seeded culture and may have potential for controlling aquatic weeds in both dry- and water-seeded rice.

A third field experiment compared efficacy of allelopathic rice in dry- and water-seeded rice cultures in row and broadcast patterns. Five allelopathic rice lines (PI 312777, 338046, 338065, 345920 and 373026) and Rexmont were compared. In dry-seeded rice unwanted weeds were controlled by propanil, Basagran and Whip, but in water-seeded rice they were controlled by handweeding. Aquatic weeds, including ducksalad, purple ammannia and disc waterhyssop, produced 140 g/m^2 dry weight in water-seeded Rexmont but produced only 36 g/m^2 in dry-seeded Rexmont, averaged for row and broadcast seeding methods. In dry-seeded rice, the five allelopathic rice lines reduced aquatic weed biomass 87 to 88% compared with Rexmont, but in water-seeded rice they reduced weed biomass by 60 to 73%. PI 312777 reduced weed biomass 88 and 73% in dry- and water-seeded cultures, respectively, which are not significantly different. Conversely, PI 338046 lowered weed biomass 87 and 60% in dry- and water-seeded cultures, respectively, which are significantly different; however, these are significantly different from the control (Rexmont). Rice lines reduced weed biomass 82 and 74% in broadcast and row-seeding methods, respectively, which are significantly different. This indicates that seeding allelopathic rice in a broadcast pattern may improve aquatic weed control.

Yellow Nutsedge Competition with Rice

Yellow nutsedge at densities of 0.5, 2 and 4 plants/ft^2 reduced grain yields of 'Lemont' rice 15 to 33% with season-long interference but did not affect grain yields at interference durations of 21, 42 or 63 days. With season-long interference, there was no significant difference for grain yield among yellow nutsedge densities. Yellow nutsedge canopied above rice by 42 days and continued to grow until 63 days when it was near its maximum height of 40 in., which was 12 in. taller than the rice. Shading probably was a major contributor to the yield losses. Also, yellow nutsedge obtained its maximum biomass by 63 days and maintained that biomass until rice maturity. Therefore, season-long interference of yellow nutsedge at a density as low as 0.5 plants/ft^2 reduced grain yield of a semidwarf cultivar. Hence, control of yellow nutsedge by midseason should prevent yield losses.

SIGNIFICANCE OF FINDINGS

Existing standard herbicide treatments of propanil, Prowl, Bolero, Whip and Arrosolo continued to provide good control of grasses. New herbicide treatments have also been studied, and their effective rates and times of application have been identified. For grass control, these included Facet at 0.38 lb/acre (silt and sandy loam soils) to 0.5 lb/acre (clay and clay loam soils) applied delayed preemergence or at the two-leaf stage of rice; Whip 360 at 0.06 lb/acre applied preflood to four-leaf rice; and Prowl at 1 lb/acre applied delayed preemergence. Inability of Facet to control BST by itself is remedied by tank-mixing it with standard grass herbicides. These new treatments expand growers' options as well as prevent continuous use of a single treatment that could lead to a buildup of weed tolerance.

Dry or liquid flowable formulations of propanil were shown to be as effective as emulsifiable concentrate formulations, particularly when tank-mixed with Bolero or Prowl. The time of application for the flowables may be more critical than for the emulsifiable concentrates. Adjuvants added to the flowables or tank-mixing with Facet may increase their activity against weeds.

New application methods for applying Select to control red rice in a rotated crop (soybean) were tried. Among these was the use of ultralow spray volumes of 0.5 gpa with air-assist nozzles that controlled red rice at 1/2X rates compared with 1X rates when applied at conventional spray volumes of 20 gpa with a conventional boom nozzle applicator.

Ordram applied preplant incorporated or Bolero preplant surface applied controlled red rice selectively in water-seeded rice. However, seedlings from pregerminated seed were injured less than those from dry seed.

The existing standard herbicides Grandstand, Buctril, Basagran, Blazer and Londax continued to provide good control of broadleaf weeds and sedges. New herbicide treatments have also been studied, and their effective rates and times of application have been identified. For broadleaf weed control propanil (3-4 lb/acre), Londax (0.3-0.6 oz/acre) or Grandstand (0.25-0.38 lb/acre) or propanil tank-mixed with Londax (0.45-0.6 oz/acre), Buctril (0.38 lb/acre), Grandstand (0.25 lb/acre), Basagran (0.5 lb/acre) or Blazer (0.125 lb/acre) provided excellent control of northern jointvetch, hemp sesbania, eclipta, morningglories and other broadleaf weeds. Tank mixtures or higher rates or both were needed as weed size increased. Also tank mixtures of Londax (0.45 oz/acre) and Blazer (0.125 lb/acre) controlled hemp sesbania and northern jointvetch. For yellow nutsedge control, 0.3-0.6 oz/acre of Londax tank-mixed with propanil was effective. These new treatments expand growers' options as well as prevent continuous use of a single treatment that could lead to a buildup of weed tolerance.

Collego applied in an invert emulsion carrier controlled northern jointvetch and hemp sesbania and suppressed Indian jointvetch. Applying Collego in an invert emulsion broadens its activity on weeds and enhances benefits of microbial herbicides.

Rice germplasm lines with allelopathic properties suppressed growth of aquatic weeds, including ducksalad, redstem and waterhyssop, comparably to standard herbicide treatments, including Londax, propanil and Basagran. Allelopathic rice suppressed aquatic weeds in dry- and water-seeded rice planted broadcast or in rows. Biological weed control with allelopathic rice may reduce dependence on herbicides.

Yellow nutsedge at 0.5 to 4 plants/ft^2 reduced grain yields of rice with season-long competition. Hence, control of yellow nutsedge by midseason should prevent yield losses of rice.

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

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ABSTRACT

Field studies were conducted at two locations to evaluate the sensitivity of several of the newer rice cultivars to the following rice herbicides: Grandstand, Ordram/Arrosolo, Bolero, Whip 360, Facet and Prowl. Studies were also conducted to evaluate injury to cotton treated with insecticides to drift rates of rice herbicides. None of the rice cultivars tested showed sensitivity to Grandstand applications at recommended rates and applied between the four-leaf and panicle differentiation development stages. Sensitivity to Whip 360 was in the following order: 'Bengal' > 'Mars' > 'Orion'. None of the cultivars tested showed sensitivity to Facet, Bolero or Prowl applied delayed preemergence on either a silt loam or a silty clay soil when the herbicides were applied at recommended rates. The new cultivar, 'Adair', showed sensitivity to Ordram. Londax application to cotton resulted in slight discoloration and stunting; however, the injury was quickly outgrown, and yields were not affected. Cotton treated with Temik showed injury from a preemergence application of propanil. Cotton treated with Facet before bed knockdown showed less injury than cotton treated immediately after planting.

INTRODUCTION

In recent years several rice herbicides have been shown to be injurious to certain rice cultivars. For example, 'L201' is sensitive to molinate (Ordram/Arrosolo) and thiobencarb (Bolero). L201 was subsequently used as a parent in several newer cultivars such as 'Millie', and this sensitivity was inherited. Another example of sensitivity is that of 'Mars' to fenoxaprop (Whip). Unfortunately, in these instances the sensitivity to the herbicides was not known until after the release of the new cultivar. Therefore, with the wide array of new herbicides and numerous new cultivars being released, it is imperative to have a screening program to evaluate for herbicide sensitivity prior to release of a cultivar.

One problem faced by rice producers in eastern Arkansas is the close proximity of rice herbicide-sensitive crops, especially cotton. Several rice herbicides have been shown to damage crops at drift rates. In most instances, rice herbicides are applied by airplane, and the potential exists for drift of the herbicide to a sensitive crop. Therefore, continued research is need to indicate alternatives in order to avoid such drift problems.

The objectives of this research are 1) to screen promising new or recently released rice cultivars for sensitivity to existing and potential new herbicides and 2) to evaluate potential drift problems of rice herbicides to cotton.

PROCEDURES

Five field tests were conducted at the University of Arkansas Southeast Branch Experiment Station (SEBS), Rohwer, Arkansas, and one test at the University of Arkansas Rice Research and Extension Center (RREC), Stuttgart, Arkansas, to evaluate the response of rice cultivars to selected herbicides. 'Katy', 'Lacassine', 'Lemont' and 'Newbonnet' were evaluated for tolerance to triclopyr (Grandstand). Bengal, Mars and Orion were evaluated for tolerance to fenoxaprop (Whip 360). 'Alan', Millie and 'Tebonnet' were evaluated for tolerance to Ordram/Arrosolo on a silt loam versus a silty clay. Alan, Bengal, Katy, Lacassine, Lemont, Millie, Newbonnet, Orion and 'Cypress' were evaluated for tolerance to quinclorac (Facet), Bolero and pendimethalin (Prowl) applied delayed preemergence. Adair was evaluated for tolerance to Ordram/Molinate. The injury potential of propanil applied at drift rates to cotton previously treated with aldicarb (Temik) and disulfoton (Disyston) was also evaluated. Cotton injury response to bensulfuron (Londax) and to Facet applied before bed knockdown and preemergence was also evaluated. Herbicide rates and timing were based on previous studies and covered an array of rates and timings.

RESULTS AND DISCUSSION

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

This test was designed to evaluate the response of four rice cultivars that may be sensitive to Grandstand based on previous tests. Figure 1 represents the interaction means for yield as affected by cultivar and application timing averaged across rates. Only Katy had reduced yields compared to its untreated check when Grandstand was applied from the five-leaf to panicle differentiation development stages. It is important to note that these data are both 0.375 and 0.75 lb active ingredient (ai)/acre combined, one- and two-fold rates. At panicle differentiation, Grandstand reduced the yield of Katy 569 lb with an LSD of 524 lb. All cultivars except Newbonnet had reduced yields when Grandstand was applied seven days past panicle differentiation, and all four cultivars had reduced yields when Grandstand was applied at booting. These data indicate that Grandstand is not likely to reduce rice yield when applied from five-leaf to panicle differentiation. We have evaluated rice cultivar response to Grandstand for four years, and no cultivars have been found to be sensitive to application made prior to panical differentiation. Cultivars tested include 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. Visual injury observations for sensitivity to Whip 360 indicated that Bengal was more sensitive than Mars and that Mars was more sensitive than Orion (data not shown). Figure 2 shows the yield of these cultivars when Whip 360 was applied at 0.067 and 0.134 lb ai/acre at selected growth stages. There was not a good correlation between visual injury and yield with several of the treatments. This may have been due to the rice plant's ability to compensate for stand loss and injury by producing more tillers and seed per panicle. Only Bengal had reduced yield when Whip 360 was applied at 0.67 lb ai/acre to five-leaf rice. All three cultivars had reduced yields at 0.134 lb ai/acre applied at this growth stage. These data are similar to last year's test in which Mars was more sensitive to Whip 360 than was Orion.

Response of Alan, Millie and Tebonnet to Arrosolo and Ordram on a silty clay and silt loam. Previous tests have indicated that molinate-sensitive rice cultivars may respond differently on silt loam versus clay soils. In our test, only Millie had reduced yield on the silty clay site with Ordram applied at panicle initiation (data not shown).

This was opposite of what was expected. These data are inconclusive, and the test will be repeated so that we may further refine the cultivar restrictions when using Arrosolo and Ordram.

Response of selected rice cultivars to Facet, Bolero and Prowl applied delayed preemergence. There were no negative responses observed with Facet at 0.375 and 0.75 lb ai/acre, Bolero at 4.0 lb ai/acre, Prowl at 1.0 lb ai/acre, Facet + Bolero at 0.375 + 3.0 lb ai/acre or Facet + Prowl at 0.375 + 1.0 lb ai/acre on a silt loam or silty clay, applied delayed preemergence to Alan, Bengal, Cypress, Katy, Lacassine, Lemont, Millie, Newbonnet or Orion (data not shown). Data collected included visual injury, stand counts and yield.

Response of Adair to Arrosolo and Ordram. This preliminary test indicates that Adair is sensitive to certain treatments with molinate. Table 1 shows injury, stand loss, maturity delay and yield reduction from various applications of Arrosolo and Ordram to Adair. Yields were not reduced with some applications that showed visual injury or stand loss. This test will be repeated and will include comparisons with Millie, Alan and Tebonnet.

Effect of in-furrow insecticide on cotton injury from preemergence and postemergence applications of propanil (Stam). There was a significant three-way interaction among insecticides, method of propanil application and propanil rate. At 14 days after treatment, propanil applied preemergence caused injury at only 4.0 lb ai/acre (data not shown). Injury was not observed until just prior to the 14-day rating date soon after 0.72 in. of rain. Temik-treated cotton displayed more injury than cotton treated with Di-syston, 73% versus 48%, respectively. Differences were also noted in plant height, maturity and yield. Figure 3 shows cotton yield as affected by in-furrow insecticide, propanil application timing and propanil rate. At 14 days after the postemergence treatment, propanil caused injury to cotton with no effect from the insecticide treatments. This response was also noted in plant height and yield.

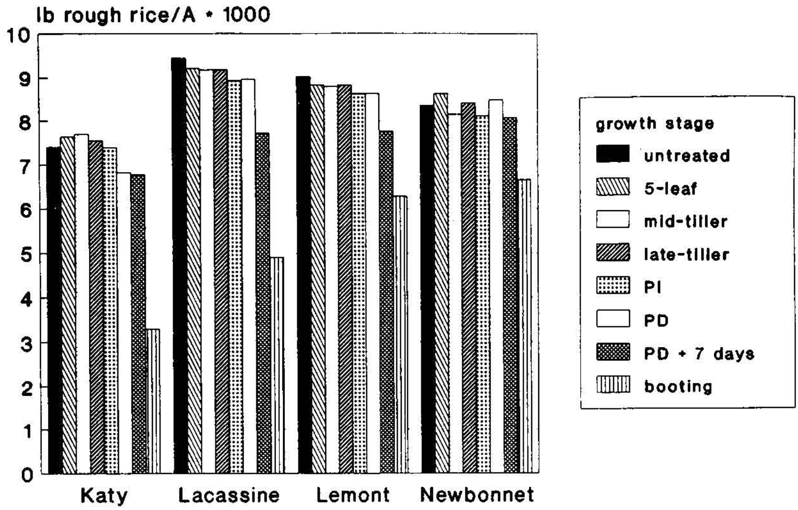
Effect of Londax rate on cotton injury and yield. Figure 4 shows cotton yield as affected by Londax rate averaged across application timing. Londax application to cotton resulted in slight discoloration and stunting (data not shown). Injury was quickly outgrown, and cotton yield was reduced only at the 0.60-oz ai/acre rate. These data are similar to last year's results in which cotton was relatively tolerant to Londax. Weed control studies at SEBS indicate that Londax may have potential for replacing phenoxy herbicides for the control of some broadleaf weeds in rice.

Effect of Facet application timing on cotton injury and yield. Previous tests have indicated that Facet will injure cotton at drift rates. This test was designed to determine if cotton injury may be avoided from Facet application prior to planting by removing treated soil at bed knockdown. Figure 5 shows cotton yield as affected by Facet application timing and rate. Cotton injury was not observed when Facet was applied before bed knockdown, regardless of rate (data not shown). Rainfall was not received between application and bed knockdown. This may have affected the results. Only the preemergence application resulted in visual injury with Facet at 0.25 and 0.5 lb ai/acre. Yield was reduced by Facet only at 0.5 lb ai/acre applied preemergence.

Table 1. Effect of Arrosolo and Ordram application rate and timing on visual injury, stand, days to 50% heading and yield of 'Adair', University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas, 1992.

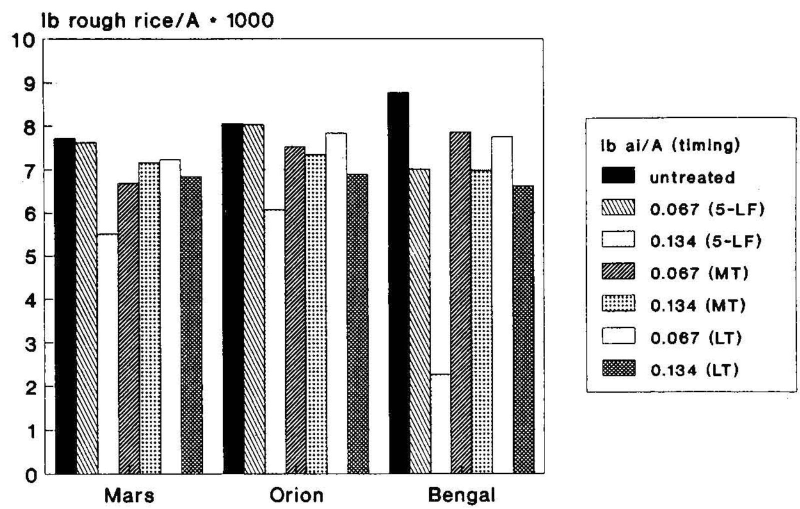
Herbicide	Rate	Timing	Injury 4 WAT[z]	Stand Prior to Flooding	Days to 50% Heading	Rough Rice Yield
	lb ai/acre		%	#/ft^2		lb/acre
Stam fb[y] Stam	4 fb 4	2 lf[x] fb 5 lf	4	28 a[s]	85 bc	6123 a
Ordram fb Stam	4 fb 4	PPI[w] fb 5 lf	90	2 c	88 a	5408 a
Bolero	4	DPRE[v]	6	22 b	85 bc	5754 a
Arrosolo + Bolero	4.5 + 3	2 lf	6	27 ab	86 b	6166 a
Stam + Bolero	3 + 3	2 lf	1	24 ab	85 bc	5795 a
Arrosolo fb Arrosolo	6 fb 6	2 lf fb 5 lf	2	22 b	86 bc	6023 a
Arrosolo fb Ordram	6 fb 5	2 lf fb MT[u]	6	22 b	85 c	5785 a
Arrosolo fb Ordram	6 fb 5	2 lf fb PI[t]	76	24 ab	88 a	2849 b
Stam fb Ordram	4 fb 5	2 lf fb MT	8	26 ab	86 bc	6026 a
Stam fb Ordram	4 fb 5	2 lf fb PI	74	23 ab	88 a	2812 b

[z]WAT = weeks after treatment, last application
[y]fb = followed by
[x]lf = leaf
[w]PPI = preplant incorporated
[v]DPRE = delayed preemergence
[u]MT = mid-tiller
[t]PI = panicle initiation
[s]Means within a column followed by the same letter are not significantly different, $P = 0.05$.



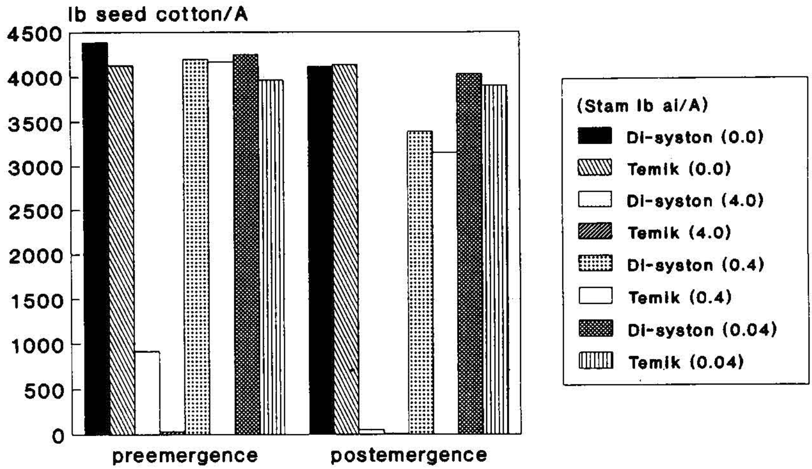
PI = panicle initiation
PD = panicle differentiation
LSD 0.05 = 524

Fig. 1. Effect of Grandstand application timing on yield of 'Katy', 'Lacassine', 'Lemont' and 'Newbonnet', University of Arkansas Southeast Branch Experiment Station, Rohwer, Arkansas, 1992 (0.38 and 0.75 lb ai/acre rates combined).



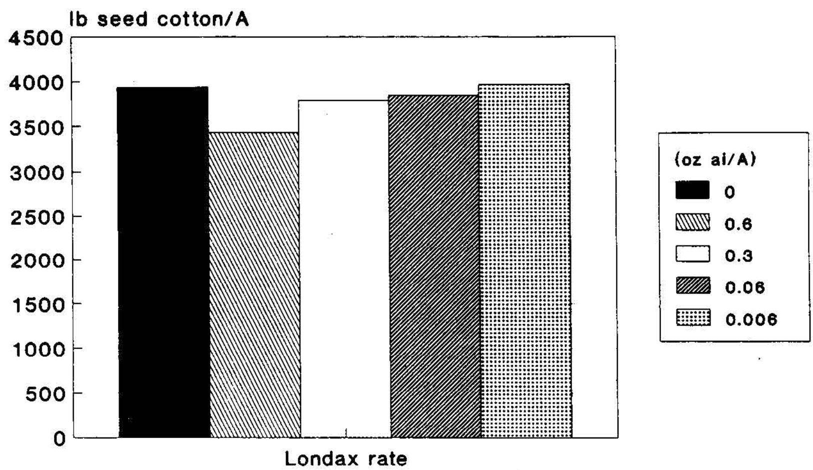
LF = leaf, MT = mid-tiller,
LT = late-tiller.
LSD 0.05 = 998

Fig. 2. Effect of Whip 360 application rate and timing on yield of 'Mars', 'Orion' and 'Bengal', University of Arkansas Southeast Branch Experiment Station, Rohwer, Arkansas, 1992.



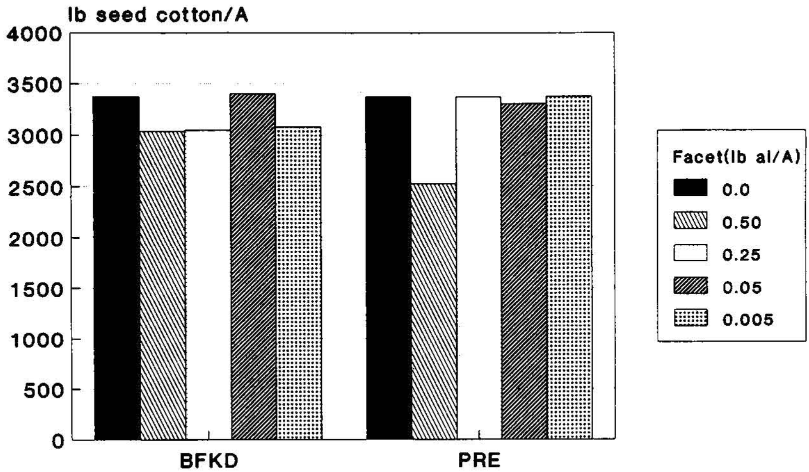
Di-syston 0.75 lb ai/A
Temik 0.5 lb ai/A
LSD 0.05 = 372

Fig. 3. Effect of in-furrow insecticide and Stam application timing and rate on cotton yield, Southeast Branch Experiment Station, Rohwer, Arkansas, 1992.



Cotyledon and early fruiting application combined.
LSD 0.05 = 265

Fig. 4. Effect of Londax rate on cotton yield, University of Arkansas Southeast Branch Experiment Station, Rohwer, Arkansas, 1992.



BFKD = before bed knock-down
PRE = preemergence
LSD 0.05 = 387

Fig. 5. Effect of Facet application timing and rate on cotton yield, University of Arkansas Southeast Branch Experiment Station, Rohwer, Arkansas, 1992.

ENVIRONMENTAL IMPLICATIONS OF PESTICIDES IN RICE PRODUCTION

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ABSTRACT

Studies were conducted at Stuttgart and Rohwer, Arkansas, in 1992 to determine the persistence of Bolero, 2,4-D and Grandstand in 1) paddy-rice soil and water, 2) dryland-rice soil and 3) clean fallowed soil and to determine the persistence of Furadan and Ordram in paddy-rice soil and water. Bolero applied as a delayed preemergence treatment dissipated to levels at or below detection levels in soil by 28 days after application (DAA) in all three cultural systems at both locations. Trace levels of Bolero were detected in water samples at Stuttgart at 0 and 1 day after flood was put on the field. Grandstand and 2,4-D dissipated in paddy water to levels at or below detectability by 28 DAA, although they were slightly more persistent in dryland rice soil and on clean fallowed soil. Since Furadan and Ordram were applied in the granular form into the floodwater, the maximum concentrations in water occurred at 1 DAA. Both chemicals dissipated rapidly in water, although Ordram was still detectable at 49 DAA in paddy water. Furadan dissipated from paddy soil by 35 DAA at Stuttgart and by 21 DAA at Rohwer. Ordram was slightly more persistent than Furadan in paddy soil. Approximately 5 and 35% of the amount of Ordram present at time '0' remained in paddy soil at 49 DAA at Stuttgart and Rohwer, respectively.

INTRODUCTION

Arkansas rice growers rely on man-made pesticides and fertilizers to achieve optimum yields. 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 and to determine the likelihood of such problems occurring in the near future.

The overall goal of this research was 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 clean fallowed ground and 2) to evaluate the persistence of Furadan and Ordram in paddy-rice soil and water.

PROCEDURES

Small plot experiments were established at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas, on a Crowley silt loam soil and at the Southeast Branch Experiment Station (SEBES), Rohwer, Arkansas, on a Perry silty clay in 1992. Standard cultural practices for rice production were followed. The paddy rice plots were approximately 15 by 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 clean fallowed area was maintained with periodic applications of Round-up and received no supplemental irrigation. The experimental design was a randomized complete block with two replications of each cultural system at each location. Bolero (4 lb/acre) was applied in 10 GPA carrier volume with a CO_2 backpack sprayer as a delayed preemergence (PRE) treatment. 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 in 10 GPA carrier volume at the panicle initiation (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 days 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. This procedure is used to confirm the presence of the analytes.

RESULTS AND DISCUSSION

The lower limits of detectability for each pesticide are shown in Table 1. Trace levels of Bolero were detected in the flood water on the silt loam soil at RREC at 0 and 1 day after the field was flooded (approximately 25 DAA). No Bolero was detected in flood water on the silty clay soil at SEBES. Bolero persistence in soil at the 0- to 3-in. depth was similar at both locations with estimated half-lives of approximately 5 days in paddy-rice and dryland-rice cultures (Fig. 1). Bolero was somewhat more persistent on clean fallowed soil with half-lives of 6 and 10 days on the silt loam and silty clay soils, respectively, but it was not detected in significant quantities below 6 in. from the surface. Dissipation of 2,4-D and Grandstand was rapid in flood water, dryland rice soil and on clean fallowed ground with half-lives of 10 days or less (Fig. 2). Trace levels of 2,4-D were detected in soil at the 3- to 6-in. depth at both locations in all cultural systems; however, more frequent occurrences were noted at RREC on the silt loam soil (data not shown). Grandstand was slightly more persistent than 2,4-D. Trace levels were detected at 35 DAA in water and soil of all three cultural systems. Trace levels of Grandstand were detected in soil at the 3- to 6-in. depths at both locations; however, Grandstand was more commonly detected at SEBES than at RREC (data not shown). This phenomenon is the opposite of that noted above for 2,4-D. Only trace levels of these chemicals were detected in the soil of paddy-rice culture, which was probably due to the high water solubilities and low soil adsorption characteristics of these herbicides.

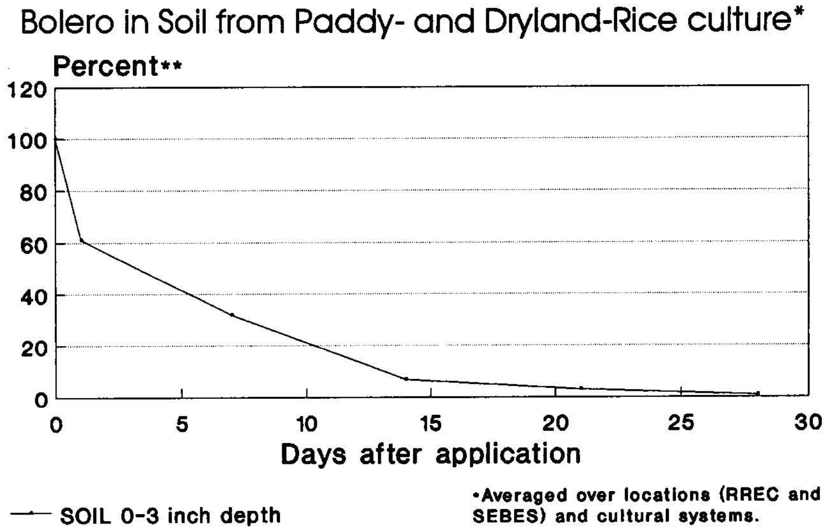
Since Furadan and Ordram were applied as granular treatments, the maximum concentrations in paddy water occurred at 1 DAA, after the granules had dissolved (Fig. 3 and 4). A five- to ten-fold increase in the concentration of these chemicals in paddy rice occurred from 0 to 1 DAA. Ordram dissipated from paddy water rapidly after 1 DAA but was still detected at trace levels at 49 DAA (Fig. 4). Furadan was not detected in paddy water after 21 DAA. Ordram dissipation from soil was rapid from 0 to 7 DAA, probably resulting from dissolution of the granules into paddy water. Ordram concentrations remaining in the silt loam soil continued to decline; however, the concentrations remaining in the silty clay soil remained fairly constant until 49 DAA, indicating that adsorption of Ordram to the silty clay soil prohibited dissipation. Furadan was continually dissipated from paddy soil, indicating that it is not as strongly adsorbed to soil as is Ordram.

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 financial support of the Rice Research and Promotion Board is also appreciated.

Table 1. Lower limits of detectability for the pesticides evaluated.

	Lower Limit of Detectability	
Pesticide	Soil	Water
	(ppm)	(ppb)
Bolero	0.01	5
Furadan	0.02	0.1
Grandstand	0.01	0.4
Ordram	0.02	3
2,4-D	0.01	0.3



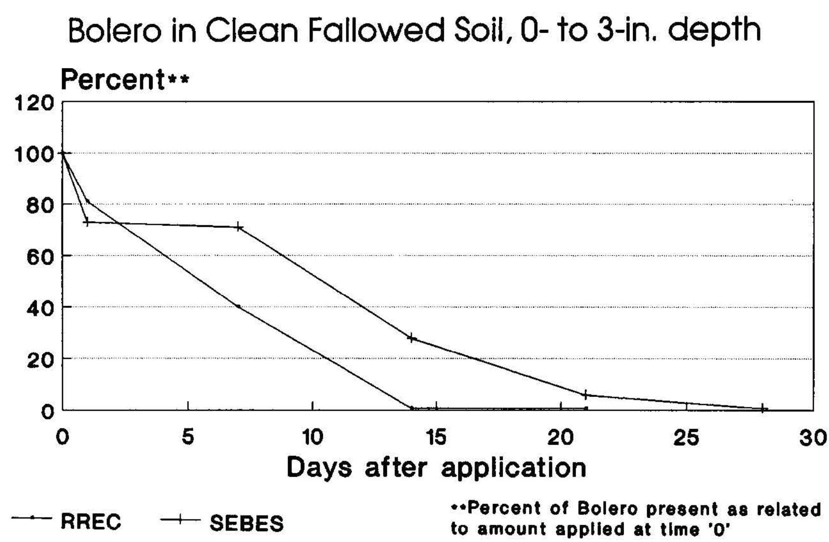
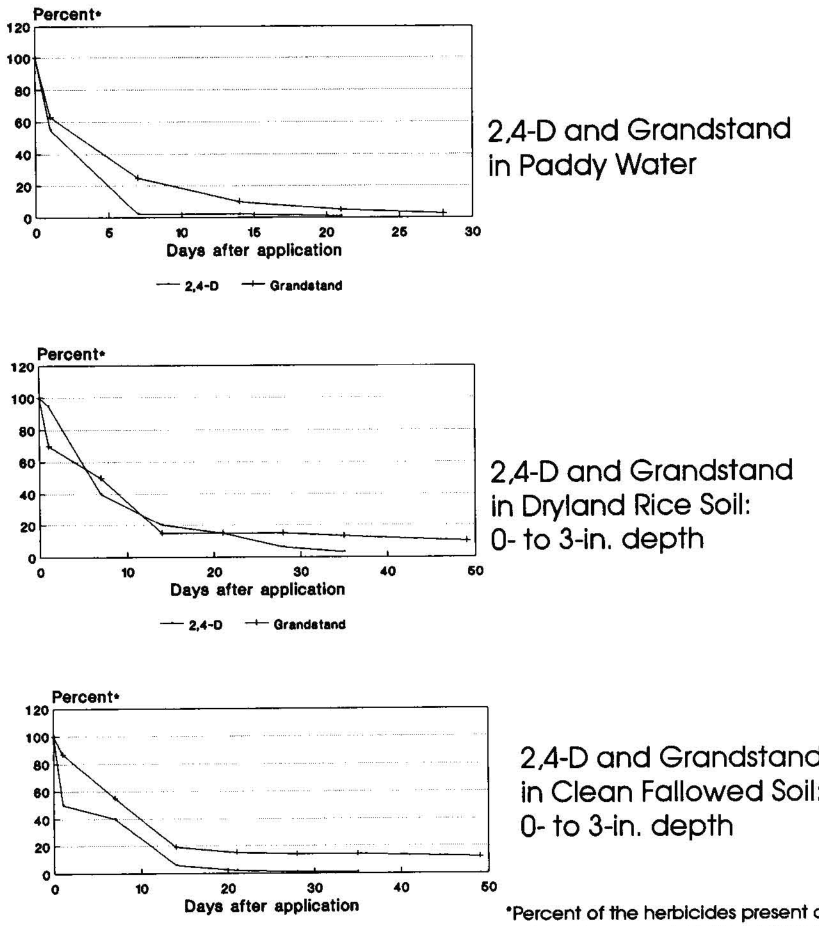
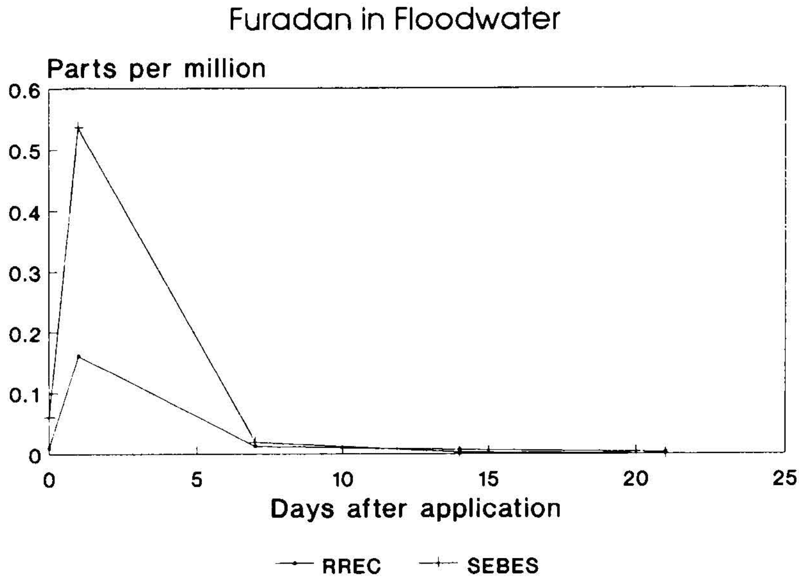


Fig. 1. Bolero persistence in three rice cultural systems, 1992.



*Percent of the herbicides present as related to amount applied at time '0'

Fig. 2. 2,4-D and Grandstand persistence in paddy water, dryland-rice soil and clean fallowed soil, averaged over location, 1992.



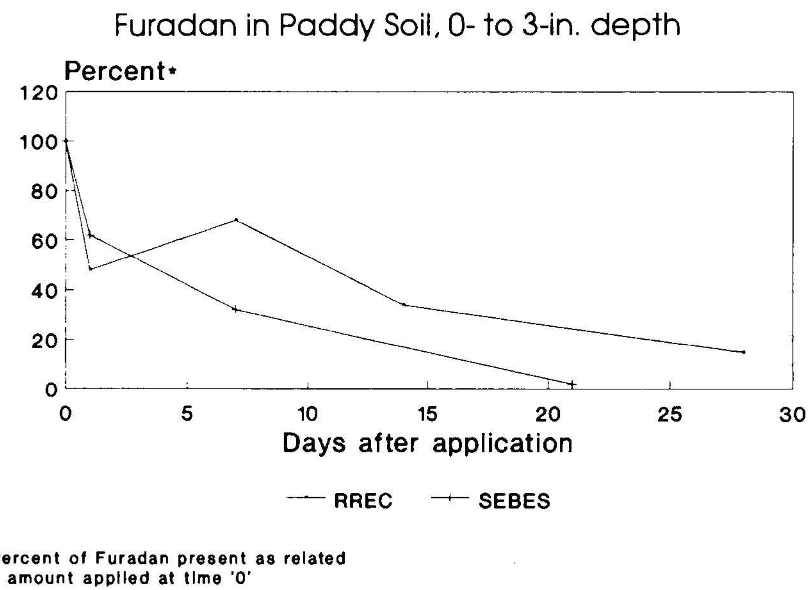
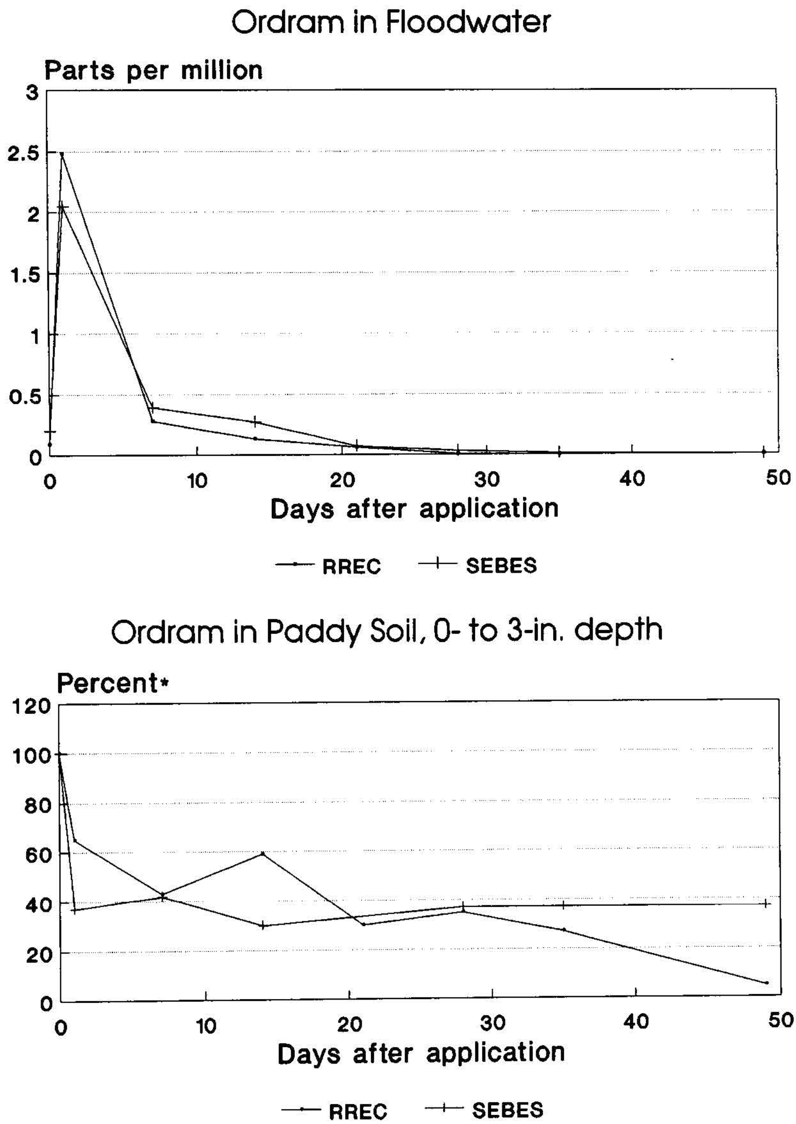


Fig. 3. Furadan persistence in floodwater and paddy soil, 1992.



*Percent of Ordram present as related to amount applied at time '0'

Fig. 4. Ordram persistence in floodwater and paddy soil, 1992.

PEST MANAGEMENT
Disease Control

PATHOGENICITY OF *TILLETIA BARCLAYANA* ISOLATES

F.N. Lee, G.E. Templeton, R.D. Cartwright, D.H. Long and J.M. Hornbeck.

ABSTRACT

Combinations of single sporidial isolates of kernel smut were tested for virulence by injection into rice plants in the "boot" development stage in the field. Inoculated panicles were evaluated for smut at maturity, and infection was rated using a smut index. Little or no smut infection occurred in tests in which isolates from the same teliospore were combined. The smut index varied from 0 to 409 when isolates from different teliospores were combined, regardless of whether they originated from a single smutted kernel or from different smutted kernels. Amount of smut varied depending upon the particular isolate combination used. The development of methods for preparation and storage of the inoculum of the smut fungus and determination of the appropriate time for inoculation make it possible to commence screening varieties for resistance to this disease.

INTRODUCTION

Kernel smut caused by *Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc., a sporadic disease in Arkansas rice production areas, frequently becomes severe in individual fields. Losses can be experienced in grain yield, reduced milling yield and discoloration of healthy kernels during the parboiling process.

The overall objectives of our research on kernel smut are to 1) establish kernel smut screening nurseries; 2) identify the most common smut biotypes in Arkansas and find genetic sources of resistance to these variants; and 3) identify sources of smut resistance by screening breeding lines. In order to achieve these goals, sufficient information must be gained about fungal infection of the rice plant and the genetic interactions between the fungus and the plant.

Information relative to kernel smut and its control is very limited. The most obvious stage of kernel smut is the coal black sooty spores (teliospores) that replace part or all of the rice kernel. Each teliospore is capable of producing approximately 60 sporidia, which in turn grow as mycelium capable of producing two additional spore types. It has been demonstrated with other smut fungi that a recombination of the mycelium or spores arising from the primary sporidia must occur to achieve infection. In addition, this serves to maintain the genetic diversity of the smut fungus. Very little is known about how or when recombination occurs in *T. barclayana* and how it relates to the ability of the fungus to cause kernel smut. This research was conducted to study factors affecting recombination of single primary sporidia isolates and their ability to cause smut.

PROCEDURES

Single sporidial isolates previously cultured from *T. barclayana* teliospores and stored in an ultra-low-temperature (-60° C) freezer were retrieved for these tests. These isolates had produced smut when paired with other isolates in previous boot inoculation tests. They were selected on the basis of whether they were from a single teliospore, different teliospores from the same kernel or teliospores originating from different kernels. The isolates were maintained on water agar (14 g Sigma agar, 1000 ml distilled water) plates. Sufficient quantities of filiform secondary sporidia were produced for use in field inoculations by culturing isolates on water agar plates for 4 to 5 days under continuous light at 22° C. The inoculum was prepared from these plates by flooding with a sterile diluent solution (0.2 g Carnation dry milk, 100 ml Humco glycerol, 1000 ml distilled water) and dislodging sporidia with a sterile rubber-tipped rod. The inoculum was sealed in 20-ml ampules and stored in the ultra-low-temperature freezer until time for field inoculations.

The inocula were removed from storage and thawed in 22°C water as needed. Sporidia concentration was estimated for each isolate with a hemacytometer and adjusted with additional diluent to yield approximately 500,000 viable spores/ml of solution as determined from a previously developed viability curve for stored spores. Equal volumes of selected isolates were mixed to achieve the desired isolate combinations. Approximately 20 ml of the mixed inoculum was dispensed into sterile 25-ml disposable syringes fitted with 20-gauge hypodermic needles. Three syringes of each combination were prepared to provide replicated inoculations. Control syringes containing only the diluent were used in each test at regular intervals to estimate kernel smut contamination from other sources in the field. The syringes were placed in a cooler containing ice blocks and immediately transported to the field. To insure that no reduction in spore viability occurred, inoculations were performed within 10 min from the time the syringes were removed from the cooler.

The field plots were prepared by seeding 'Labelle' rice at approximately four seeds/hill on an 18-in. spacing. The plots were managed using standard agronomic practices throughout the growing season. Four well-developed tillers with a development stage estimated to be 24 hours before the beginning of panicle emergence were selected in each plot. The remaining tillers and any that subsequently developed were severed near the water line to insure that only inoculated panicles remained at the end of the growing season. Plants were inoculated by inserting the needle near the top of the leaf sheath enclosing the panicle and filling the boot with inoculum (2-5 ml/plant). The plants were then allowed to mature normally. Panicles were collected when grains were mature but before smutted kernels began to rupture. Panicles from each plot were wrapped in nylon mesh immediately after harvest and stored in the laboratory until assayed.

Inoculated panicles were placed in a 0.27-M KOH solution until the grain hulls cleared (approximately 12 hours). They were then rinsed with tap water and removed from the mesh, and individual panicles were examined over a light box. Dark kernels were separated into a) smut; or b) other grain discolorations. The number of smutted kernels per panicle and the number of panicles examined per plot were recorded. A smut index was calculated, defined as (total number smutted kernels) X [(number smutted panicles)/(number panicles assayed)] per plot. A mean smut index was determined for each combination of isolates used for inoculation.

Three experiments were conducted to estimate the compatibility of the single primary sporidia isolates. In the first experiment, five single sporidial isolates obtained from a single teliospore were combined in all possible combinations. The test was repeated using five single sporidial isolates from each of two additional teliospores. Isolates were from 'Lemont' rice collected near Lonoke, Arkansas (LMLN), 'Skybonnet' rice from McGehee, Arkansas (SKMG) and 'Newbonnet' rice from near Newport, Arkansas (NWNP). The second experiment was designed to compare smut caused by paired sporidia derived from the same kernel. Isolates selected from the Lemont Lonoke collection were designated T1i1, T1i4, T1i6 and T1i9 (teliospore 1, isolates 1, 4, 6 and 9); T2i1 T2i3 T2i4 T2i5 and T2i6; T4i1 T4i2 T4i3 T4i4 and T4i5; T3i1; and T5i4. The third experiment was designed to compare smut caused by pairwise combinations of single sporidial isolates derived from teliospores produced by different kernels. Isolates were LMLN T1i6, T2i4, T3i1, T4i5 and T5i5; NWNP T1i3 and NWNP T3i5; SKMG T5i9; and TBHZ ('Tebonnet' rice near Hazen) T2i2 and T2i4.

RESULTS AND DISCUSSION

Grain developed normally on plants following boot injection with sterile cryogenic solution alone but were smutted when injected with the solution containing virulent smut spores. Isolate pairs were considered to be incompatible and avirulent if smut failed to develop. The smut index varied from 0 to 409 depending on the test and single sporidial isolates combination.

Very little smut developed in plants inoculated with all possible combinations of single sporidial isolates from one teliospore. The smut index was below one in all combinations of single sporidial isolates from LMLN and from NWNP. Inoculating with combinations from SKMG T4 caused some smut, but the largest smut index recorded for a specific combination was seven. Although only pairwise comparisons were made in previous tests, test results were similar because single sporidial combinations of SKMG T4 isolates also resulted in very low levels of smut this year. These data suggest that limited combinations of single sporidial isolates from the same teliospore are only weakly virulent.

Various levels of smut were observed when plants were injected with pairwise combinations of single sporidial isolates originating from different teliospores produced in the same rice kernel (Table 1) or between single sporidial isolates from different teliospores originating from different kernels (Table 2). Pathogenicity was entirely dependent on the specific single sporidial isolates used; however, combinations of isolates from different teliospores on the same kernel appeared less likely to result in smut than combinations between isolates from different kernels.

SIGNIFICANCE OF FINDINGS

These data provide additional information about genetic diversity of the fungus and its interaction with rice. Although closely related smut isolates were pathogenic, the more virulent combinations were those in which isolates had diverse origins. These data have direct utilization in screening germplasm for kernel smut resistance. Results confirm that the boot inoculation technique is a practical means of determining the smut reaction of a breeding line and the complexity of the genetics of the smut fungus that must be taken into account in the screening process. A number of rice lines were identified with an apparent tolerance to kernel smut. These data suggest that the next step in evaluating these lines as parents is to screen with isolates from all rice production areas.

Table 1. Mean smut index in 'Labelle' plots following boot inoculation with paired single sporidial isolates from different teliospores on a 'Lemont' rice kernel.

Isolate	T1i3	T2i1	T2i3	T2i4	T2i5	T2i6	T3i1	T4i1	T4i2	T4i3	T4i4	T4i5	T5i4
T1i1	-	66	19	17	53	162	-	0	2	1	1	0	-
T1i4	-	89	24	24	33	44	-	1	2	12	0	0	-
T1i6	1	81	12	18	41	62	0	1	1	1	0	0	0
T1i9	-	0	0	0	1	4	-	4	20	5	15	2	-
T2i1								10	48	11	23	27	24
T2i3								13	6	9	8	6	-
T2i4								2	5	3	3	2	-
T2i5								36	24	19	27	14	-
T2i6								43	30	18	64	11	-
T3i1													0
T4i3													0
T5i4													0

Table 2. Mean smut index in 'Labelle' plots following boot inoculation with paired single sporidial isolates derived from teliospores produced in different rice kernels

Kernel		LMLN	LMLN	LMLN	LMLN	LMLN	SKMG	TBHZ	TBHZ	NWNP	NWNP	
	Isolate	T1i6	T2i4	T3i1	T4i5	T5i4	T5i9	T2i1	T2i4	T1i3	T3i5	CRTL
LMLN	T1i6	0	57	1	0	0	197	33	6	173	409	-
LMLN	T2i4		0	53	8	0	10	16	19	76	156	-
LMLN	T3i1			2	0	0	107	27	58	208	362	-
LMLN	T4i5				1	0	139	21	31	135	265	-
LMLN	T5i4					1	19	23	91	86	185	-
SKMG	T5i9						0	35	45	106	126	-
TBHZ	T2i1							0	0	0	59	-
TBHZ	T2i4								0	1	157	-
NWNP	T1i4									1	190	-
NWNP	T3i5										0	-
CONTROL												0

INFECTIVITY OF TWO SPORIDIAL TYPES OF THE RICE KERNEL SMUT PATHOGEN

F.N. Lee, G.E. Templeton, D.H. Long and J.M. Hornbeck

ABSTRACT

Filiform and allantoid secondary sporidia of *Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc. were compared for inoculation efficiency in a "boot" inoculation test. Three isolates derived from single primary sporidia of *T. barclayana* were cultured in a manner to facilitate production of filiform or allantoid sporidia. Equal quantities of filiform sporidia, allantoid sporidia or 3- to 15-cell mycelial fragments were mixed with compatible mating types to yield final concentrations of 1 X 10^4, 5 X 10^4, 1 X 10^5 or 5 X 10^5 colony forming units/ml of inoculum and used to inoculate rice, *Oryza sativa* L., by injection into rice plants at the boot stage in the field. Filiform sporidia were pathogenic and induced higher levels of smut in all compatible combinations than did the allantoid sporidia in the same combinations. Allantoid sporidia were infective only in combinations in which infection from filiform sporidia was high. Mycelial inoculations did not result in smutted kernels. These data suggest that filiform sporidia are least likely to result in false negatives if used in boot inoculations to evaluate rice germplasm for kernel smut resistance.

INTRODUCTION

Tilletia barclayana (Bref.) Sacc. & Syd. in Sacc., the causal organism of kernel smut in rice, produces morphologically distinct filiform and allantoid secondary sporidia. In previous studies, kernel smut symptoms in rice, *Oryza sativa* L., were induced by injecting filiform sporidia into the leaf whorl of the plant during the late boot growth stage. This was not the case with closely related *Tilletia indica* (Mitra), which causes karnal bunt of wheat. Allantoid sporidia of *T. indica* caused high levels of smut in boot and in spray inoculations while filiform sporidia were essentially avirulent (Warham, 1990). Thus the use of filiform sporidia produced on solid media was discouraged in order to reduce the risk of false negatives when screening wheat germplasm for karnal bunt resistance. Our research was conducted to compare the relative infectivity of allantoid sporidia, filiform sporidia and mycelium and to determine the most efficacious inoculum in screening rice germplasm for kernel smut resistance.

PROCEDURES

Inoculum Production

Single sporidial isolates SSD26, SSD29 and SSD40, previously isolated from individual teliospores of *T. barclayana*, were retrieved from long-term storage in an ultra-low-temperature (-60°C) freezer. The isolates were selected for this experiment because all possible pair combinations had been classified as highly virulent, moderately virulent or avirulent in previous compatibility tests. Isolates were maintained on water agar (14 g Sigma agar, 1000 ml distilled water). The isolates produce almost entirely filiform sporidia when cultured on water agar for four to five days under continuous light at 22°C. Sporidia produced in this manner were harvested in a sterile diluent solution (0.2 g Carnation dried milk, 100 ml Humco glycerol, 1000 ml distilled water) with the aid of a rubber-tipped rod. These sporidia were stored in the ultra-low-temperature freezer in 20-ml bottles until retrieved and thawed in a water bath (22°C) for use in production of inoculum for field inoculations.

Filiform spores used for field inoculations were produced by inoculating water agar plates with 500 µl of stock inoculum and culturing as described. The filiform spores were then harvested in diluent at concentrations greater than 600,000 spores/ml as estimated with a hemacytometer. The spore type formed was confirmed with a microscope. The spores were then stored in 20-ml bottles in the ultra-low-temperature freezer until thawed for use in inoculations in the field.

Allantoid sporidia were produced by inoculating sorghum agar (2.0 g ground brown sorghum, 0.025 g Difco peptone, 14.5 g Sigma agar, 1000 ml distilled water) plates with the inoculum from the freezer. When inverted and incubated for four to six days under continuous light at 22°C, allantoid spores were produced in abundance. These sporidia were also harvested in diluent, checked for spore type purity and concentration using a hemacytometer and stored in 20-ml bottles until used for plot inoculations.

Mycelial inoculum was produced in sorghum broth (0.2 g ground brown sorghum; 0.025 g peptone; 1000 ml distilled water) in shake cultures inoculated with the standard inoculum (5 ml/100 ml broth).

Cultures were maintained on a reciprocating shaker (150 rpm) for 8 to 10 days at 22 C until a thick mycelial growth could be observed. Mycelial cultures were stabilized by adding 100 mM sucrose, 0.2 g dried milk and 100 ml glycerol per liter of shake culture then aseptically blended for 40 sec in a blender to yield 3 to 15 cells per mycelial fragment. Cultures were checked for purity and returned to the shaker for an additional four to six hours. Cultures were stored in 20-ml bottles in the ultra-low-temperature freezer until used in field tests.

Isolate Combinations

The various inocula were retrieved from the ultra-low-temperature freezer and thawed in 22°C water. The concentration was estimated and then adjusted with additional diluent to 500,000 colony forming units (CFU)/ml by using a standard curve for estimating viability of stored inoculum. Isolates were then mixed in all possible combinations by spore type, and dilutions were made to achieve final concentrations of 1.0×10^4, 5.0×10^4, 1.0×10^5 and 5.0×10^5 CFU/ml. Approximately 20 ml of the mixed inoculum was dispensed into sterile 25-ml disposable syringes fitted with 20-gauge hypodermic needles. Three syringes of each combination were prepared to provide replicated inoculations. Control syringes containing only diluent were inserted into each test at regular intervals to estimate kernel smut contamination from other sources. Syringes were placed in a cooler containing ice blocks and immediately transported to the field. To insure that viability was not reduced, inoculations were performed within 10 min after syringes were removed from the cooler.

Field plots were prepared by planting approximately four seeds of the susceptible cultivar 'Labelle' in hills 18 in. apart. Plots were managed using standard agronomic practices throughout the growing season. As plants neared the panicle exsertion development stage, four well-developed tillers were selected in each plot that were approximately 24 hours away from the beginning of panicle emergence. The remaining tillers and all that subsequently developed were severed near the water line to insure that only inoculated panicles remained at the end of the growing season. Plants were inoculated by inserting the needle near the top of the panicle and filling the boot with inoculum (2-5 ml/plant). Plants were then allowed to mature normally. The panicle was removed when grains were nearly mature but before smutted kernels began to rupture. Panicles from an individual plot were wrapped as a group in nylon mesh immediately after harvest and stored in the laboratory until assayed.

The panicles were placed in a 0.27-M KOH solution until the grain hulls cleared (approximately 12 hours), rinsed with tap water and removed from the mesh, and individual panicles were examined over a light box. Dark kernels were separated into a) smut; or b) other grain discolorations. The number of smutted kernels per panicle and the number of panicles examined were recorded. A smut index was calculated, defined as (total number smutted kernels) X [(number smutted panicles)/(number panicles assayed)] per plot. A mean smut index was determined for each combination of isolates used for inoculation.

RESULTS AND DISCUSSION

Grain developed normally, and smut was not observed in plots inoculated with diluent alone. The relative incidence of smut observed in plots following inoculation with different combinations of isolates confirmed results of previous experiments. Inoculation with combinations SSD26 X SSD29, SSD26 X SSD40 and SSD29 X SSD40 resulted in very low, moderate and high smut levels, respectively (Table 1).

Filiform sporidia caused some infection in all inoculations (Figures 1A, 1B and 1C). A maximum smut index of 19 was recorded for the highest concentration of SSD26 X SSD29 filiform sporidia. The smut index increased from 71 to 88 as concentration of filiform sporidia for the moderately virulent combination SSD26 X SSD40 was increased from 1 X 10^5 to 5 X 10^5 spores/ml. In contrast, the smut index increased from 72 to 241 in inoculations at these concentrations of the more virulent combination SSD29 X SSD40. Smut developed in plants inoculated with allantoid sporidia of combinations SSD26 X SSD40 and SSD29 X SSD40. However, the smut index was always less than that of the respective filiform inoculations. Little if any smut resulted when plants were inoculated with mycelia from the isolates.

SIGNIFICANCE OF ACCOMPLISHMENTS

Both types of secondary sporidia of the rice smut pathogen are infective. Isolate compatibility does not appear to be affected by type of secondary sporidia used. These data suggest that either filiform sporidia or mixtures of filiform and allantoid sporidia provide good inoculum for use in evaluation of rice germplasm without increasing the possibility of false negatives.

LITERATURE CITED

1. Warham, E.J. and P.A. Burnett. 1990. Influence of media on pathogenicity and morphology of secondary sporidia of *Tilletia indica*. Plant Dis. 74:525-527.

Table 1. Mean smut index over all concentrations in 'Labelle' rice following boot inoculation with different combinations of single sporidial isolates

	Isolate Combination		
Inocula	SSD26 X SSD29	SSD26 X SSD40	SSD29 X SSD40
Filiform	10.3a[z]	53.5a	82.3a
Allantoid	0.3b	26.5b	70.2a
Mycelium	0.3b	0.9c	2.4b

[z]Means followed by the same letter within a column are not statistically significant (least significant difference test, SAS Institute).

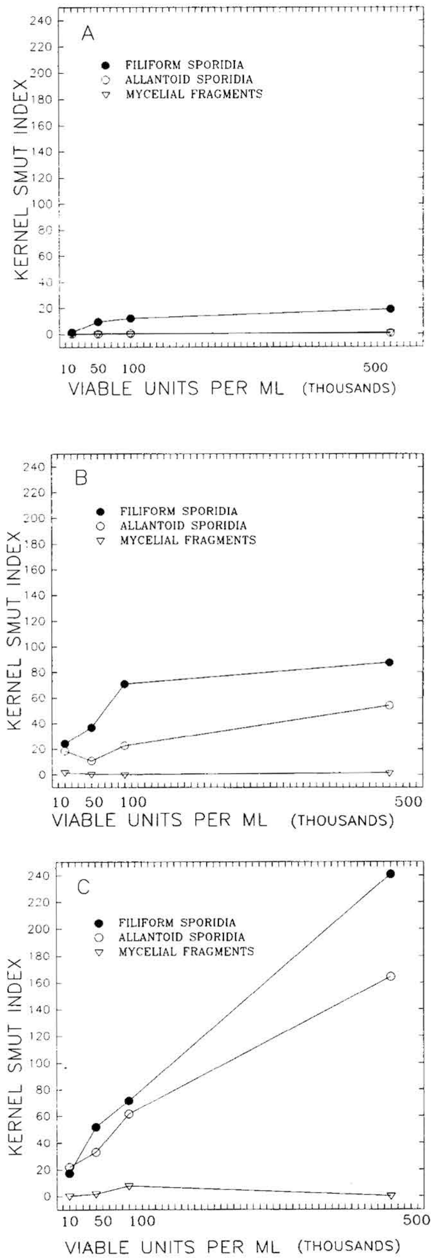


Figure 1. Relative smut index in 'Labelle' rice following boot injection with either filiform spores, allantoid spores or mycelium fragments of isolate combinations, (A) SSD26 X SSD29, (B) SSD26 X SSD40, and (C) SSD29 X SSD40.

RICE VARIETY RESPONSE TO SHEATH BLIGHT 1990-1992

R.S. Helms, F.N. Lee, R.J. Norman, B.R. Wells and J.A. Grove

ABSTRACT

Ten rice varieties were screened for their tolerance to sheath blight from 1990 through 1992. Inoculated plots were compared to non-inoculated plots to determine the effects of sheath blight on grain yield and milling quality. Grain yield and milling quality reductions varied considerably among the varieties. For example, sheath blight reduced grain yields an average of 242 lb/acre in 'Alan' and 1,032 lb/acre in 'Maybelle'. The results of these studies were used to develop new sheath blight thresholds that consider plant type as well as sheath blight susceptibility.

INTRODUCTION

Sheath blight (*Rhizoctonia solani*) is a common rice disease in Arkansas that can reduce both grain yield and milling quality under severe infestations. In addition, if sheath blight weakens the stem tissue, lodging may occur, and grain yield and quality losses may be greater.

Previously, the threshold for recommending fungicide applications for sheath blight control has been when sheath blight symptoms were noted at 10 to 15% of the sampling locations within a field. This threshold was based on 'Lebonnet', a tall, older rice variety that is highly susceptible to sheath blight. An objective of the University of Arkansas rice breeding program is to develop rice varieties with sheath blight tolerance, varieties that would be more profitable to grow because of the decreased probability of the need for fungicide applications. The objective of this study was to evaluate new rice varieties for tolerance to sheath blight and to assess the current fungicide treatment threshold.

PROCEDURES

Ten rice varieties were evaluated from 1990 through 1992 for tolerance to sheath blight at the Pine Tree Experiment Station (PTES), Colt, Arkansas; the Rice Research and Extension Center (RREC), Stuttgart, Arkansas; and the Southeast Branch Experiment Station (SEBES), Rohwer, Arkansas. The rice varieties were 'Tebonnet', 'Texmont', Maybelle, 'Millie', Alan, 'Katy', 'Newbonnet', 'Lemont', 'L202' and 'Gulfmont'. In 1992, five additional new varieties ('Orion', 'RT7015', 'Cypress', 'Bengal' and 'Lacassine') were evaluated at the three locations. Inoculations with sheath blight were made at beginning internode elongation and seven days later. In each test, inoculated plots were compared to non-inoculated plots. Fungicides were not applied. Parameters measured included grain yield, milling quality and visual sheath blight ratings prior to harvest.

RESULTS AND DISCUSSION

Grain yield and milling quality reductions varied among the rice varieties. In the 10 tests conducted from 1990 through 1992, Alan, Millie and Katy were the most tolerant to sheath blight (Table 1) with grain yield reductions of 242 lb/acre, 256 lb/acre and 282 lb/acre, respectively. Grain yield reductions were greatest in Maybelle, Gulfmont and Texmont with reductions of 1,032, 626 and 591 lb/acre, respectively. Sheath blight reduced head rice an average of 3% in Maybelle. Bengal and Orion were the most tolerant of the five varieties evaluated in 1992 (Table 2). Grain yield reductions from sheath blight averaged 407 lb/acre for Bengal and 689 lb/acre for Orion. Grain yield reductions from sheath blight for Lacassine and Cypress averaged 813 and 763 lb/acre, respectively. Cypress head rice yields were reduced an average of 3%. Grain yields and head rice yields were reduced 1,157 lb/acre and 6 percentage points, respectively, in RT7015. Further research will continue to evaluate response of new rice varieties to sheath blight as well as cultural practices that could reduce the severity of the disease.

SIGNIFICANCE OF FINDINGS

The results of these studies demonstrated that the new varieties differ greatly in tolerance to sheath blight. This information and data from other sheath blight studies were used to develop new sheath blight thresholds for fungicide applications.

The new disease threshold levels were based on the plant type—either closed or open canopy—and susceptibility to sheath blight—

either highly susceptible or moderately susceptible. Three groups were developed that are designated as 1) closed canopy, highly susceptible, 2) open canopy, highly susceptible and 3) open canopy, moderately susceptible. Information on the new thresholds is available from the county offices of the Cooperative Extension Service.

Table 1. Sheath blight screening of 10 varieties grown at three locations, 1990-1992.

Variety	Yield (lb/acre)	Milling (HD/Total)	Sheath Bight Ratings
Tebonnet			
Non-Inoculated	5808	59/67	1.4
Inoculated	5413	59/67	5.4
Texmont			
Non-Inoculated	5704	52/66	3.4
Inoculated	5113	51/65	7.9
Maybelle			
Non-Inoculated	5986	53/68	2.8
Inoculated	4954	50/67	7.4
Millie			
Non-Inoculated	5985	61/70	0.7
Inoculated	5729	62/70	4.6
Alan			
Non-Inoculated	6175	59/67	1.3
Inoculated	5933	58/66	6.2
Katy			
Non-Inoculated	5979	61/67	1.0
Inoculated	5697	61/67	3.9
Newbonnet			
Non-Inoculated	6077	59/66	1.8
Inoculated	5669	60/66	5.0
Lemont			
Non-Inoculated	6143	60/69	3.5
Inoculated	5712	59/68	7.2
L202			
Non-Inoculated	6229	55/66	1.9
Inoculated	5745	54/65	6.8
Gulfmont			
Non-Inoculated	6252	60/68	3.2
Inoculated	5626	59/68	6.8

Table 2. Sheath blight screening of five varieties grown at three locations in 1992.

Variety	Yield (lb/acre)	Milling (HD/Total)	Sheath Blight Ratings
Orion			
Non-Inoculated	7591	62/70	2.4
Inoculated	6902	61/70	3.3
RT7015			
Non-Inoculated	6917	60/69	3.1
Inoculated	5760	54/66	6.7
Cypress			
Non-Inoculated	6842	63/69	3.2
noculated	6079	60/68	6.0
Bengal			
Non-Inoculated	7783	66/71	2.2
Inoculated	7376	65/71	3.9
Lacassine			
Non-Inoculated	7123	57/69	4.8
Inoculated	6310	57/68	7.4

PEST MANAGEMENT
Insect Control

SCREENING FOR RICE STINK BUG RESISTANCE

J.L. Bernhardt

ABSTRACT

Rice grain samples of varieties from several sources were evaluated for resistance to rice stink bug. When evaluated for pecky rice, all rice sample sources supported the same conclusion: susceptibility was greatest in short-grain varieties, followed by medium-grain varieties, and lowest in long-grain varieties. Among currently used varieties, 'Katy' was found to have the most resistance. Yearly evaluations for levels of pecky rice in varieties in the Arkansas Rice Performance Trials (ARPT) are now being published in the extension publication *ARPT Fact Sheet*.

INTRODUCTION

The rice stink bug is a common pest in every rice field in Arkansas. Adults and nymphs feed on rice kernels and cause losses in yield and quality of the grain. To minimize losses and gain short-term control of the rice stink bug, growers can use insecticide applications. Although relatively inexpensive insecticides are available, other means of rice stink bug control are desirable. Recent research projects have investigated strategies of management that integrate control methods such as 1) insecticides, 2) conservation and enhancement of a parasite (*Telenomus podisi* Ashmead) that attacks and destroys eggs of the rice stink bug and 3) rice lines that have reduced susceptibility and/or reduced attractiveness to the rice stink bug. This report is a summary of research to identify rice lines with degrees of resistance to the rice stink bug.

Plant resistance to insects is always relative. Thus, the degree of resistance is based on repeated comparisons of plants. Plants that are more severely damaged are termed susceptible, while those with consistently lesser amounts of damage under similar test conditions are resistant.

PROCEDURES

Samples of rice from the following sources and years were evaluated: 1) rice varieties that are currently used and those no longer used in commercial rice production (1990-1991); 2) rice lines in the rice breeding program of the University of Arkansas placed in the Arkansas Rice Performance Trials (ARPT) (1988-1991); 3) rice lines released from breeding programs of other universities and private seed companies placed in the ARPT (1988-1991); and 4) rice varieties from grower fields in nearly all Arkansas counties with rice acreage (1987-1991).

Group 1 - Current and Obsolete Varieties

Fifty-seven rice accessions were selected from the USDA world germplasm collection. They were placed into one of four maturity groups. Individual varieties were drill-seeded in rows 4 ft long with six varieties per drill strip. Ten drill strips comprised one replicate. There were six replications. Barnyardgrass was planted along drill strip borders to enhance rice stink bug infestations. Rice was seeded on 9 May in 1990 and 21 May in 1991.

Mature panicles were hand harvested and dried. Grain was removed from the panicles by a laboratory thresher, hulled and 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) pecky rice caused by the rice stink bug, b) kernels infected with the kernel smut pathogen, c) a linear discolored split on the kernel not caused by insects and d) other kernel discolorations such as pink, red or yellow and discolorations of the bran. The amount of discolored kernels in a category was expressed as a percentage of the total weight of brown rice adjusted to a 10% moisture content.

Groups 2 and 3 - Rice Varieties in the ARPT

The trials are conducted at several locations each year to compare promising new experimental and newly released rice varieties with previously released ones. Rice samples were taken from each variety grown at three to four locations in Arkansas each year. The locations were the Rice Research and Extension Center, Stuttgart (RREC, Arkansas Co.); the Cotton Branch Experiment Station, Marianna (CBES, Lee Co.); in a northeast Arkansas county (Clay or Jackson County) and/or at the Southeast Branch Experiment Station, Rohwer (SEBS, Desha Co.). Each location had 12 rice varieties replicated four times in each of the very-short-, short- and mid-season maturity groups. Brown rice preparation, sorting and evaluation were handled as described for group 1.

Group 4 - Samples from Grower Fields

Samples were selected at random from rough rice samples taken by grower cooperatives and independent marketing services in Arkansas. The number of samples each year reflected the geographic distribution and proportion of cultivars that were grown in the state. Brown rice preparation, sorting and evaluation were handled as described for group 1. In addition, data were recorded on the amount of red rice, the identity and amount of weed seeds and the county in which the rice was grown.

RESULTS

Current and Obsolete Varieties

Rice stink bug damage (pecky rice) was found in all varieties in these tests. The level of peck was increased in 1990 by the use of barnyardgrass on the plot borders that enhanced rice stink bug infestation. The lower level of peck in the varieties in 1991 was unexpected; however, a later-than-usual seeding date of the varieties may have accounted for the reduced presence of rice stink bugs in the plots.

Differences in the amount of pecky rice were found between grain types within each year (see Tables 1 and 2). The average amount of peck for all varieties of a grain type was highest for the short-grain varieties and lowest for the long-grain varieties. In addition, differences in the amount of pecky rice were also found among varieties of similar grain types. For example, among the 22 medium-grain varieties, most of the varieties developed in California ('Calrose', 'M7', 'Cal Pearl', 'M302' and 'M301') had high averages of pecky rice, while one variety developed in Arkansas, 'Mars', averaged low amounts of pecky rice. Likewise, among the 30 long-grain varieties a few varieties, Katy and 'Gulfmont' for example, had amounts of pecky rice that were much lower than the other varieties.

Rice Varieties in the ARPT

Among the many rice varieties tested in the ARPT studies, four were found to have good agronomic qualities and were released into certified seed production. The varieties were named Katy, 'Millie', 'Alan' and 'Orion'. Results of the evaluations of the four varieties for susceptibility to rice stink bug damage are found in Table 3. Among all varieties tested, Katy consistently had the lowest amounts of pecky rice. Orion and Mars are medium-grain varieties and had slightly higher amounts of pecky rice than the long-grain varieties. Among the very-short-season varieties, Millie had lower amounts of peck than 'Tebonnet' and 'L202'. Alan, another very-short-season variety, had high but highly variable amounts of pecky rice. Very-short-season rice varieties such as Alan often are planted early and thus may be among the first fields of rice to begin heading within a locality. Consequently, rice stink bug infestation may be heavy and cause a high amount of pecky rice if the fields are untreated.

Samples from Grower Fields

A total of 6110 samples from 25 rice varieties were evaluated for amounts of pecky rice. Results of the evaluations once again revealed differences in the amount of pecky rice related to grain type (see Table 4) and region in the state where the rice was grown (see Fig. 1). Samples from short- and medium-grain varieties within a year averaged more pecky rice than did those from the long-grain rice varieties. The amount of peck varied each year and was higher in certain areas of the state. Peck values from samples in 1987 and 1988 clearly show differences in overall population density of rice stink bugs. In addition, counties in northeastern Arkansas had higher levels of peck than did counties in central or southern Arkansas.

SIGNIFICANCE OF FINDINGS

Among the many varieties tested over the years, one long-grain variety, Katy, has shown appreciable resistance to rice stink bug. Katy is being used as a source of resistance to diseases and to the rice stink bug in the University of Arkansas breeding program. The objective is to have a high-yielding rice that has resistance to diseases and insects.

The major significance of these research data is that all sources of rice samples, when evaluated for pecky rice, supported the same conclusions concerning grain type susceptibility to rice stink bug damage. Especially important were the yearly evaluations of advanced rice lines in the Arkansas breeding program. These evaluations have great utility to identify rice lines susceptible to rice stink bug damage. Results of the ARPT pecky rice evaluations are now being placed in the Cooperative Extension Service publication called the *ARPT Fact Sheet*.

Table 1. Average percent, by weight, of discolored kernels in brown rice samples of long-grain rice varieties (smut not included), Stuttgart, Arkansas.

		1990		1991		Average	
Rice Line	Origin	Peck[z]	Other[y]	Peck	Other	Peck	Other
Della	LA	2.55	0.66	0.37	0.35	1.46	0.51
Tebonnet	AR	2.39	0.46	0.45	0.27	1.42	0.37
Newrex	TX	2.02	1.10	0.19	0.77	1.28	0.94
Bonnet 73	AR	1.89	0.42	0.30	0.16	1.10	0.29
Lemont	TX	1.80	0.78	0.22	0.55	1.01	0.67
Newbonnet	AR	1.75	0.68	0.58	0.20	1.17	0.44
LA110	LA	1.73	1.14	0.82	0.26	1.28	0.70
Alan	AR	1.66	0.25	0.65	0.66	1.16	0.46
Bluebonnet	TX	1.51	0.39	0.17	0.53	0.84	0.46
Labelle	TX	1.42	0.58	0.75	0.36	1.09	0.47
Sh. St. Dawn	AR	1.40	0.45	0.26	0.58	0.83	0.52
Skybonnet	TX	1.19	0.75	0.18	0.20	0.69	0.48
Starbonnet	AR	1.15	0.38	0.12	0.32	0.64	0.35
Bond	AR	1.12	0.63	0.33	0.36	0.73	0.50
Leah	LA	1.04	0.85	0.13	0.11	0.59	0.48
Gulfmont	TX	1.03	0.63	0.08	0.19	0.56	0.41
Bluebelle	TX	1.02	0.57	0.29	0.34	0.66	0.46
Lebonnet	TX	1.00	0.74	0.39	0.40	0.70	0.57
Katy	AR	0.97	0.39	0.10	0.23	0.54	0.31
Jasmine 85	TX	0.96	0.60	0.16	0.31	0.56	0.46
L201	CA	0.94	0.60	0.44	0.70	0.69	0.65
Rexmont	TX	0.91	0.90	0.13	0.44	0.52	0.71
L202	CA	0.89	0.52	0.36	0.69	0.63	0.61
Millie	AR	0.89	0.68	0.52	0.53	0.71	0.61
Cal Belle	CA	0.83	0.27	0.72	0.78	0.78	0.53
Vegold	AR	0.78	0.50	0.23	0.34	0.51	0.42
Bellemont	TX	0.67	0.62	0.18	0.27	0.43	0.45
Dawn	TX	0.62	0.15	0.08	0.16	0.35	0.16
RT V7817	LA	0.52	0.83	0.29	0.85	0.41	0.84
AVERAGE		1.22		0.30			

[z]Discolored by rice stink bug.

[y]Other discolored kernels excluding smut.

Table 2. Average percent, by weight, of discolored kernels in brown rice samples of medium- and short-grain rice varieties (smut not included), Stuttgart, Arkansas.

Grain Type		1990		1991		Average	
Rice Line	Origin	Peck[z]	Other[y]	Peck	Other	Peck	Other
Medium-Grain							
Cal Rose	CA	4.37	2.48	1.01	0.28	2.69	1.38
M7	CA	3.87	2.88	0.53	0.28	2.20	1.58
Cal Pearl	CA	3.29	2.62	1.20	2.12	2.25	2.37
M302	CA	3.22	5.57	0.67	0.73	1.95	3.15
M301	CA	2.84	2.21	0.84	1.22	1.84	2.03
Nova	AR	2.48	0.88	0.67	0.58	1.58	0.73
Nova 76	AR	2.11	0.78	0.54	0.19	1.33	0.49
Zenith	AR	2.01	0.71	0.67	0.57	1.34	0.64
Vista	LA	1.90	0.66	0.68	0.37	1.29	0.52
Brazos	TX	1.87	0.66	0.52	0.46	1.20	0.56
Saturn	LA	1.64	0.95	0.51	0.27	1.08	0.61
M9	CA	1.53	2.47	0.96	1.26	1.25	1.11
Nato	LA	1.52	0.91	0.40	0.39	0.96	0.65
Mercury	LA	1.46	3.38	0.35	0.44	0.91	1.91
Arkrose	AR	1.41	0.79	0.35	0.25	0.88	0.52
Northrose	AR	1.37	1.41	0.25	0.19	0.81	0.80
Pecos	TX	1.33	0.89	0.83	0.67	1.08	0.78
M201	CA	1.20	1.76	0.73	1.60	0.97	1.68
Gulfrose	TX	1.17	0.55	0.95	0.40	1.06	0.48
Mars	AR	0.96	0.50	0.23	0.25	0.60	0.38
Palmyra	MO	0.87	0.55	0.92	0.61	0.90	0.58
Dular	India	0.36	0.05	0.63	0.35	0.50	0.20
AVERAGE		1.97		0.66			
Short-Grain							
Nortai	AR	4.44	1.52	0.54	0.37	2.49	0.95
Colusa	CA	3.82	3.13	1.53	0.83	2.33	1.98
S201	CA	3.37	1.75	0.86	0.62	2.12	1.19
Cody	LA	2.93	2.37	1.68	0.97	2.31	1.67
Calmochi	CA	2.19	3.27	0.60	0.61	1.40	1.94
Nova Dwarf	AR	1.02	4.95	0.77	5.71	0.90	5.33
AVERAGE		3.55		1.09			

[z]Discolored by rice stink bug.

[y]Other discolored kernels excluding smut.

Table 3. 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
Mid-Season					
Nortai	S	1.45	0.32	1.65	-
Newbonnet	L	0.88	0.14	0.80	0.79
Lemont	L	0.54	0.17	0.64	0.45
Katy	L	0.48	0.09	0.40	0.31
Short-Season					
Rico	M	-	0.23	1.25	1.13
Mercury	M	1.31	0.28	-	-
Mars	M	0.92	0.17	0.98	0.90
Gulfmont	L	0.64	0.19	0.70	-
Orion	M	0.81	0.22	0.96	0.81
Very-Short-Season					
L202	L	0.99	0.15	0.87	0.86
Tebonnet	L	-	0.17	0.90	0.72
Maybelle	L	-	0.19	0.70	0.71
Millie	L	0.65	0.18	0.68	0.58
Alan	L	1.22	0.27	1.20	0.69

Table 4. Average percent, by weight, of pecky rice in brown rice samples of varieties from grower fields in Arkansas.

Grain Type	Year			
& Variety	1987	1988	1990	1991
Short-Grain				
Nortai	1.22	2.98	-	-
Medium-Grain				
M7	0.50	1.35	-	-
Mars	0.80	1.31	0.41	0.98
Mercury	-	1.57	-	-
Rico	-	-	0.57	0.98
RT V4716	-	1.63	0.52	1.02
Long-Grain				
Alan	-	-	-	0.81
Bellevue	-	1.11	-	-
Bond	0.68	1.10	-	-
CB 801	-	0.68	-	-
Gulfmont	0.38	1.13	0.43	0.95
Katy	-	-	-	0.49
L201	0.88	1.05	0.66	0.87
L202	0.93	0.97	0.48	0.81
Labelle	0.54	0.80	0.26	0.52
Lebonnet	0.57	1.08	0.28	0.31
Lemont	0.61	0.93	0.29	0.67
Maybelle	-	-	-	0.96
Newbonnet	0.60	1.05	0.28	0.68
Rexmont	0.17	0.62	-	-
RT V7713	-	0.79	-	-
RT V7817	-	0.45	-	-
Skybonnet	0.53	0.61	-	-
Starbonnet	0.38	1.07	-	-
Tebonnet	0.65	0.99	0.29	0.71

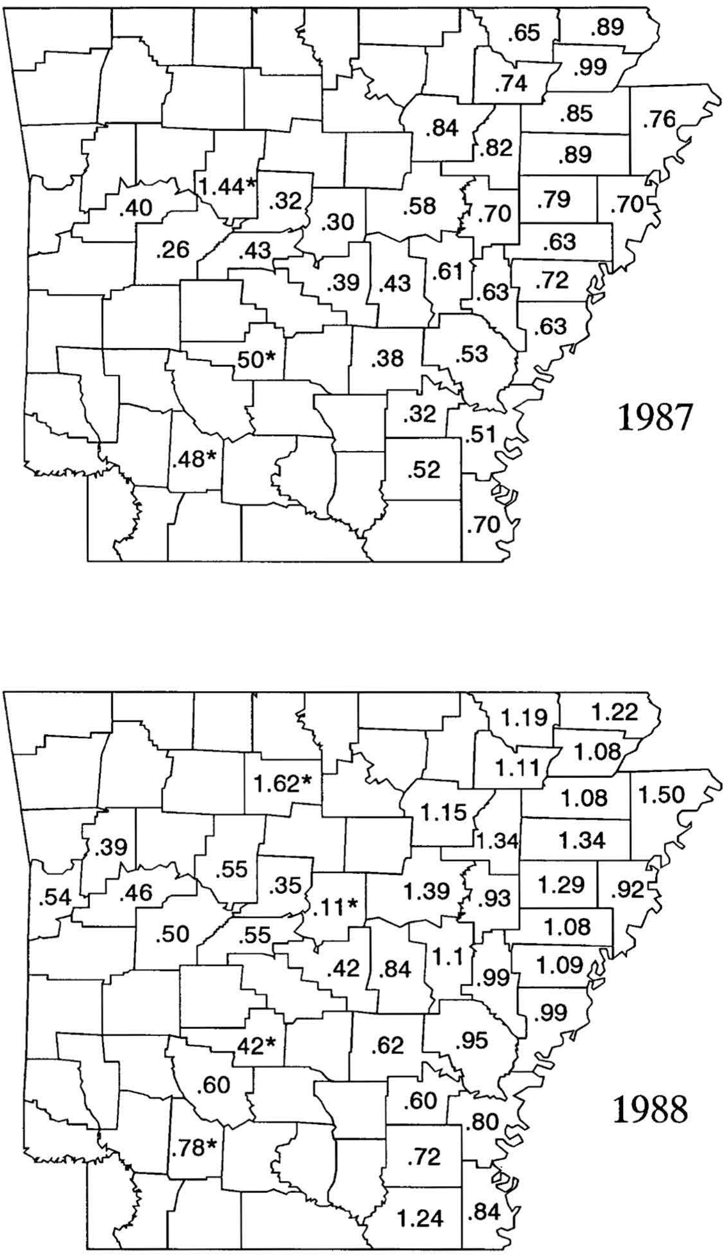


Fig. 1. Average percent, by weight, of pecky rice in brown rice samples of all varieties taken from counties in Arkansas in 1987 and 1988 (* indicates one sample).

CULTURAL PRACTICES RESEARCH

1992 RICE RESEARCH VERIFICATION TRIALS

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ABSTRACT

Nine Rice Research Verification Trials with a total of six cultivars were conducted during 1992 in eight rice-producing counties in Arkansas. Agronomic and economic data for specified operating costs were collected for each verification field. The nine fields totaled 691 acres, and field size ranged from 41 to 120 acres. Yields ranged from 5490 to 7830 lb/acres and averaged 6264 lb/acre. Eight of the nine fields were drill or broadcast dry seeded. The remaining field was water seeded. Seeding dates ranged from 8 April to 15 May. The early seeding dates and abnormally cool temperatures resulted in slow emergence and thin stand densities in several verification fields. The nine fields averaged 15 days between seeding and establishment of a DD50 emergence date. The break-even price for each field, excluding charges for land, overhead and management, ranged from $2.25 to $3.36/bu. Based on the weighted means for yield and total specified operating ($295.86/acre) and fixed ($70.36/acre) costs, the average break-even price was $2.62/bu. Fertilizer cost represented 13.5% of the specified operating cost followed by drying at 12.7%, herbicide at 11.7%, irrigation at 10.6%, seed at 8.8%, aerial application at 8.8% and fungicide at 3.9%.

INTRODUCTION

The average rice yield in Arkansas has not dropped below 5000 lb/acre since 1985. Record yields of 5350 and 5600 lb/acre were produced in 1988 and 1989. A portion of this success can be attributed to research conducted by University of Arkansas researchers and the distribution of the research results by the Cooperative Extension Service. The Rice Research Verification Trials (RRVT), initiated in 1983, use an interdisciplinary approach that stresses management intensity. Information from the trials helps to verify and improve recommendations that increase the potential for profitable rice production by identifying data gaps; to accumulate data bases for rice economic programs;

to provide training to county agents; and to assist in the transfer of research technology.

PROCEDURES

Each verification field was selected prior to seeding and had no built-in barriers that initially would inhibit success. Farm cooperators agreed to pay production expenses, provide crop expense data for economic analysis and implement the recommended production practices in a timely manner from seedbed preparation to harvest. A designated Extension agent from each participating county served as a field technician who assisted the Area Rice Specialist in collecting data, scouting the verification field and maintaining regular contact with the grower. Management decisions were made during weekly field inspections by the Area Rice Specialist based on current University of Arkansas recommendations. Additional technical assistance was provided by the appropriate Extension specialist or researcher, as needed. Economic analysis was performed by a designated Extension economist.

SUMMARY OF RESULTS

Nine RRVT were established during 1992 on 691 acres. Six different varieties, 'Alan', 'Jackson', 'Katy', 'Millie', 'Newbonnet' and 'Orion', were seeded in the nine verification fields ranging in size from 41 to 120 acres with an average of 77 acres (Table 1). Eight of the nine fields were drill or broadcast dry seeded. The remaining field was water seeded due to a severe red rice infestation. Counties participating in the 1992 RRVT were Arkansas, Jackson (2 fields), Lincoln, Jefferson, Prairie, Poinsett, White and Woodruff. Soil series and acreage for each field are listed in Table 1.

Grain yield averaged 6264 lb/acre (Table 1) compared to the projected mean state yield of 5500 lb/acre. The Orion rice seeded in the Arkansas County RRVT produced 7830 lb/acre, the highest yield recorded in the history of the verification trials. Newbonnet seeded in the Lincoln County RRVT produced 7155 lb/acre, the highest yield of the long-grain varieties.

Seeding dates ranged from 8 April to 15 May (Table 2). The weather in late March was dry and warm, allowing farmers to prepare fields for seeding. The early seeding dates and abnormally cool temperatures in April and May resulted in slow emergence and thin stand densities in several verification fields. The nine fields averaged 15 days between seeding and establishment of a DD50 emergence date compared to 7 days in 1991. Stand densities were less than 15 plants/ft^2 in two fields

(Table 2). The cool temperatures also slowed rice development, resulting in an average of 32 days between rice emergence and flood establishment compared to an average of 18 days in 1991. The extended time between seeding and flooding, 47 days on the average, presented farmers with several management problems, including stand establishment and weed control.

Residual herbicide programs were used on all verification fields due to the early planting dates. Propanil was used as a grass option on only one field where Arrosolo was tank-mixed with Bolero and followed by propanil prior to flooding (Table 3). Residual herbicides, namely Facet or Bolero, were applied alone as a delayed pre-emergence or early post-emergence treatment on the seven remaining dry-seeded fields. Bolero (4 lb/acre) was preplant surface applied on the water-seeded field. In general, excellent grass control was obtained at all locations. An additional herbicide application was required on several fields to control broadleaf weeds. The primary reasons for relying on residual herbicides for grass control were 1) early planting dates associated with cool temperatures and poor performance of contact herbicides such as propanil, 2) control of propanil-resistant barnyardgrass and 3) risk of herbicide drift to nearby susceptible crops. The average herbicide cost was $34.53/acre.

Fertilizer cost averaged $39.89/acre, the single largest operating cost, representing 13.5% of the total. Extra nitrogen was applied to several fields due to thin stands and minor damage from rice water weevil larvae. The plant area board indicated that extra midseason nitrogen was needed at four locations (Table 2). A field that had been recently precision leveled was involved in the RRVT for the first time in 1992. Fresh poultry litter was applied to part of the field at a rate of 1500 lb/acre. This field had the highest overall fertilizer cost due to the application of P, K, Zn EDTA chelate, ammonium sulfate and urea. The field, seeded in Katy, yielded 5760 lb/acre despite several acres of rice dying from zinc deficiency. Katy was selected due to its relatively low cost of production and excellent disease resistance compared to other varieties.

Fungicide was applied to five of the nine fields (Table 3). Although sheath blight was present in all fields, only the Jackson County water-seeded field required treatment. Rovral was used to spot treat 50 of the 80 acres at this location. Blast was present in all fields except those seeded with Katy and Orion. The Lincoln County Newbonnet field was the only field to receive two Benlate applications. Verification fields located in Jefferson, Prairie and Poinsett Counties each received one Benlate application. Blast symptoms were found and verified in fields prior to treatment. In general, blast did not cause severe yield losses in any RRVT field. Fungicide costs averaged $11.66/acre. Field observations indicated that kernel smut was present in high amounts in the two RRVT fields seeded to the Jackson variety.

ECONOMIC ANALYSIS

The break-even price for each field, excluding charges for land, overhead and management, ranged from $2.25 to $3.36/bu (Table 4). Based on the weighted means for yield and total specified operating ($295.86/acre) and fixed cost ($70.36/acre), the average break-even price was $2.62/bu. Specified operating costs were 6% lower than in 1991. Lower specified production costs were primarily due to fewer fungicide and herbicide applications. The water-seeded field had the lowest production cost per bushel produced. In the future, additional water-seeded fields will be included in the RRVT program to determine if production costs are consistently lower than for dry-seeded fields. Nitrogen fertilizer was the single highest input cost, representing 13.5% of the total. Among direct crop inputs, grain drying cost represented 12.7%, herbicides 11.7%, aerial application of pesticides and fertilizer 8.8%, fungicides 3.9% and seed 8.8% of the specified operating costs.

SIGNIFICANT FINDINGS

1 In 1992 the RRVT average grain yield was over 6100 lb/acre for the second year in a row. The 1992 RRVT mean yield was the second highest in the program's ten-year history.

2 The new medium-grain variety, Orion, produced an excellent yield (7830 lb/acre) at its only location. The variety exhibited excellent tolerance to sheath blight. Blast symptoms were not found on any panicles at harvest. However, Orion does appear to have a characteristic spot on the flag leaf that could be mistaken for blast collar rot. On about 50% of the plants, a necrotic spot was found on the underneath side of the flag leaf where the collar meets the leaf midrib. This spot was attributed to wind damage and did not affect yield or cause the flag leaf to die prematurely.

3 Residual herbicides were used extensively and provided excellent season-long grass control. Facet was used at five locations as a delayed pre-emergence application of both barnyardgrass and broadleaf signalgrass. Bolero was used alone on two dry-seeded fields as a delayed pre-emergence to control barnyardgrass and sprangletop.

4 The first water-seeded RRVT field was successful in controlling red rice. This field also had the lowest production cost, $2.25/ bu, of the nine RRVT fields. The RRVT program will include more water-seeded fields in the future to collect agronomic and economic information.

Table 1. Acreage, soil series, previous crop, yield and cultivar for the 1992 Rice Research Verification Trials.

County	Acres	Soil Series[z]	Previous Crop	Yield[y] Grain	Milling	Cultivar
				bu/acre	%	
Arkansas	41	Crowley & Stuttgart silt loam	Soybean	7830	63/70	Orion
Jackson[x]	120	Foley Calhoun Complex	Fallow	5760	66/71	Katy
Jackson-W[w]	86	Jackport silty clay loam	Soybean	5985	56/65	Jackson
Jefferson	53	Perry clay	Rice	6255	56/66	Alan
Lincoln	119	Desha clay	Soybean	7155	61/70	Newbonnet
Poinsett	76	Tunica silt loam & Sharkey clay	Cotton	6390	53/68	Jackson
Prairie	64	Kobel silty clay loam	Soybean	6300	59/70	Alan
White	80	Oaklimeter & Tichnor silt loam	Soybean	5490	61/73	Millie
Woodruff	52	Calhoun & Calloway silt loam	Soybean	5580	62/70	Katy
Average	76.8			6264		

[z]Predominant soil series in field determined by the County Soil Survey Report
[y]Grain yields reported at 12% moisture; Milling yield = whole kernel/total
[x]Field was precision graded in 1991
[w]W stands for water seeded

Table 2. Stand density, seeding rate and nitrogen rates applied in a three-way split application with important dates during the season.

Location	Stand density	Seeding rate	Nitrogen rate	Seeding date	Emergence date	Harvest date
	plants/ft^2	lb/acre	lb/acre	-----------	month/day	-----------
Arkansas	28	96	41-41-46-46	4/16	4/28	9/09
Jackson	27	135	78-20-30-30	4/11	4/29	9/27
Jackson-W[z]	36	135	76-32-32	5/15	5/21	9/12
Jefferson	13	119	115-46-46	4/15	5/01	9/09
Lincoln	12	113	32-65-30-30	4/13	5/01	9/25
Poinsett	23	148	96-30-30	4/08	4/18	9/09
Prairie	29	131	83-46-46	4/27	5/14	9/23
White	25	136	58-46-30	4/24	5/14	9/15
Woodruff	19	135	83-46-46	4/11	4/20	10/5

[z]W stands for water seeded.

Table 3. Pesticide[z] use on the 1992 RRVT fields.

Location	Pesticide Treatments and (Dates) of Application[y]
Arkansas	Facet 0.75 lb + Crop Oil 1 pt (4/24); 2,4-D 1 qt (6/25)
Jackson-	Arrosolo 2 qt + Bolero 2 pt (4/24); Propanil 4 qt (5/16)
Jackson-W[x]	Bolero 4 pt (5/05); Propanil 3 qt + Grandstand 0.67 pt (6/25) 10 acres; Collego (7/18); Rovral 1 pt (7/18) 30 acres; Rovral 1 pt (7/24) 20 acres
Jefferson	Bolero 4 pt (4/24); Propanil 3 qt (6/08) 40 acres; Benlate 1 lb (7/20)
Lincoln	Bolero 4 pt (4/25); Whip Propanil 3 qt + Buctril 1 pt (6/17); Benlate 1 lb (7/30); Benlate 1 lb (8/07) 49 acres; Benlate 1 lb (8/15) 70 acres
Poinsett	Facet 0.75 lb + Crop Oil (4/24); Ordram rate (6/01) 11 acres; Propanil 4 qt + 32% Nitrogen (6/24) 4 acres; Benlate 1 lb (7/23)
Prairie	Facet 1 lb (5/08); Benlate 1 lb (8/08); Sevin 80S 2 lb (8/07) 3 acres
White	Facet 0.75 lb (5/09); 2,4-D 1 qt (7/03); Sodium Chlorate 6 lb (9/10)
Woodruff	Facet 0.75 lb + Crop Oil (5/15); Propanil 4 qt on 5 acres (5/15); Whip (6/08) 7 acres, 2,4-D 1 qt (6/25)

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

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

[x]W stands for water seeded

Table 4. Selected economic information from the 1992 Rice Research Verification Trials.

County	SCI[z]	SOC[y]	SFC[x]	TSC[w]	Break-even[v]
	$/acre	$/acre	$/acre	$/acre	$/bu
Arkansas	106.54	341.25	105.00	446.25	2.66
Jackson-W[u]	94.75	350.65	32.20	299.76	2.25
Jackson	154.77	267.56	79.70	430.35	3.36
Jefferson	114.86	293.35	79.75	373.10	2.68
Lincoln	118.71	297.64	66.93	364.57	2.29
Poinsett	102.51	304.00	73.69	377.69	2.66
Prairie	109.40	275.85	66.53	342.38	2.45
White	87.52	259.62	81.40	341.02	2.80
Woodruff	92.38	247.46	65.74	313.20	2.41
Mean	112.74	295.86	70.36	366.22	2.62

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

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

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

[w]TSC = Total specified operating and ownership cost

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

[u]W stands for water seeded

MANAGEMENT OF AGRONOMIC FACTORS IN RICE PRODUCTION

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ABSTRACT

Optimum grain yields of 'Adair', 'LaGrue', 'Bengal' and 'Cypress' were achieved at nitrogen (N) fertilizer rates of 120 to 150 lb N/acre; 'Lacassine' generally required 150 lb N/acre; and 'Delmont' required at least 150 lb N/acre and usually 180 lb N/acre. A study on the influence of soil moisture and time of application of the preflood N on preflood ^{15}N fertilizer uptake, loss and grain yield of rice indicated that preflood N should be applied to dry soil and flooded in 5 to 10 days. Preflood fertilizer N applied onto muddy soil usually resulted in lower grain yields of rice, even when flooded within 5 days. Research on the effect of split applying the preflood N showed that excellent grain yields of semidwarf cultivars were achieved when 25% or less of the preflood N was split-applied preplant or preflush. Split application of the preflood N into the water after flooding resulted in inferior grain yields. Studies on the accumulation and partitioning of N by the rice plant revealed that N loss from the plant was influenced by climate, cultivar and N fertilizer rate. Semidwarf cultivars appeared to translocate N more efficiently than standard-stature cultivars.

INTRODUCTION

The central focus of this research project is to determine the influence that nitrogen (N) from fertilizers, crop residues and soils has on rice production. 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.

Frequently, untimely rains at the preflood N fertilizer application time have left the soil saturated, and producers have questioned when and how they should apply and manage the preflood N fertilizer in this situation. Questions that need to be answered are how much of the N fertilizer applied to dry and muddy soil surfaces is lost and how long after the urea is applied to each of these soil surfaces does a producer have to get a flood across the field. A study was conducted for two years to determine how much N is lost, how much N is utilized by the rice crop and the effect on rice grain yields when urea is applied onto dry and muddy soil up to 10 days prior to flooding.

The large preflood N rates required by the new rice cultivars to obtain optimum yields are difficult to apply evenly with aerial application. Producers have questioned if they can split-apply some of the preflood N fertilizer preplant, preflush or postflood without a detrimental loss in N uptake and rice grain yield. First-year results are reported from a study on the N uptake and grain yields of rice when a portion of the preflood N fertilizer was split-applied at preplant, preflush or postflood.

Basic understanding of how the rice plant accumulates and partitions N from fertilizer and soil helps in planning future N fertilizer application and management strategies in rice as well as in breeding more N-efficient cultivars. The study on the accumulation and partitioning of N in the rice plant using the isotopic tracer N-15 provided results on the transfer of N to the panicle and the loss of N from the rice foliage.

PROCEDURES

Six cultivars were included in the N fertilizer response study in 1992. Delmont and Lacassine were in their second and last year of study; Cypress, Bengal, Adair and LaGrue were in their first year. Delmont, Lacassine, Cypress and Bengal are semidwarf; Adair and LaGrue are upright cultivars.

Fertilizer N response curves were developed utilizing the conventional three-way split application method (i.e. preflood, 1/2-in. internode elongation (I.E.) and 1/2-in. I.E. + 10 days). Fertilizer N rates ranged from 0 to 180 lb N/acre for all cultivars, except the semidwarfs in 1992, which had an additional N rate of 210 lb N/acre. The four locations and soils on which the study was conducted were as follows: Rice Research and Extension Center (RREC), Stuttgart, Arkansas, Crowley silt loam; Northeast Research and Extension Center (NEREC), Keiser, Arkansas, Sharkey clay; Pine Tree Experiment Station (PTES), Colt, Arkansas, Calloway silt loam; and Southeast Branch Experiment

Station (SEBES), Rohwer, Arkansas, Perry clay. A randomized complete block experimental design with five replications was utilized.

Investigation of the effect of soil moisture condition and time of fertilizer N application prior to flooding on the N loss, N uptake and grain yields of 'Lemont' rice was conducted at RREC on a Crowley silt loam. Preflood N treatments consisted of applying ^{15}N-labeled urea at a rate of 120 lb N/acre onto dry and muddy soil 0, 5 and 10 days prior to flooding. Measurement parameters included ammonia-N volatilized, fertilizer and soil N uptake, fertilizer N in the soil and grain and total dry matter yield. A split plot experimental design with four replications was utilized.

The study on the influence of split applying the preflood N application on fertilizer N uptake and grain yields of Lemont rice was conducted at RREC on a Crowley silt loam. Urea labeled with ^{15}N was applied at a 120-lb N/acre rate in a single preflood and preplant application and in a variety of split applications where a portion of the preflood N was applied at preplant, preflush or postflood. Measurement parameters included fertilizer N uptake, total N uptake, total dry matter and 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. Three cultivars, 'Newbonnet', Lemont and 'Lebonnet', were used in the studies because they represent the types of rice cultivars grown in Arkansas. Urea labeled with ^{15}N was applied in two split applications at 80, 120, 160 and 200 lb N/acre in one study; in the other two studies, the preflood N (120 lb N/acre) and the midseason N (45 lb N/acre) accumulation in the plant 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. Measurement parameters included total dry matter and fertilizer and total N uptake in individual plant parts and in the total plant. Split-plot and randomized complete block experimental designs were used.

RESULTS AND DISCUSSION

Delmont grain yields peaked at N rates of 150 to 180 lb/acre at all locations in both 1991 and 1992 (Table 1). Lacassine showed no significant grain yield increase in 1991 when more than 150 lb N/acre was applied at NEREC and SEBES (Table 2). Grain yield increases through 180 lb N/acre were found at RREC in 1991; however, Lacassine showed no significant grain yield increase when more than 120 lb N/acre was applied at PTES in 1991. No significant grain yield increases to N rates greater than 150 lb/acre were measured at any of the locations in 1992. At RREC in 1992, only 120 lb N/acre was required for maximum yields.

Cypress reacted somewhat differently than the other semidwarfs (Table 3). Cypress showed no significant grain yield increase when more than 90 lb N/acre was applied at NEREC and when more than 120 lb N/acre was applied at RREC and SEBES. Cypress showed no significant grain yield increase when more than 90 lb N/acre was applied at PTES due to an increase in sheath blight at the higher N rates.

Bengal showed no significant grain yield increase when more than 120 lb N/acre was applied at all locations except NEREC where only 90 lb/acre was required (Table 4). There were trends towards higher yields at all locations when 150 lb N/acre was applied. These three new semidwarfs released by Louisiana (i.e., Bengal, Cypress and Lacassine) appear to have the high yield potential of the older semidwarfs; however, they require 30 to 60 lb/acre less N.

Adair (Table 5) and LaGrue (Table 6) produced excellent grain yields at all locations except RREC. This was due to land leveling conducted in 1991, the results from which caused seedling damage and significant loss of stand and plant vigor. Consequently, the data from RREC for these two cultivars are not included. In general, 120 lb N/acre resulted in excellent yields at the other locations. Only at PTES was 150 lb N/acre required for Adair and LaGrue to reach maximum yields.

A study with the Lemont variety utilizing ^{15}N showed that soil moisture and time interval between preflood N application and flooding influenced the preflood N taken up by the rice crop and, ultimately, the rice grain yield. In general, more fertilizer N was taken up by the rice and less lost via ammonia volatilization when the fertilizer N was applied onto dry soil compared to muddy soil (Table 7). Time of application had little effect on fertilizer N uptake when N was applied onto dry soil in 1990. Significantly more fertilizer N was taken up in 1991 and less lost via ammonia volatilization when N was applied onto dry soil the day of flooding compared to 10 days prior to flooding.

Time of application had the most significant effect on fertilizer N uptake and loss when the fertilizer N was applied onto muddy soil. Significantly more fertilizer N was taken up and significantly less lost via ammonia volatilization the closer the application time was to flooding. When fertilizer N is applied onto a muddy field soil, flooding should be completed in less than five days.

Application of fertilizer N into the flood water resulted in the least fertilizer N uptake by rice and the most lost via ammonia volatilization. This was reflected in the total N uptake as well as the grain and total dry matter yields that were the lowest of all treatments studied (Table 8).

Grain and total dry matter yields were reflective of the fertilizer N uptake for all treatments studied (Table 8). Application time had no significant effect on total N uptake and grain yields when the fertilizer N was applied onto dry soil in 1990. In 1991, however, significantly more total N was taken up and higher yields resulted when the fertilizer N was applied onto dry soil the day of flooding compared to 10 days prior to flooding. In general, application of fertilizer N onto muddy soil resulted in lower total N uptakes and yields compared to fertilizer N applied onto dry soil. When the fertilizer N was applied onto muddy soil, total N uptake and yield generally increased the closer the fertilizer N application time was to flooding.

Difficulty in evenly applying the large preflood N rates required by the semidwarf cultivars has necessitated the split application of the preflood N with a portion applied at preplant, preflush or postflood. Results from the first year of a study on the influence of split applying the preflood N on rice growth indicated that some of the preflood N can be split applied preplant or preflush without reducing rice yields. Highest rice grain yields were achieved when the urea was applied in a single application preflood or in a split application of 25% applied preplant or preflush and 75% applied preflood. Grain yields declined significantly when 50% of the preflood N was applied preplant or preflush. Inferior grain yields always resulted when 25% or more of the preflood N was split applied into the flood water 1 to 2 weeks postflood. Fertilizer N applied in a single preplant application resulted in the lowest grain yield. The efficiency ranges with which the fertilizer ^{15}N applied preplant, preflush, preflood and postflood was taken up by the rice crop were 27 to 40%, 53 to 57%, 76 to 80% and 13 to 20%, respectively. The second study on the accumulation and partitioning of ^{15}N-labeled urea by the rice plant was completed in 1992. It appears 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 loss is added to the fertilizer N loss, the overall loss can be as great as 40 to 60 lb N/acre from the rice plant per year. The N loss from the rice plant appears to be influenced by year (climate), cultivar and N fertilizer rate. The standard-stature rice cultivars such as Lebonnet appear to lose more N than the semidwarfs and require midseason N to a greater degree because they are not as efficient in their translocation to the panicle of preflood N accumulated in the leaves. In addition, it appears that more N is lost from the rice plant at high N rates. The N loss from the rice plant varies from year to year and, thus, is probably influenced by climate.

SIGNIFICANCE OF FINDING

The N fertilizer rate study determined that for optimum yield, the new cultivars Adair, Bengal, Cypress and LaGrue will require 120 to 150 lb N/acre; Lacassine will usually require 150 lb N/acre; and Delmont will require 150 to 180 lb N/acre. Preflood N should be applied to dry soil and the field flooded in 5 to 10 days. When preflood N is applied to muddy soil, the field should be flooded in 5 days or less. Application of preflood N to muddy soil was inferior to application on dry soil but superior to application into the flood. The high preflood N rate required by semidwarfs can be split applied at preplant or preflush without a reduction in yield if at least 75% is applied preflood. Nitrogen loss from the rice plant is influenced by climate, cultivar and N rate. Semidwarfs appear to translocate N more efficiently than do standard-stature cultivars.

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

	Grain yield by location							
	NEREC[z]		PTES		RREC		SEBES	
N rate	1991	1992	1991	1992	1991	1992	1991	1992
lb N/acre	lb/acre							
0	2926	2282	4060	3473	2935	3049	2146	3645
60	4881	4703	6107	5386	3872	4795	3085	5158
90	5713	5565	6291	6508	5283	5489	3894	5873
120	7060	6924	7368	6975	6101	6286	5902	6708
150	7954	7095	7619	7268	6885	7348	6783	7398
180	8575	7387	7598	7469	7629	6862	6995	7201
210	—	7296	—	7626	—	6548	—	7111
LSD 0.05	732	770	542	555	789	1316	755	611

[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 'Lacassine' rice as influenced by nitrogen (N) fertilizer rate and location.

	Grain yield by location							
	NEREC[z]		PTES		RREC		SEBES	
N rate	1991	1992	1991	1992	1991	1992	1991	1992
lb N/acre	lb/acre							
0	2378	2708	3731	4521	3241	3895	1980	3914
60	4207	5162	5820	6166	3974	6139	2985	6199
90	5086	6781	5959	7126	4819	6295	5142	6458
120	6111	7294	7023	7612	5709	6800	6092	8057
150	7136	8312	7316	7847	7060	7030	7632	8871
180	7723	8441	7475	8308	7996	7019	7763	9051
210	---	8552	---	8126	---	6908	---	8813
LSD 0.05	659	924	1215	663	533	555	847	892

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

	Grain yield by location			
N rate	NEREC[z]	PTES	RREC	SEBES
lb N/acre	lb/acre			
0	3211	5033	2861	3643
60	5587	6610	4188	5540
90	6485	7214	3993	6030
120	7585	7400	4913	6362
150	7655	7624	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 4. Grain yield of 'Bengal' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

	Grain yield by location			
N rate	NEREC[z]	PTES	RREC	SEBES
lb N/acre	lb/acre			
0	3831	5083	3900	3127
60	6211	7002	4811	6647
90	7969	7228	5768	7803
120	7937	8163	6300	8939
150	8145	8330	6554	9349
180	8543	8512	6265	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 'Adair' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

N rate	Grain yield by location			
	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	8231	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 6. Grain yield of 'LaGrue' rice as influenced by nitrogen (N) fertilizer rate and location in 1992.

N rate	Grain yield by location			
	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 7. Influence of application time and soil moisture condition on fertilizer nitrogen (N) uptake, total recovery and ammonia volatilization loss in dry-seeded 'Lemont' rice, Rice Research and Extension Center, Stuttgart, Arkansas.

Application time prior to flood	Soil moisture	Fertilizer N recovery: Plant 1990	Plant 1991	Soil[z] 1990	Soil[z] 1991	Ammonia Loss 1990	Ammonia Loss 1991	Total 1990	Total 1991
days		% of applied N							
10	dry	63	67	19	16	11	7	93	90
10	mud	40	44	12	13	33	27	85	83
5	dry	68	73	19	17	5	3	92	93
5	mud	47	52	15	16	27	17	89	85
0	dry	69	76	23	18	2	<1	94	95
0	mud	51	62	14	13	25	6	90	91
0	flood	26	30	13	14	45	39	84	83
LSD 0.05		6	7	4	5	4	5	9	9

[z]Greater than 95% of fertilizer N recovered in the soil was in organic N form.

Table 8. Influence of application and soil moisture condition on the yield and total nitrogen (N) uptake of dry seeded rice.

Application time prior to flood	Soil moisture	Total N uptake[z] 1990	Total N uptake[z] 1991	Grain Yield 1990	Grain Yield 1991	Total dry weight 1990	Total dry weight 1991
days		— kg N/ha—		kg/ha			
10	dry	156	174	6319	7187	12264	13859
10	mud	112	127	5246	5641	10336	11352
5	dry	166	197	6572	7519	12841	14459
5	mud	126	148	5493	6203	10938	12276
0	dry	171	203	6670	7781	12805	15256
0	mud	130	170	5673	6931	11217	13217
0	flood	88	97	3874	4513	7844	8777
LSD 0.05		16	19	418	474	831	887

[z]Total N uptake determined at maturity

SHOOT AND ROOT GROWTH OF EIGHT RICE CULTIVARS

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ABSTRACT

Shoot dry weights, root lengths and yields were measured on eight rice cultivars representing early- and late-maturity groups. Early-maturing cultivars generally had shorter root systems than late-maturing cultivars. Cultivar differences in shoot and root growth were also found within maturity groups. The pattern of root development was similar for all cultivars, with maximum root length at booting and net root senescence between heading and physiological maturity. Average yields were the same for both maturity groups.

INTRODUCTION

Many aspects of rice production directly impact the growth and development of root systems. Some of these factors include fertilizer and water management, tillage and pathogen infestation. Yet surprisingly little is known about rice root growth and the impact of root growth on shoot growth and grain yields. In addition, a data base is needed that describes differences in root growth characteristics for the major rice cultivars grown in Arkansas. This information could be used for selection of cultivars with unique rooting characteristics necessary for specific management practices. Consequently, a two-year study was conducted to characterize root and shoot growth of eight rice cultivars commonly grown in Arkansas.

PROCEDURES

A field study was conducted in 1991 and 1992 on a Crowley silt loam (Typic Albaqualfs) at the Rice Research and Extension Center (RREC) near Stuttgart, Arkansas. Eight cultivars were selected from two maturity groups, an early-maturing group in which heading occurred in less than 90 days after seedling emergence and a later-maturing group in which heading occurred 90 days or more after emergence (Table 1). Each maturity group contained one semi-dwarf, one tall-statured and two short-statured cultivars. At the time the study was initiated, these eight cultivars comprised nearly 95% of the total rice acreage in Arkansas. For both years, plots were seeded on 15 May, and seedling emergence was on 21 May. Each plot contained two clear plexiglass tubes (3 in. by 3 in. by 36 in.) located within two rice rows, oriented at a 45-degree angle to the soil surface and vertically extending 20 in. below the soil surface. Images of roots growing along the upper two sides of each tube were obtained with a microvideo camera. These image measurements were made at five physiological growth stages: maximum tillering (MT), 1/2-in. internode elongation (IE), booting (B), heading (HD) and physiological maturity--harvest (H). A 1.5-ft length of row (all above-ground plant parts) was harvested from each plot at corresponding dates of root measurements, and total dry weights were determined. The middle four rows of each plot, measuring 12 ft in length, were harvested at physiological maturity. Yields are reported as lb/acre at 12% moisture.

RESULTS AND DISCUSSION

The pattern of root length development was the same for all cultivars and did not differ between maturity groups (Fig 1). A rapid increase in root length was measured during vegetative and reproductive growth with maximum length at booting. Net root length remained relatively constant between booting and heading and then decreased significantly by harvest. Similar patterns of root length development have been measured in all of our field studies since 1985. Although not statistically significant, diversity in root length was found among cultivars within a maturity group and between maturity groups (Table 2). Root length ranged between 53 and 71 cm for the early-maturing cultivars and between 62 and 94 cm for the late-maturing cultivars. There was no apparent relationship between root length and plant size. 'Texmont', the semi-dwarf, early-maturing cultivar, had an intermediate root length, and 'Lemont', the late-maturing semi-dwarf, had the longest roots.

Average total shoot dry weights were about 340 lb/acre lower for the early-maturing cultivars (Table 3). It is interesting that of the early-maturing cultivars, 'Tebonnet' had the longest roots and highest shoot dry weight, and 'Maybelle' had the shortest roots and lowest shoot dry weight. The opposite pattern was observed for the late-maturing cultivars. 'Newbonnet' had the shortest root length but highest shoot dry weight, and Lemont had the longest roots but lowest shoot dry weight.

In this study, the early-maturing cultivars had shorter root systems and lower shoot dry weights than the late-maturing cultivars. However, differences in root growth between maturity groups did not translate into grain yield differences (data not shown). Shorter-season cultivars condense both vegetative and reproductive development into a smaller window of growth. This window is apparently of sufficient size to allow for adequate plant development necessary for optimum grain yields.

SIGNIFICANCE OF FINDINGS

We are just beginning to develop a data base such that cultivars can be chosen for differences not only in shoot growth but in root growth. Development of alternative water and fertility management schemes may necessitate selection of a rice cultivar with specific root growth characteristics. For example, with reduced water inputs, deeper-rooting cultivars should be preferred. Plant response to stresses such as those imposed by improper water or fertilizer management may differ among cultivars. An understanding of the growth of the entire plant may provide an explanation for growth differences observed under a variety of conditions and provide additional information for managers and researchers to use when choosing cultivars.

As shorter-season cultivars are developed, both shoot and root growth appear to be reduced. With even shorter-season cultivars, it is possible that the time available for vegetative development could be narrowed to the point that root and shoot growth is not sufficient to support satisfactory grain yields.

Table 1. Stature and maturity characteristics of the eight cultivars chosen for this study.

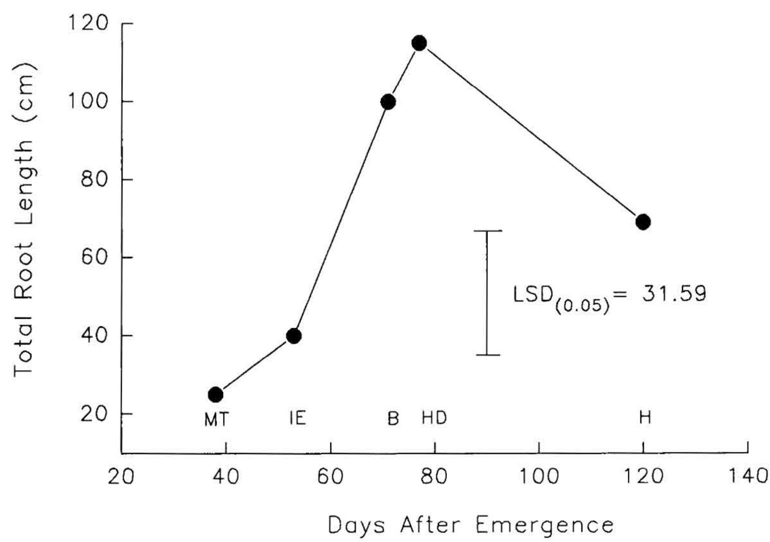
Cultivar	Stature	Days to Heading	Maturity
Alan	Short	76	Early
Maybelle	Short	78	Early
Tebonnet	Tall	82	Early
Texmont	Semi-dwarf	87	Early
Mars	Tall	90	Late
Lemont	Semi-dwarf	94	Late
Newbonnet	Short	95	Late
Katy	Short	95	Late

Table 2. Root lengths of eight rice cultivars averaged over five growth stages.

Early Maturing Cultivars	Length	Late Maturing Cultivars	Length
	cm		cm
Tebonnet	71	Lemont	94
Texmont	59	Mars	81
Alan	57	Katy	78
Maybelle	53	Newbonnet	62
Ave	60	Ave	79

Table 3. Dry weights of eight rice cultivars averaged over five growth stages.

Early Maturing Cultivars	Weight	Late Maturing Cultivars	Weight
	lb/acre		lb/acre
Tebonnet	7909 a	Newbonnet	8183 a
Alan	7364 ab	Katy	7974 a
Texmont	6746 bc	Mars	6970 b
Maybelle	6089 c	Lemont	6333 b
Ave	7027	Ave	7365



MT – mid–tillering
IE – internode elongation
B – booting
HD – heading
H – harvest––maturity

Fig. 1. Average pattern of root length development in the upper 40 cm of soil for eight rice cultivars. Vertical line indicates LSD (0.05) among growth stages.

PADDY RICE RESPONSE TO PHOSPHORUS FERTILIZATION

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ABSTRACT

A greenhouse study was conducted to evaluate the response of root and shoot growth of rice to phosphorus (P) fertilizer additions on three Arkansas soils: a Crowley silt loam from Arkansas County; a Hillemann silt loam from Cross County (Hillemann-Cross); and a Hillemann silt loam from Poinsett County (Hillemann-Poinsett). Shoot and root growth and several yield components were increased with 10 and 20 lb/acre of P added as fertilizer. However, Mehlich III extractable P did not show an increase to P addition except at the 80-lb/acre level. Plant response was lowest on the Hillemann-Cross, which had the highest pH and the highest percentage of inorganic P in the hydrous oxide-occluded phase. Evaluation of several soil test procedures are currently being conducted to enhance the current capability to predict P response on flooded soils.

INTRODUCTION

Phosphorus availability to rice plants increases following flooding of the soil. Flooding a soil has been found to increase the concentration of P in solution from less than 0.05 ppm to about 0.6 ppm (Yoshida, 1981). The critical soil test level for P is 25 lb/acre (Mehlich III) (University of Arkansas Soil Test Recommendation Guide, 1993).

Recent studies have identified several soils in Arkansas responsive to P fertilization of paddy rice (Beyrouty et al., 1991). However, the current soil test method (Mehlich III) has been unable to consistently predict P response under flooded conditions. The inconsistent rice response to P applications could result from transformation processes of P in flooded soils that are greatly different from those in nonflooded soils. An understanding of these transformation processes is important in developing analytical techniques that allow for efficient P fertilization of flooded rice.

Therefore, the objectives of this study were 1) to characterize rice response to fertilizer P application on three soils, 2) to relate changes in plant response and soil P to fertilizer P additions and 3) to relate P soil chemistry to P availability.

METHODS AND MATERIALS

The rice cultivar 'Lemont' was grown on three soils in the greenhouse: a Crowley silt loam collected from Arkansas County, a Hillemann silt loam collected from Cross County (Hillemann-Cross) and a Hillemann silt loam collected from Poinsett County (Hillemann-Poinsett). The soils were collected from the top 2 in. of control plots (zero fertilizer P added) from a P fertilizer field study (Norman et al., 1992) in which rice was found to respond to P additions. Soils were passed through a 2-mm sieve, air dried and stored. Untreated non-flooded samples of each soil were fractionated for various forms of P. Five P fertilization treatments, 0, 10, 20, 40 and 80 lb P/acre, were prepared by spraying appropriate amounts of KH_2PO_4 dissolved in solution onto bulk soil samples that were then air dried and mixed thoroughly. Sufficient water was added to increase the water content to field capacity, and the soils were incubated at constant moisture for three weeks at 25°C, following which they were air-dried and sieved in preparation for soil analysis and the greenhouse study.

Two kilograms of soil were packed into 3-liter pots to a bulk density of about 1.18 g/cm^3. Lemont was seeded and thinned to five plants/pot at the three-leaf stage. Urea fertilizer was then applied at the rate of 135 lb N/acre and the pots flooded to the 2-in. depth. At each sampling date, 37 (vegetative growth), 44 (vegetative growth) and 137 (50% heading) days after emergence, shoots were removed at soil level, the tissue dried for 72 hr at 60°C and dry weights determined. Dried shoot tissue was ground, wet ashed with sulfuric acid and hydrogen peroxide and analyzed for total P. For the plants sampled at 137 days after emergence, panicles were removed, and the number of panicles and florets and floret weight per pot were counted. Soil was washed from the roots harvested from each pot, and root lengths and dry weights were measured.

RESULTS AND DISCUSSION

Both soil and P fertilization affected shoot and root growth. Root and shoot dry weight (averaged over the three harvest dates) and number of panicles and florets harvested per pot (at 137 days after emergence only) were lowest for rice grown on the Hillemann-Cross (Table 1). Note that the pH of this soil was 7.8 in contrast to the somewhat acidic pH values for the Crowley silt loam and the Hillemann-Poinsett soils. Mehlich III P was lowest for the Hillemann-Cross soil, which is not surprising because of the high pH. Phosphorus availability decreases as pH increases above 6.5 to 7.0. However, soil pH cannot be used as the sole indicator of P availability. The pH values of the Crowley and the Hillemann-Poinsett soils were similar; yet the Mehlich III soil P value for the Crowley was nearly triple that of the Poinsett County soil. Phosphorus fractionation of the three soils showed that hydrous oxide-occluded P was highest on the Hillemann-Cross and lowest on the Crowley (data not shown). Occluded P likely is not readily available for plant uptake. An understanding of the chemistry of these three soils might help explain differences in plant-available P.

Root length and yield components increased with increase in P fertilizer rates (Table 2) as did shoot dry weights (Fig. 1). Shoot dry weight response to P, however, depended upon plant growth development stage with the greatest response occurring 137 days after emergence.

It is interesting that plant growth responses were observed at the 10- to 20-lb/acre rate of P fertilization, yet an increase in Mehlich III soil P was only observed at the 80-lb/acre P fertilization rate. This would suggest that the Mehlich III is not as sensitive as plant growth in predicting a response to P fertilization. Consequently, we are looking at several different soil test methods to enhance our ability to identify P-responsive soils.

SIGNIFICANCE OF RESULTS

Results from this study showed that rice response to P fertilization was obtained on soils with soil P levels of 14 to 140 lb/acre. Response was observed in root and shoot growth and various yield parameters. Although the data are preliminary, it would appear the percentage of P in various chemical fractions may help explain some of the soil differences in plant-available P. Our results also suggest that the Mehlich III-extractable P does not appear to be as good a predictor of available soil P for rice growth. Studies are currently underway to evaluate several additional soil test methods for assessing plant available P on flooded soils.

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Table 1. Differences in pH, extractable phosphorus (P) and several plant growth parameters as a function of soil.

Soil	pH	Mehlich extractable P	Root dry wt.	Shoot to root ratio	Florets	Panicles
		lb/acre	g/pot	g:g	----- no./pot	-----
Crowley	6.6 b[z]	141 a	1.3 a	4.8 a	660 a	11.0 a
Hillemann - Poinsett	6.4 c	48 b	1.3 a	3.7 a	376 b	8.4 b
Hillemann - Cross	7.8 a	14 c	0.4 b	2.8 b	147 c	3.9 c

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

Table 2. Rice root length, yield parameters and extractable phosphorus (P) as affected by P fertilizer additions averaged over three soils.

Fertilizer P Applied	Mehlich extractable P	Root Length	Panicles	Florets	Floret wt.
---------lb/acre	---------	cm/pot	---------no./pot	---------	g/pot
0	64 b[z]	40162 d	4.6 c	188 d	0.9 b
10	57 b	53278 c	6.4 b	304 c	2.1 ab
20	61 b	63007 bc	7.8 b	428 b	2.9 a
40	72 ab	69963 b	10.3 a	470 b	2.5 a
80	86 a	93298 a	10.8 a	582 a	3.4 a

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

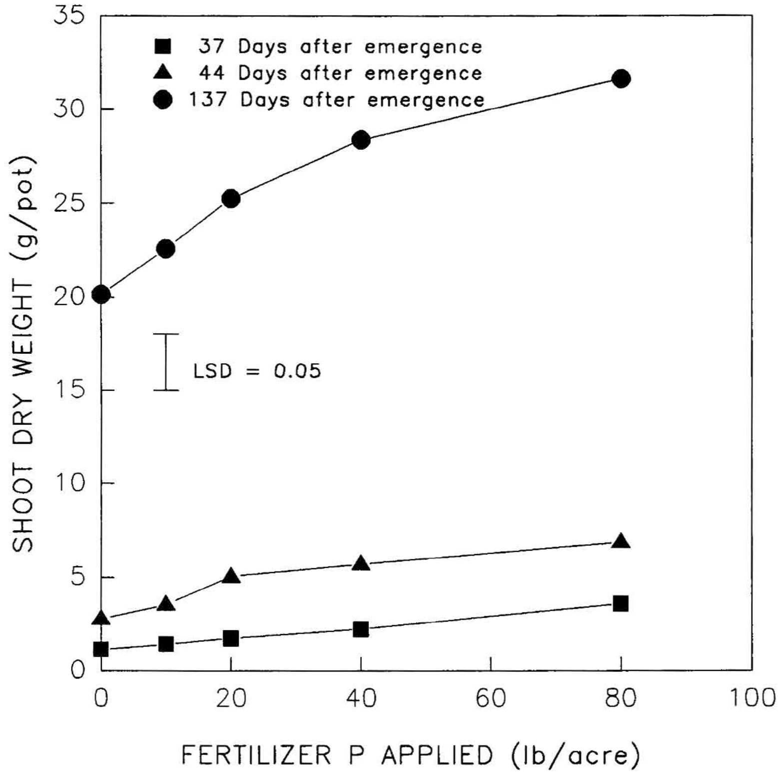

Fig. 1. Shoot dry weight response to phosphorus (P) fertilizer additions averaged over three soils at three sampling times.

YIELD RESPONSE OF RICE TO WATER AND NITROGEN MANAGEMENT

C.A. Beyrouty, R.J. Norman, B.R. Wells, M.G. Hanson and E.E. Gbur

ABSTRACT

A field study was conducted in 1991 and 1992 at the Rice Research and Extension Center near Stuttgart, Arkansas, to measure the effects of reduced water inputs and nitrogen (N) management on growth and yield of rice. Three cultivars were subjected to normal flood application or flush irrigation during a 25-day delay in flood application combined with either normal timing of the flood removal or earlier-than-normal flood removal. Superimposed on these treatments were N timings of a normal three-way split, an early three-way split or all N applied preflood. Two-year averages showed that time of application or drainage of flood and N management did not affect grain yields or shoot dry weights. However, delayed flood resulted in a 13% average reduction in plant heights.

INTRODUCTION

Research has suggested that groundwater levels in the Quaternary aquifer in some areas of the Grand Prairie will drop at least 28 ft by 1993 (Peralta et al, 1985). Increases in pumping costs could represent a 12% reduction in profits for the rice producer. Currently rice is flood irrigated at the four- to five-leaf stage and the flood is removed 14 days prior to harvest. Approximately 2 acre-ft of water is required to irrigate rice throughout the growing season. Under current water management, when sources of ground water become inadequate for rice production, the producer will have the options of finding an alternative source of water or growing a different crop. However, we have been conducting research since 1987 to determine if rice can be satisfactorily grown in a limited flooding environment. Results with the cultivar 'Tebonnet' have been very promising and suggest that response depends upon soil series and N timing. Consequently, we have continued our studies to evaluate the yield response of three rice cultivars to water and N management.

PROCEDURES

A field study was conducted in 1991 and 1992 on a Crowley silt loam (Typic Albaqualfs) at the Rice Research and Extension Center (RREC) near Stuttgart, Arkansas. Soil characteristics of the upper 4 in. were pH (1:1 wt/wt soil:water mixture), 5.4; organic matter, 0.9%; extractable P, 9 lb/acre; exchangeable K, 151 lb/acre.

Three rice cultivars, 'Alan',Tebonnet and 'Texmont', were seeded on 15 May in 9-row plots measuring 15 ft by 6 ft with 7-in. spacing between rows. Each cultivar was subjected to four water management and three N timing treatments. The water management treatments were 1) flood applied at four- to five-leaf stage and removed 21 days after heading (normal flood), 2) flood applied at 1/2-in. internode elongation (IE) and removed 21 days after heading (delayed flood), 3) same as treatment 1 but flood removed 7 to 10 days earlier (normal flood-early removal) and 4) same as treatment 2 but flood removed 7 to 10 days earlier (delayed flood-early removal). Plots subjected to a delayed flood were flush irrigated until application of the permanent flood. Flush irrigation was applied when tensiometers placed at the 4-in. soil depth read -0.3 bar or less. Water from the flush irrigations remained on plots for 15 to 18 hours before removal.

Nitrogen treatments consisted of 1) a three-way split application as recommended (normal N), 2) a three-way split application with the second and third splits applied at panicle differentiation (PD) minus 10 days and at PD, respectively (early N) and 3) all N applied preflood (preflood). Nitrogen was applied as urea at recommended rates (University of Arkansas Cooperative Extension Service, 1988). When N was applied to non-flooded plots, fertilizer was applied to a dry soil surface followed by flushing, as described previously.

Plots were maintained weed free with Propanil and Thiobencarb applied on 24 May at 2 lb/acre active ingredient each and on 10 June at 3 lb/acre active ingredient each. Bensulfuron was also applied on 17 June at 0.5 lb/acre active ingredient.

Flood treatments were arranged as individual strips within each of two blocks. Cultivars were randomly located in two blocks within each strip. Nitrogen treatments were superimposed on each cultivar-water treatment combination. The experimental design was a split-split plot with water management as the whole plot, cultivar as the first split and

N timing as the second split. Each treatment combination was replicated four times.

RESULTS AND DISCUSSION

Heights of plants subjected to flush irrigation and delayed flood were reduced from 9 to 16% below plants subjected to normal flood timing (data not shown). Total plant dry weights were not affected by water or nitrogen management and did not differ among cultivars (data not shown). Reduction in plant height as a result of delayed application of the floodwater did not translate into a yield reduction. Average grain yields for the two years of the study were not affected by water or N management (Table 1). However, there were differences in yields among the three cultivars. Texmont consistently yielded the lowest among the three cultivars, averaging 4977 lb/acre, and Tebonnet was the highest yielding cultivar, averaging 5560 lb/acre.

SIGNIFICANCE OF RESULTS

Results from this and previous studies suggest that reduced water inputs should not result in significant yield reductions on a silt loam soil. Neither a delay in flood water application until internode elongation nor early draining negatively impacted yields; however, plots receiving delayed flood were flush irrigated prior to flooding to reduce water stress. Our previous studies show that rice does need the presence of the floodwater during reproductive growth. Yields have been shown to be severely depressed when rice has been flush irrigated during this period of plant development. There apparently is a physiological basis for maintaining a flood during reproduction for our modern cultivars.

Nitrogen timing did not affect yields. Nitrogen applied all preflood resulted in grain yields equal to those where N was applied as a three-way split. It should be noted, however, that plots were immediately flushed following N application, thus minimizing volatilization losses.

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Table 1. Grain yield response of three rice cultivars to timing of floodwater application and drainage, 1991-1992, Rice Research and Extension Center, Stuttgart, Arkansas.

Flood	Drain	Cultivar		
		Alan	Tebonnet	Texmont
		---------------------lb/acre---------------------		
Delayed	Early	5718 a[z]	5595 a	4989 b
	Normal	5532 a	5573 a	4937 b
Normal	Early	4974 b	5287 a	5013 b
	Normal	5251 b	5786 a	4967 c

[z]Means within the same flood-drain combination followed by the same letter are not significantly different (P = 0.05).

EVALUATION OF A MODEL TO PREDICT NUTRIENT UPTAKE BY FIELD-GROWN RICE

Y.H. Teo, C.A. Beyrouty, R.J. Norman, B.R. Wells and E.E. Gbur

ABSTRACT

A field study was conducted on a Crowley silt loam at the Rice Research and Extension Center (RREC). Stuttgart, Arkansas, to evaluate the ability of a model to predict nitrogen (N), phosphorus (P) and potassium (K) uptake by rice. Three cultivars ('Lemont', 'Katy' and 'Mars') were selected for this study based on their diverse N fertilization requirements. The model accurately predicted nutrient uptake during vegetative growth but underpredicted uptake during reproductive growth. It is postulated that rapid root senescence during reproductive growth prevented accurate estimation of root length development during this stage of growth and resulted in the underprediction. Approximately 90% of the total N, P and K uptake and root length of the rice cultivars occurred within the surface 10 in. of the soil. Nitrogen and P uptake in the top 2 in. of soil were most sensitive to root competition and nutrient solution concentration. Potassium uptake was most sensitive to maximum influx rate by the plant and root radius.

INTRODUCTION

Plant roots are important for absorption of nutrients and water. Root length and radius can influence nutrient uptake as can root surface area and the rate of root growth. The mean rate of nutrient uptake per unit of root surface area depends upon the uptake kinetics of the root and the nutrient supply characteristics of the soil.

A mathematical model that can describe nutrient uptake by plants as affected by root and soil factors can increase our understanding of how plants obtain nutrients and can be useful for improving the efficiency of fertilizer management. Such models have been developed that accurately predict soil nutrient uptake by plants. The models relate size and morphology of the root system, kinetics of nutrient absorption by the root and supply of soil nutrients to the root by mass flow and diffusion to calculate nutrient uptake.

Research that we recently conducted in a greenhouse showed that the Barber and Cushman (1981) uptake model can be used to predict N, P and K uptake by rice (*Oryza sativa* L.) grown under flooded condition (Teo et al., 1992). Nitrogen uptake was most sensitive to root growth rate, N concentration in the soil solution and the distance between roots. Parameters most influencing P and K uptake by rice were root growth rate, root radius and maximum influx rate.

These results are from an evaluation of this model to predict nutrient uptake by paddy rice under field conditions. The main objectives of this research were to further evaluate the ability of the model to predict N, P and K uptake by rice grown under field conditions and to conduct sensitivity analyses to determine how each soil and plant parameter influences nutrient uptake.

PROCEDURE

A nutrient uptake study was conducted at RREC on a Crowley silt loam (Typic Albaqualfs, pH = 5.0), using three rice cultivars (Katy, Mars and Lemont). Plots, nine rows (7-in. spacing) wide by 32 ft long, were seeded on 14 May 1991. Emergence was 21 May for the three cultivars. Plots were flooded at the four-leaf stage (11 June). Urea nitrogen was applied to all plots as a three-way split. At preflood 120, 65 and 50 lb N/acre were applied for Lemont, Katy and Mars, respectively. At both 1/2-in. internode elongation (IE) and 1/2-in. IE + 10 days, 30 lb N/acre was applied to Lemont and Mars and 35 lb N/acre was applied to Katy. Stages of growth and timing of rice management practices were determined by visual inspection and the DD_{50} computer program.

Plants (above-ground parts) were harvested from 1.6 ft of row from each plot at 36, 41, 59, 77 and 88 days after emergence. At 36 and 41 days after emergence, rice was at the tillering stage, and at 59, 77 and 88 days after emergence, rice was at 1/2-in. IE, 50% booting and 50% heading, respectively. Plant samples were dried in an oven at 65°C, dry weights determined and analyzed for total N, P and K content.

Soil-root cores were taken in 2-in. increments to a depth of 18 in. at each harvest date. Roots were separated from soil by wet sieving, and root lengths (L) were determined with the line-intercept method.

Soil and plant data were inputs into a microcomputer program to predict nutrient uptake (Oates and Barber, 1987). Nutrient uptake for roots growing in each soil depth was calculated separately. The relationship between predicted and observed N, P and K uptake was modeled using analysis of covariance. The covariate was observed elemental uptake by the plant, and the factor was rice cultivar.

Sensitivity analyses were conducted to estimate the influences of soil and plant factors on N, P and K uptake by rice grown under field conditions.

RESULTS AND DISCUSSION

There was good agreement between predicted and observed N (slope = 1.08), P (slope = 0.889) and K (slope = 1.052) uptake by rice during vegetative growth, and these relationships were independent of cultivar (Figs. 1, 2 and 3). However, the model underpredicted N, P and K uptake during reproductive growth by about 66, 38 and 53%, respectively. We were unable to account for the total length of roots developed in a given interval of time during reproductive growth because of the rapid senescence of roots. This likely contributed to the underprediction of nutrient uptake.

We can use this model during vegetative growth to locate depths within a soil profile where the greatest uptake of nutrients occurs and can also identify the soil or plant factors contributing most to nutrient uptake. This information should aid in developing and refining fertilizer management strategies and identifying plant characteristics to consider when choosing cultivars for high or low fertility regimes.

Using the data from the model during vegetative growth only, about 90% of the total uptake of N, P and K and total root length of rice occurs within the 0- to 10-in. soil depth (Table 1). The parameters most influencing N and P uptake at the 0- to 2-in. soil depth were root competition and nutrient solution concentration. However, parameters most influencing K uptake were maximal influx rate and root radius.

SIGNIFICANCE OF RESULTS

These data suggest that N and P uptake by rice can be enhanced by increasing levels of fertilization in situations where these nutrients are found to be limiting. Potassium soil levels were not low enough to limit uptake and, where desirable, enhanced plant uptake can be achieved by selecting cultivars with an increased capacity to absorb soil K.

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Table 1. Percentage of total nutrient uptake and associated root length with depth during vegetative growth.

Depth	N	P	K	Root Length
in.		%		
0 - 2	49.1	57.0	60.0	49.0
2 - 4	16.0	26.0	14.0	25.0
4 - 8	13.2	10.0	12.0	14.0
8 - 10	9.0	3.4	3.5	6.4
10 - 12	4.0	1.4	3.3	2.4
12 - 14	3.6	0.8	3.2	1.4
14 - 16	3.0	0.7	3.0	0.9
16 - 18	2.1	0.7	1.0	0.9

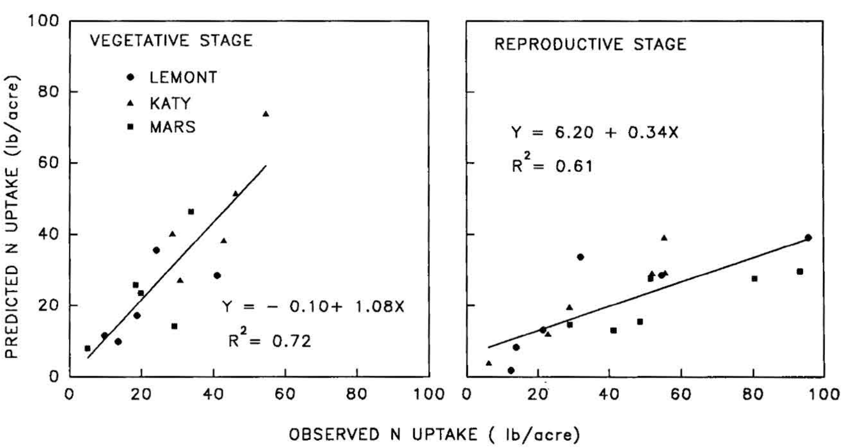

Fig. 1. The relationship between observed and predicted nitrogen uptake by three rice cultivars during vegetative and reproductive growth.

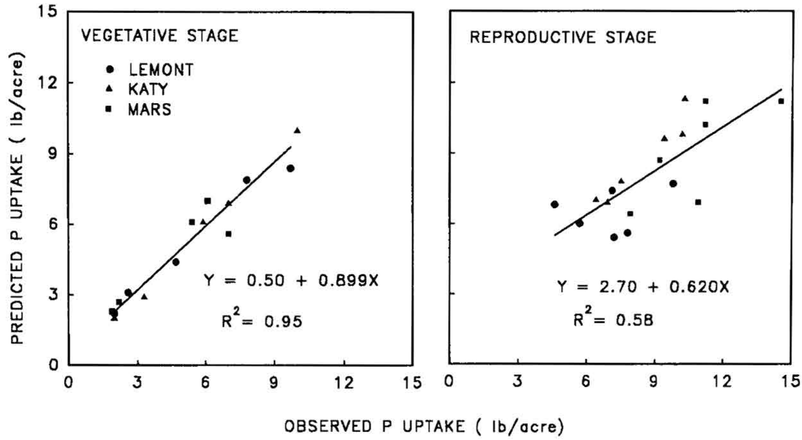

Fig. 2. The relationship between observed and predicted phosphorus uptake by three rice cultivars during vegetative and reproductive growth.

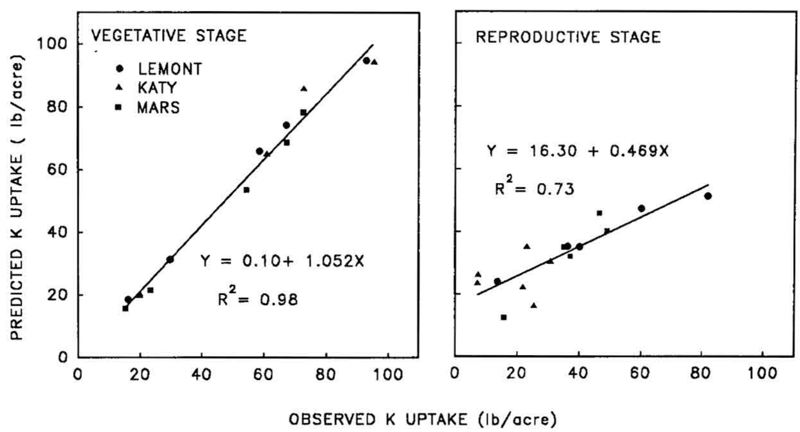

Fig. 3. The relationship between observed and predicted potassium uptake by three rice cultivars during vegetative and reproductive growth.

USE OF PLANT AREA MEASUREMENTS TO ESTIMATE MID-SEASON NITROGEN RATES FOR RICE

B.R. Wells, R.J. Norman and R.S. Helms

ABSTRACT

Field studies were conducted in 1992 on a Crowley silt loam soil at the University of Arkansas Rice Research and Extension Center (RREC), Stuttgart, Arkanss, to evaluate the growth, color and yield response of three new rice varieties to rates of early- and mid-season nitrogen (N) fertilizer. Growth was estimated by use of the "Plant Area Board," color by the SPAD meter and yields as grain (12% moisture) at maturity. Grain yields for 'Orion', 'Bengal' and 'Alan' were largely determined by the early-season N application with only limited grain yield responses being measured from mid-season N applications. Plant area and SPAD measurements associated with optimum grain yields varied among the varieties, indicating differences in growth habit and intensity of color. The data indicate that either plant area or SPAD reading may be used to estimate the need for a mid-season N application.

INTRODUCTION

The ability to more accurately estimate mid-season N rates for rice has potential to save N fertilizer, to minimize any adverse environmental effects and to optimize grain yields. In California, N concentration in rice leaf tissue is used as the criterion; however, research in Arkansas has not shown this method to provide reliable information due to: a) large changes in N concentration over relatively short time spans during late tillering and b) large sample-to-sample variability within the field. More recently efforts to estimate mid-season N needs have included estimates of chlorophyll content using the Minolta SPAD meter and measurements of rice plant area. The study reported here has the objective of relating rice plant area and SPAD meter measurements made at panicle initiation to grain yields as influenced by cultivar and both early- and mid-season N fertilizer rates.

PROCEDURES

The study was conducted at RREC on a Crowley silt loam (Typic Albaqualfs). The experimental design was a split plot with early-season 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. The treatments were replicated four times. Separate studies were conducted with each of three cultivars, Orion, Alan and Bengal. The rice was drill seeded at 100 lb/acre in nine-row plots (7-in. row spacings), 15 ft in length. Weed control was achieved with standard herbicide applications. All plots received the early-season N application prior to flooding when the rice was at the four- to five-leaf stage of development. Mid-season N applications were made into the flood water. Plant area measurements and Minolta SPAD readings were taken weekly beginning two weeks after flooding and continuing until panicle initiation. Plant area was measured as the plant height by leaf spread with the plant treated as a triangle. At maturity, 12-ft segments from the center four rows of each plot were harvested with a small combine, the grain weighed, moisture content determined and the yields calculated as lb/acre at 12% moisture content. Statistical analyses were conducted using procedures developed by SAS, Inc. Means separations were by LSD at the 5% level of probability.

RESULTS AND DISCUSSION

Grain yield responses to early- and mid-season N applications are shown in Tables 1-3. Yield response to the early-season N applications were considerably greater than those from the mid-season N applications.

Maximum grain yields for Alan (Table 1) were associated with an early-season N rate of approximately 80 lb/acre. Grain yield response to mid-season N rates was much less and varied with preflood N rate. Addition of mid-season N significantly increased grain yields only at the 0-lb/acre preflood N rate. There was a trend toward yield reductions with the preflood N rate of 160 lb/acre and with a combination of preflood N rates above 80 lb/acre and mid-season rates above 30 lb/acre.

Grain yields for Orion (Table 2) followed the same trends as were noted for Alan. Most of the yield response was associated with the preflood N application with the mid-season N application significantly increasing grain yields when associated with no preflood N. As with Alan, addition of mid-season N to Orion that had received 160 lb/acre of preflood N caused a trend toward a yield reduction.

Grain yields of Bengal (Table 3) followed the same trends as were noted for Alan and Orion with most of the yield response associated with the preflood N application. However, addition of mid-season N resulted in increased grain yield for the treatments receiving either 0 or 40 lb/acre of preflood N. As with the other two cultivars, there was a trend toward yield reduction with high rates of both early- and mid-season N.

Minolta SPAD readings and plant areas measured at panicle initiation increased with increasing early-season N rates for Orion and Bengal (Table 4). Readings were not taken for Alan due to delay in plant development associated with a zinc deficiency at the site. Plant areas associated with optimum yields for Orion ranged from 700 to 800 cm^2, whereas SPAD readings at these same N rates were 36 to 38. Maximum SPAD readings were approximately 41; however, these were associated with early-season N rate treatments above those needed to maximize grain yields. Plant area and SPAD readings associated with maximum grain yields for Bengal were approximately 600 cm^2 and 45, respectively. Based on this one study, Bengal appears to have a darker green color and a wider range of SPAD readings than any of the other rice cultivars for which we have measurements.

SIGNIFICANCE OF FINDINGS

Results from the 1992 studies continue to indicate that either plant area or the SPAD meter may be used to estimate the need to apply mid-season N fertilizer to rice. The data also indicate that rice cultivars vary as to the optimum size and color associated with proper N nutrition at panicle initiation.

The data also continue to show that all the new cultivars are much more responsive to preflood as compared to mid-season N applications; therefore, a successful N management program should be composed of an adequate amount of N fertilizer applied preflood to optimize yield followed by monitoring of the plants using either plant area or SPAD meter to estimate need for a mid-season N application.

Table 1. Grain yields of 'Alan' rice as influenced by preflood and mid-season nitrogen (N) fertilization, Rice Research and Extension Center, Stuttgart, Arkansas, 1992.

Preflood	Mid-season N rate (lb/acre)			
N Rate	0	30	60	90
	lb/acre			
0	3317	4156	4215	4943
40	5017	5118	5469	5436
80	5993	6367	6003	6054
120	6275	6207	5966	5935
160	5883	5781	5264	5579
LSD (0.05) -	Preflood N - 1035 lb/acre			
	Mid-season N - 772 lb/acre			

Table 2. Grain yields of 'Orion' rice as influenced by preflood and mid-season nitrogen (N) fertilization, Rice Research and Extension Center, Stuttgart, Arkansas, 1992.

Preflood	Mid-season N rate (lb/acre)			
N Rate	0	30	60	90
	lb/acre			
0	4524	4928	5322	6029
40	6975	7157	7695	7659
80	7810	8100	7776	8170
120	7793	7737	7255	7582
160	7551	7222	7086	6998
LSD (0.05) -	Preflood N - 1022 lb/acre			
	Mid-season N - 906 lb/acre			

Table 3. Grain yields of 'Bengal' rice as influenced by preflood and mid-season nitrogen (N) fertilization, Rice Research and Extension Center, Stuttgart, Arkansas, 1992.

Preflood	Mid-season N rate (lb/acre)			
N Rate	0	30	60	90
	lb/acre			
0	3632	4388	4673	5397
40	5893	6247	6412	6842
80	6877	7076	6751	7220
120	7429	7257	7469	7301
160	7061	7279	6560	6660
LSD (0.05) -	Preflood N - 1250 lb/acre			
	Mid-season N - 787 lb/acre			

Table 4. Plant area and SPAD meter measurements of 'Orion' and 'Bengal' rice as influenced by early-season nitrogen (N) rate, 1992.

	Cultivar			
Preflood	Orion		Bengal	
N Rate	Chl[z]	PA	Chl	PA
lb/acre		cm^2		cm^2
0	30	350	32	245
40	32	548	37	434
80	37	777	42	505
120	39	798	45	555
160	41	916	46	613
LSD (0.05)	2	123	2	95

[z]Chl-Chlorophyll estimate by SPAD meter reading; PA-Plant area in cm^2

NUTRIENT RUNOFF FROM RICE FIELDS

P.A. Moore, Jr., K.K. Baugh, R.J. Norman, B.R. Wells and R.S. Helms

ABSTRACT

Small-plot and field-scale studies were conducted to assess the amount of nutrient runoff from rice fields and to determine management strategies that improve the efficiency of nutrient utilization by rice. In the small-plot experiment, three different nitrogen (N) management schemes were evaluated: (1) urea applied to a dry soil prior to flooding, (2) urea applied to a muddy soil prior to flooding and (3) urea applied directly into the floodwater. The results of this study showed that when urea is applied onto a muddy soil or into the floodwater, relatively high concentrations of ammonium are observed in the floodwater. Applying N to a muddy soil or flooded field resulted in less N in the soil and subsequent yield reductions. In 1990 and 1992, yields were not reduced when urea was added to either muddy or dry soil. However, when the urea was applied into the floodwater, yields were decreased. In 1991 addition of the urea to muddy soil resulted in yield reduction as compared to application on a dry soil. Field-scale studies on nutrient runoff from rice paddies were conducted to determine if this is of environmental significance. Floodwater samples were taken throughout the season for ammonium, nitrate and phosphate. Results of this study indicated that inorganic N concentrations (ammonium and nitrate) in floodwater are very low most of the season. Increases in floodwater N were observed at midseason; however, the concentrations were always less than 10 mg N/liter, the EPA drinking water standard. Soluble phosphate concentrations were usually less than 0.05 mg P/liter in runoff water from rice fields. Although more research is needed before conclusions can be drawn, preliminary results indicate that nutrient runoff from rice fields does not pose a threat to the environment.

INTRODUCTION

Currently, the expanding environmental movement has become a major political force in this country. Due to this movement, legislation on non-point-source pollution (i.e., nutrient runoff from farmland) will probably be enacted by the turn of the century. Therefore, it is important to know exactly what nutrients are contained in the tailwater from rice fields. This will help us to determine best management strategies for fertilizer applications and irrigation practices and provide realistic values for legislatures if (or when) they enact laws on nutrient runoff.

Earlier work on irrigation water quality in rice paddies has shown that concentrations of some metals such as Ca and Mg will decrease as the water moves from the well across the field, due to CO_2 degassing that results in higher pH and precipitation as carbonates (Gilmour et al., 1978). Scant information is available on the N and P status of floodwater in rice fields. Moore (1981) found that NH_4^+ concentrations in rice fields receiving 130 kg N/ha were usually below 1 mg N/liter. Studies reporting the nitrate or phosphate concentrations in rice field floodwater are lacking.

Best management strategies for fertilization of rice should result in increased rice yields and be environmentally sound. For years the University of Arkansas has been recommending that the early-season (preflood) N application to rice should be applied to a dry soil rather than onto a muddy soil or into the floodwater. This recommendation was based on studies in which yield information was determined (Wells et al., 1988). However, information on the effect of soil conditions on N dynamics in the plant/soil/water system is lacking. The objectives of this study are: 1) to monitor changes in the N level of rice irrigation water with time interval after N fertilizer applications as influenced by soil moisture conditions at the time of N application, 2) to monitor N, P, K, Ca, Mg, etc. movement and runoff from rice fields after fertilizing to determine if there is a potential environmental problem associated with these nutrients and 3) to use information from objectives 1) and 2) to determine best management practices to maximize fertilizer N uptake by rice and minimize N runoff into adjacent water bodies.

PROCEDURES

Small-Plot Study

A nitrogen management study was conducted with 'Katy' rice from 1990 to 1992 at the Rice Research and Extension Center (RREC), Stuttgart, Arkansas, using three fertilizer management schemes: 1) N fertilizer applied to a dry soil, 2) N fertilizer applied to a muddy soil and

3) N fertilizer applied into the floodwater one day after application of the flood. The plots were flooded immediately after N application in treatments 1 and 2. Water samples were taken immediately after flooding and daily for the next seven days, then at three-day intervals for the second week after flooding. The water samples were analyzed for ammonium and nitrate-N. At mid-season all plots received N fertilizer into the standing water, and samples were taken immediately and at 3 hours, 6 hours, 12 hours, 24 hours and 3 days after fertilization. Plant samples (for N uptake) were taken at 7, 14 and 21 days after flooding and at panicle initiation, booting and three weeks after heading. Grain yields were also determined.

Field Study

In 1991 and 1992, six production rice fields were sampled systematically from water entry point to water exit point, including tailwater. The fields were located in Ashley, Drew and Lincoln Counties in Arkansas. Water samples were taken throughout the season; however, more concentrated sampling was conducted after each fertilizer application. Floodwater pH, temperature and electrical conductivity (EC) were measured in the field at the time of sampling. Samples were filtered on site for dissolved As, Ca, K, Mg, Na, P and for inorganic N (ammonium and nitrate). Water samples (100 ml) for N analysis were frozen and will be analyzed for ammonium, nitrate and urea. Since water samples from 1992 have not been analyzed to date, only 1991 results will be discussed.

RESULTS AND DISCUSSION

Experiment 1 - Effect of Nitrogen Management Techniques on Rice Yields

Yield reductions can occur when the early-season application of urea is made to a muddy soil or into the floodwater rather than onto dry soil (Table 1). In 1990 and 1992, yields were not significantly affected by addition of the N fertilizer to a muddy soil as compared to addition to the dry soil; however, there was a trend toward lower yields with N placed on the muddy soil. This trend is supported by the significant decrease in yield seen in 1991. As compared to N applied on the dry soil, addition of the early-season N into the flood water resulted in drastic yield reductions in all three years of the study.

In a similar study, Wells et al. (1988) measured yields that were comparable to those from this study in 1990 and 1992. Their yields were 6580, 6540 and 5290 lb/acre when the preflood urea was applied to a crusted soil, saturated soil and flooded soil, respectively.

When the early-season N fertilizer (urea) was applied to dry soil, very little ammonium N could be detected in the floodwater (Fig. 1). However, when the N fertilizer was applied to either a muddy soil or directly into the irrigation water soon after flooding, fairly high NH_4^+ concentrations were measured. The explanation for these results is simple; when N is applied to dry soil, it moves downward with water after flooding as the water infiltrates the soil. When the soil is already saturated with water (muddy), then there is little water movement into the soil, causing the N fertilizer to stay near the soil surface where it is more susceptible to loss. When it is applied into the floodwater, NH_4^+ concentrations are highest and losses are greatest. Wells et al. (1988) showed that these N losses from the floodwater could not be compensated by adding additional N fertilizer.

Experiment 2 - Nutrient Runoff from Production Rice Fields

Inorganic nitrate nitrogen concentrations in the floodwater were less than 1 ppm throughout the season; however, a peak in ammonium concentration followed the midseason urea application (Fig. 2). This peak, which occurred immediately after fertilization, corresponded to 4.52 mg N/liter. Since the EPA nitrate limit for drinking water is 10 mg N/liter, these waters would legally be fit for human consumption (with respect to nitrogen).

Water samples from the 1992 season are currently being analyzed. In 1991 phosphorus concentrations at the well averaged 0.235 mg P/liter, which is relatively high. However, as the water flowed across the field, the average concentration of P decreased to less than 0.05 mg P/liter (Fig. 3) except at the Summerford farm. Apparently, rice fields behave in the same manner as artificial wetlands that are constructed to remove nutrients from water. The EPA target P concentration is 0.10 mg P/liter for flowing waters, such as rivers, and 0.05 mg P/liter for lakes. Although more research is needed before definite conclusions can be drawn, preliminary results indicate that nutrient runoff from rice fields does not pose a threat to the environment. Therefore, rice growers should not be affected by non-point-source legislation, when it is enacted.

There is strong evidence that many wetland ecosystems function as filters for waters containing elevated concentrations of N and P (Boyt et al., 1977; Lakshman, 1979; Reddy and DeBusk, 1985; Tilton and Kadlec, 1979). Plant uptake of nutrients and incorporation into the sediment are two mechanisms by which wetlands are operative in water purification. Much of the N entering wetlands is lost as a result of nitrification/denitrification reactions (Engler and Patrick, 1974; Reddy et al., 1980). Losses of N from floodwater can also occur via ammonia volatilization.

SIGNIFICANCE OF FINDINGS

This research showed that grain yields could be reduced from 30-50% when poor N fertility practices are employed. Applying the early-season N to a muddy soil sometimes results in significant yield reductions. When the urea was applied directly into the floodwater, drastic yield reductions were measured. Therefore, the preflood N fertilizer should be placed on a dry soil surface if possible. If not, it may be placed on a muddy soil; however, in this case the field should be flooded within three to five days (Wells et al., 1988).

Preliminary results from the field study indicated that nutrient runoff from rice fields does not pose a significant threat to the environment. If non-point-source pollution laws are enacted in the future (as expected), rice farmers will probably not be affected since the concentration of nutrients in rice field tailwater is low.

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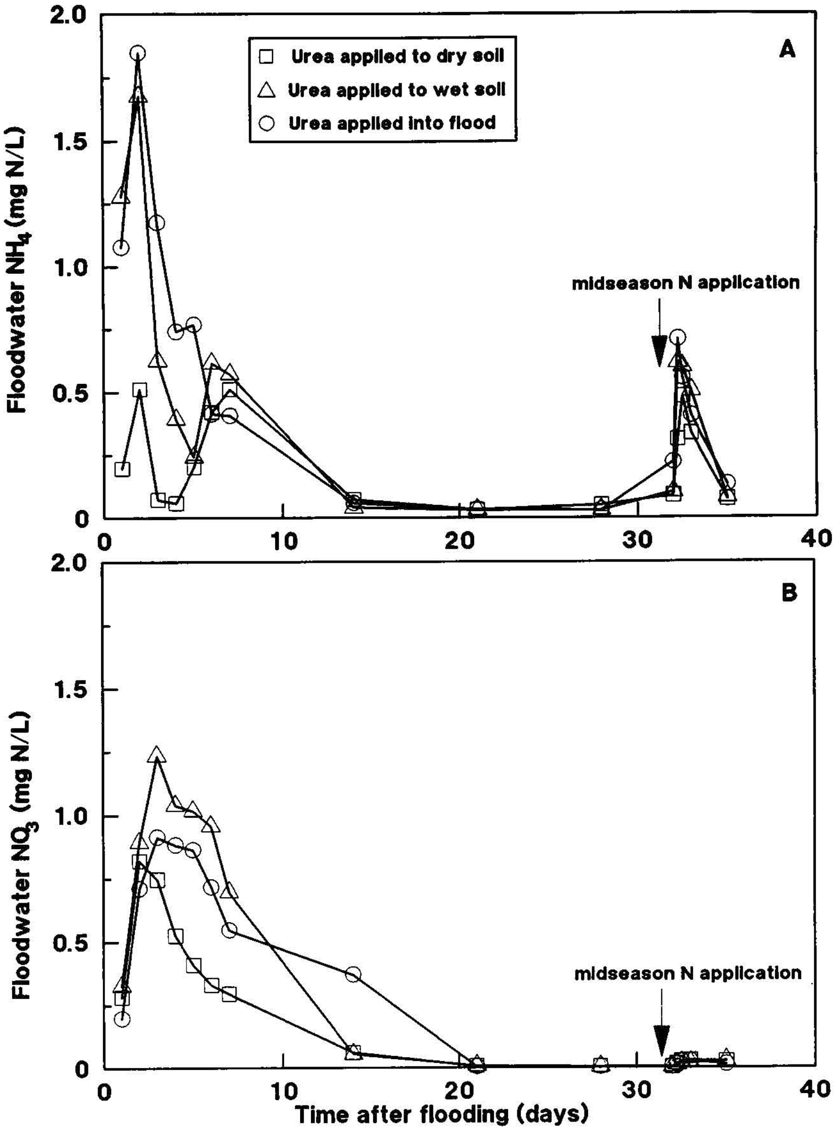

Fig. 1. Effect of nitrogen management technique on seasonal changes in floodwater (A) ammonium and (B) nitrate concentration.

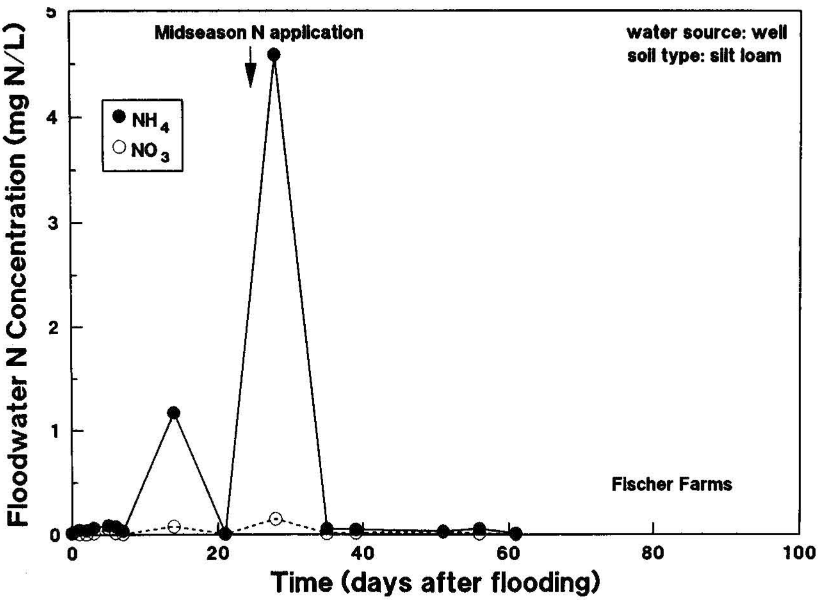

Fig. 2. Floodwater nitrogen (N) levels at Fisher Farms.

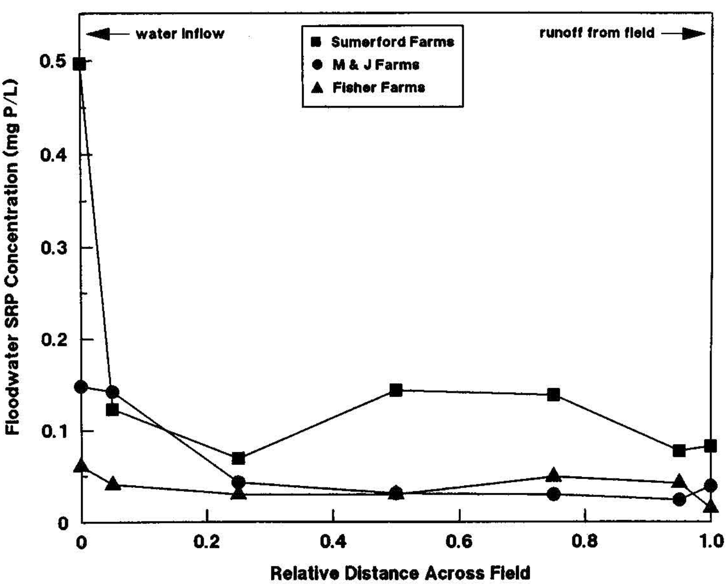

Fig. 3. Floodwater SRP concentrations from water inflow to outflow.

Table 1. Response of 'Katy' rice to soil moisture conditions at the time of the early-season nitrogen (N) fertilizer application.

Soil Moisture	1990	1991	1992
Dry	5415a	5420a	5184a
Muddy	4965a	3785b	4992a
Flooded	4073b	2923c	3629b
LSD (0.05)	559	173	504

DEVELOPMENT OF THE DD50 DATABASE FOR NEW RICE VARIETIES

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ABSTRACT

The DD50 computer program, to be effective, must be continually updated as new varieties are named and released. We conduct studies each year to gather plant development data for promising new lines. In 1992 the study, conducted on a Crowley silt loam at the University of Arkansas Rice Research and Extension Center (RREC), Stuttgart, Arkansas, included 16 varieties/lines, one seeding date and three replicates. Data from this study were combined with 1991 data to formulate threshold values necessary to add six new rice varieties into the 1993 DD50 computer program. These are 'Adair', 'LaGrue', 'Bengal', 'Cypress', 'RT7015' and (Texas) 'Maybelle'.

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 Arkansas rice farmers utilize this program as a management tool in rice production. The program requires plant development data for all varieties based on accumulation of DD50 units from date of seedling emergence. These data are gathered for all promising new rice lines for two to three years prior to naming and releasing the line as a variety. When the new variety is released to farmers, these data are used to provide threshold DD50 values in the computer program. Therefore, the objective of this study are to develop databases for promising new rice lines, to verify databases for existing varieties and to assess the effect of seeding date on DD50 accumulations.

MATERIALS & METHODS

The study was conducted at RREC on a Crowley silt loam soil. Sixteen varieties/lines were seeded on 13 April 1992. There was no May seeding date because of excessive rainfall during the entire last half of May. The rice was drill-seeded at a rate of 100 lb/acre in nine row plots (7-in. spacing), 15 ft in length. The design of the experiment was a randomized complete block with three replications. The cultural practices were as normally conducted for standard rice culture. Data collected included the following: date of seedling emergence, maximum and minimum daily temperatures, length of elongating internodes at three-day intervals beginning 35 days after seedling emergence, date of 50% heading and grain yields at maturity. The temperature data were then converted into DD50 accumulations from seedling emergence until the developmental stage of interest. Yield data were subjected to statistical analysis.

RESULTS AND DISCUSSION

New varieties in the study were Adair, LaGrue, Bengal, Cypress, RT7015 and Maybelle (Table 1). Data from this study will be used to include these varieties in the 1993 DD50 program. Also included in the study were several promising experimental lines that are likely to be released as varieties within the next two or three years. Among the named cultivars in the study, 'Newbonnet' and Bengal required the highest accumulation of DD50 units to heading (Table 1); Maybelle required the fewest DD50 accumulations to reach any given stage of development. Data from this study show that the thresholds utilized previously for Maybelle are those of Jackson and the Maybelle currently being grown in Texas is approximately one week earlier.

Differences in growth duration of the varieties resulted from variation in accumulation of DD50 units over the intervals from emergence to internode elongation (IE) and from IE to heading. For example, Maybelle, a very-short-season variety, required 1191 DD50 units from emergence to IE and 547 units from IE to heading while Newbonnet, a mid-season variety, required approximately 1400 and 800 DD50 units, respectively, for the two intervals. These data are further proof that the variation in growth duration among varieties is a function of differences in both the vegetative and the pre-heading reproductive growth periods, not just the vegetative growth period, as has been previously reported.

Grain yields for the varieties are given in Table 1. LaGrue and Lacassine had the highest grain yields among the cultivars whereas

Newbonnet had the lowest yield. Two of the experimental lines, RU9101136 and RU9101142, also had excellent grain yields. These data are indicative of the continued progress of the breeding programs in producing higher-yielding varieties.

SIGNIFICANCE OF THE FINDINGS

Data from this study will be utilized to include Adair, LaGrue, Bengal, Cypress, RT7015 and Maybelle (new Texas) in the 1993 DD50 computer program. Conversion of the data into the thresholds utilized for all the management decisions of the DD50 program illustrates the increased level of management required of the farmer as the days to maturity of the variety decreases. An excellent example is Maybelle (Texas). This variety is approximately seven days earlier than previous varieties. Use of Londax on Maybelle has only one date (550 DD50 units) rather than a safe window. This results from the 80-days-prior-to-harvest interval required by the label for use of this herbicide. Subtraction of 80 from the total days to maturity of the variety means the Londax can be applied only immediately after flooding when the rice is at the four- to five-leaf stage of plant development rather than over a period of several days or weeks as for longer season varieties.

Table 1. Degree day accumulations and grain yields for rice varieties/lines seeded 13 April 1992, Rice Research and Extension Center, Stuttgart, Arkansas.

Variety/	DD50			Grain
Line	IE	Heading	IE-H	Yield
		units		lb/acre
Adair	1322	2005	683	7035
Bengal	1405	2214	809	6201
Cypress	1266	2093	827	6312
LaGrue	1235	2036	801	7496
RU9101133	1405	2093	688	6574
RU9101136	1348	2154	806	7418
RU9101142	1296	2064	768	7475
RU9101130	1377	2064	687	6622
RU9101164	1461	2214	753	5885
RU9101179	1296	2123	827	6083
Alan	1210	1893	683	6807
Newbonnet	1405	2214	809	5096
Orion	1431	2064	633	6781
Maybelle	1191	1738	547	6049
RT7015	1348	1921	573	6437
Lacassine	1377	2123	746	7328
LSD(0.05)				1070
C.V. (%)				9.7

EFFECT OF SALINITY ON RICE GROWTH AND PROCESSES THAT OCCUR IN FLOODED SOILS

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ABSTRACT

Studies were conducted to investigate the nature and severity of the salinity problem in southeastern Arkansas and to determine best management practices for growing rice on saline soils. The laboratory studies focused on the effect of salinity on nitrogen and phosphorus transformations in rice soils. The greenhouse studies were conducted to estimate the effect of the different kinds of salt on rice production. Small plot studies were conducted to determine the salt tolerance of rice varieties used in Arkansas and to determine seasonal variations in nutrient contents of floodwater, soil and rice in salt-affected and normal rice fields. A total of ten different experiments on salinity were conducted; however, due to space limitations, only two of these studies will be discussed in detail: (1) a salinity survey of irrigation wells used for rice production and (2) a small-plot study to determine the salt tolerance of rice varieties. A total of 151 sources of water used for irrigating rice in five counties in Arkansas were sampled in 1991 and 1992. The samples were analyzed for pH, electrical conductivity (EC), anions (Cl and SO_4) and metals (Al, As, B, Ca, Cd, Cr, Cu, K, Fe, Mg, Mo, Mn, Ni, Pb, Si and Zn). Results of this research showed that in areas in which salty well water was a problem (such as the Beouff River area in Chicot County), surface rather than well waters should be used for irrigating rice. The EC of bayous, rivers, reservoirs and catfish ponds ranged from 58-1314 µS/cm, whereas the well water EC ranged from 269-4820 µS/cm. Currently, the University of Arkansas recommends not using water with an EC over 1200 µS/cm for rice production. Results from water sample analyses and interpretation of the data are being provided to all of the growers whose irrigation water was sampled. In the small plot study, 2000 lb NaCl/acre reduced the number of seedlings for all 20 varieties.

INTRODUCTION

The quality of water used for irrigating rice can greatly affect rice grain yields. Saline water (water with high amounts of soluble salts) causes stunted growth, leaf burn and mortality of rice seedlings. If the salt concentration of irrigation water is high when flushing seedling rice, substantial stand loss can occur. The tips of the leaves of salt-affected rice seedlings are usually grayish-white, and sometimes they are rolled. In some cases a lack of rain early in the season necessitates flushing a field several times. If the water used for flushing is high enough in salinity, then the entire stand can be lost. Usually the salt accumulates in high spots in the field, such as the tops of levees, from wicking.

In order to characterize the types and amounts of salts present in irrigation water and soils used for rice production in southeastern Arkansas, a salinity survey was conducted to identify the nature and extent of the problem.

The type and amount of salts in the water as well as the soil type, rice variety and weather conditions will dictate the damage incurred. Varietal screening of rice was carried out to determine salt tolerance and overall yield performance under high saline conditions.

There are several reasons why rice responds to flooding: better weed control, increased release of soil N as ammonium and increased availability of micronutrients such as Fe and Mn, to name a few. However, the effects of salinity on processes occurring in flooded rice soils, such as Fe and Mn reduction, and the processes that make up the N cycle are not known. Since these reactions are vital for high productivity, a knowledge of their effect on salinity is needed.

PROCEDURES

Salinity Survey

A total of 151 sources of water used for irrigating rice in Ashley, Chicot, Desha, Drew and Monroe Counties in Arkansas were sampled in 1991 and 1992. Temperature, EC and pH measurements were made on site. Water samples were filtered and frozen for analysis. Each of the samples was analyzed for anions (Cl and SO_4) and metals (Al, As, B, Ca, Cd, Cr, Cu, K, Fe, Mg, Mo, Mn, Ni, Pb, Si and Zn). Mud and plant samples were also taken in each field. The mud samples were centrifuged, and the porewater was analyzed for the same parameters as the irrigation water. Plant samples were dried, ground and digested in acid to determine the amounts of various salts. Changes in reservoir and well water quality during the season were also monitored at one location in Chicot County.

Small Plot Study

A small plot study was conducted in 1992 at the Southeast Branch Experiment Station (SEBS) at Rohwer, Arkansas, to evaluate 10 short-season and 10 long-season rice varieties for salt tolerance. There were two treatments, a control (no salt added) and 2000 lb NaCl/acre. Salt was added immediately prior to flooding. Stand counts were taken from a square meter in each plot both before and after the addition of salt. Percent stand reduction following addition of the salt was calculated from the stand counts. The rice was grown to maturity and grain yield determined.

RESULTS AND DISCUSSION

Salinity Survey

Samples of surface water contained much less salt than samples of well water (Table 1). The average EC (which is a measure of the amount of salt dissolved in water) of wells sampled in 1991 and 1992 was 1516 µS/cm; the average EC of the surface water was only 581 µS/cm. Currently the University of Arkansas does not recommend using water with an EC over 1200 µS/cm to irrigate seedling rice. Several of the wells sampled in Chicot County had conductivities exceeding 4000 µS/cm. Water this salty could result in large yield reductions, and continued use will lead to a highly salinized soil. Most of the wells containing high salt concentrations were located in Chicot County.

The dominant anion in the irrigation waters tested was chloride, followed by the cations, calcium and sodium (Table 2). The concentration of salts in well water varied greatly from location to location. Chloride concentrations ranged from 0.9 to 1276 mg/liter. The sodium adsorption ratio (SAR) of all the samples taken was less than 10, indicating that sodic soil formation is unlikely. This is good news, since sodic soils (soils saturated with sodium) are unproductive and very difficult to reclaim. Irrigation water quality greatly affects the chemistry of the soil. The salt content of the soil porewater (from the mud samples taken) was found to increase as the irrigation water salt content increased, as expected (data not shown).

There are numerous streams, creeks, bayous, rivers, ponds, lakes and reservoirs in the rice-producing areas of the state that could be used as sources of irrigation water. The surface water sources sampled in this study had less than half the sodium and chloride concentrations of well water samples (Table 2). The water in most of these surface water sources, including catfish reservoirs, is from rainfall in the early part of the growing season, when rice is at the susceptible growth stage for salinity damage. Rainwater contains very low salt concentrations, making it exceptionally good water for irrigation. Rice is most susceptible to salinity damage at the seedling stage; therefore, use of these surface water sources early in the season should minimize salt damage. In addition, the water from catfish reservoirs has a higher nutrient content (nitrogen, potassium and phosphorus), which is derived from catfish feces; thus it adds nutrients for use by the rice crop. Surface water will be less likely to increase soil pH and induce zinc deficiency since the carbonates (lime) will have precipitated in the pond rather than on the field.

The computer program WATER is being used to predict whether or not salinity problems will be anticipated for each water source. Individual growers whose wells (or surface waters) were sampled for this study are being supplied with results and interpretation of their water analyses. This will allow them to determine whether or not to continue using that source of water. A map of well water salinity is being developed for rice-producing counties that have salinity problems. Irrigation water testing will continue in the rice-producing counties next year to determine areas where there are possible salinity and/or alkalinity hazards. Some of the counties in which salt problems are anticipated are Ashley, Chicot, Cross, Desha, Miller, Monroe, Poinsett and White.

Small Plot Study

The salt treatment of 2000 lb NaCl/acre reduced seedling counts for all 20 varieties. The initial stand count, stand after salt treatment and percent stand reduction are shown in Table 3. The difference between initial stand and stand after salt treatment was significantly different between varieties at the 0.06 level of probability. 'Jasmine-85', 'Texmont', 'Gulfmont', 'Maybelle' and 'L202' lost significantly fewer seedlings than the rest of the varieties. This confirms earlier work conducted by Baser et al. (1992) that found Jasmine85 to exhibit salt tolerance in a hydroponic system. However, 'Alan', which ranked tenth in the control plots, was the highest-yielding variety while Jasmine85 ranked only sixth in the salt-treated plots (Table 4). This indicates that, although Alan initially lost 18 seedlings/m^2 due to salt, its ability to rapidly tiller caused it to out-yield all the other varieties, including Jasmine85. Also, the results may have been affected by the relative maturity of the varieties and by weather conditions.

SIGNIFICANCE OF FINDINGS

The salinity survey is providing rice producers with an important service: testing of irrigation waters for salt content. Recommendations are being made to each farmer on the use of the irrigation water currently being used. Well water salinity maps for rice-producing counties in southeastern Arkansas are also being developed. These maps will help identify areas of good well water, as well as trouble spots where more intensive sampling may be needed. Basic research on the relationships between irrigation water quality, soil physical and chemical characteristics and rice growth should also benefit rice producers. For example, this research confirms that surface water, if available, is superior to well water in areas with salinity problems.

The preliminary results from the small plot study indicate that currently available varieties with high tillering capacity may be seeded into a saline situation and satisfactory yields can be obtained even after an initial stand reduction. However, there is a threshold of salt tolerance for all varieties, and research will continue in this area.

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Table 1. Electrical conductivity (EC), temperature and pH of well water and surface water samples from Ashley, Chicot, Desha, Drew and Monroe Counties.

	Well Water (n = 108)			Surface Water (n = 20)		
Item	EC	Temp.	pH	EC	Temp.	pH
	µS/cm	°F		µS/cm	°F	
Average	1516	65	7.07	581	82	8.06
Std. dev.	1017	3.0	0.30	362	6.2	0.61
Range	269-4820	60-82	6.20-8.97	58-1314	71-92	6.84-9.20

Table 2. Average concentration in well water and surface water from Chicot, Desha and Monroe Counties, Arkansas.

	Well Water (n = 54)			Surface Water (n = 15)		
Analyte	Average	Std.Dev.	Range	Average	Std.Dev.	Range
	mg/liter					
Cl	360.8	301.5	0.9-1276	164.5	182.4	0.3-738
Ca	161.6	70.9	61.9-323	52.7	50.9	6.7-208
Na	160.1	97.5	18.1-407	72.3	65.7	4.89-160
SO_4-S	50.3	37.9	1.9-165	15.5	16.0	1.5-29.8
Mg	46.9	19.5	13.0-89.1	20.5	18.9	3.9-78.8
Fe	6.73	3.26	0.40-12.58	0.10	0.10	0.02-0.39
K	2.26	0.87	0.90-4.09	3.83	1.20	1.79-6.15
Si	1.78	1.47	0.31-7.84	0.58	0.71	0.08-2.70
Mn	0.91	1.08	0.20-8.22	0.26	0.35	BDL[z]-1.10
P	0.57	0.21	0.22-1.18	0.11	0.054	0.02-0.23
B	0.18	0.14	0.07-1.01	0.12	0.093	0.06-0.44
As	0.12	0.04	0.04-0.24	0.058	0.033	0.03-0.13
Al	0.067	0.033	0.01-0.17	0.064	0.027	0.03-0.12
Zn	0.058	0.031	0.01-0.15	0.062	0.026	0.01-0.10
Pb	0.028	0.015	BDL-0.060	0.028	0.017	0.01-0.08
Mo	0.008	0.003	BDL-0.014	0.005	0.002	BDL-0.011
Cu	0.007	0.011	BDL-0.056	0.018	0.013	BDL-0.044
Cr	0.005	0.003	BDL-0.016	0.002	0.002	BDL-0.009
Ni	0.005	0.003	BDL-0.015	0.004	0.004	BDL-0.012
Cd	0.003	0.001	BDL-0.008	0.001	0.001	BDL-0.004

[z]BDL = Below detection limits.

Table 3. Rice varietal response to salt (2000 lb NaCl/acre), University of Arkansas Southeast Branch Station, Rohwer, Arkansas.

Most Salt Tolerant	Initial Stand	Stand after Salt Trt.	Stand Reduction
	plants/m^2		%
1. Jasmine85	34	29	16
2. Texmont	25	20	19
3. Millie	40	29	27
4. Maybelle	24	17	29
5. L202	24	16	31
6. Gulfmont	20	14	34
7. Tebonnet	35	22	38
8. Alan	41	23	44
9. Jackson	28	15	46
10. Newbonnet	27	15	46
11. Katy	24	13	46
12. Lemont	23	12	48
13. RT 4716	27	14	49
14. Orion	27	13	50
15. Rexmont	30	15	50
16. Mars	27	13	53
17. RT 7015	31	14	54
18. Lacassine	23	10	57
19. Newrex	25	10	58
20. Rico 1	43	16	62
LSD (0.06)	n.s.	9.76	n.s.

Table 4. Grain yields for rice varietal response to salt (lb/acre) University of Arkansas Southeast Branch Station, Rohwer, Arkansas.

Varieties	Control	2000 lb NaCl/acre
	------------------lb/acre------------------	
Short Season Varieties		
Alan	6554	6896
Millie	6347	6167
L202	7946	6106
Tebonnet	4772	5945
RT 4716	4358	5818
Texmont	6091	5604
Jackson	6995	4669
RT 7015	7773	3998
Maybelle[z]	2683	2718
Newrex	5937	2442
Long Season Varieties		
Jasmine85	4994[y]	5673
Gulfmont	7838	5658
Newbonnet	7241	5305
Rico 1	7965	5198
Lemont	7490	4531
Katy	6225	4347
Orion	7827	4197
Mars	5907	4113
Lacassine	5930	3959
Rexmont	7333	3450

LSD(0.05) = 1974 for comparison of means within the same treatment.
LSD(0.05) = 4051 for comparison of means between treatments.

[z]Maybelle suffered extensive bird damage.

[y]Jasmine85 yield decreased due to straighthead damage.

RICE PRODUCTION MANAGEMENT SUPPORT SYSTEM

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ABSTRACT

Expert systems for rice producers have been developed and tested. Two software products are field-ready, and other products are at various stages of development. The weed management package (RiceWeed) was pilot-tested in five counties in 1992. The fertilizer management package (RiceFertility) was tested in-house and will be pilot-tested in 1993. Results of verification testing of both packages are presented, based on comparisons with the Rice Research Verification Trials. Other modules being developed address rice harvest management and disease management. Another program will provide support for scheduling field activities and logging pesticide usage.

INTRODUCTION

Rice growers cannot afford unnecessary expenditures for pesticides, fertilizers and other resources. Computers will play an increasing role in decision-making as a tool to evaluate the economics of production alternatives. The computer will provide the manager with quick access to customized information pertaining to a specific field situation on a given farm. The present generation of expert systems, designed for personal computers, is already capable of meeting the needs of rice growers in making specific weed and fertilizer management decisions. The status of a package of computer-based tools for rice growers will be detailed in this report.

PROCEDURES

A prototype expert system for rice weed management was developed and used as a guide for development of subsequent modules. The new fertilizer expert system and future modules on harvest management, disease management, insect management, water management and stand establishment benefit from the initial investment in the creation of the weed management expert system, RiceWeed.

For each module, experts are queried regarding decision-making logic. Research results are used to support economic analyses. Originally, logic was coded in rules using a commercial expert system shell; however, the shell has now been eliminated using custom-designed software that reduces the size of the package, speeds up execution and lessens the memory requirements of the computer. Input and output routines are coded using an advanced programmer's toolbox. Economic analyses are presented in spreadsheet format. Software usage is supported by on-line, context-sensitive help messages and an on-line user's guide. Individual modules have been designed to be released as stand-alone products. An integrating environment, nearly completed, will unify the entry point for all modules and allow for uniform input-output style and shared databases. The integrated system will include a graphics-based calendar for scheduling and record-keeping.

RESULTS AND DISCUSSION

The weed management support system, RiceWeed, was completed and sent to the Cooperative Extension Service for pilot testing in 1992. Five counties participated in the pilot-test. Results from those tests are not yet available. Validation of the system was performed using the 1991 Rice Research Verification Trials as input scenarios. From a total of 29 scenarios tested, 100% of the system's recommendations were found to be reasonable, with 72% matching the expert's recommendation exactly. The rule-base was updated for 1992 to include recommendations for Facet herbicide.

Software revisions were made to represent the inference-engine using a programming language, thereby eliminating the need for a commercial expert system shell. This change reduced rule processing time, decreased memory requirements and reduced file size on the distribution disk.

Major improvements were made to the user-interface to allow editing, saving and recalling a set of input field conditions. Users will find the new program to be more convenient to use, especially if season-long queries are made for multiple fields.

The fertilizer management support system, RiceFertility, was completed and is currently being tested in-house before sending it to the Cooperative Extension Service for pilot-testing in the spring of 1993. Again, validation was accomplished using the Rice Research Verification Trials (1992). From a total of 31 scenarios tested, 94% of the system's recommendations were found to be reasonable, with 77% matching the expert's recommendation. Careful testing did expose errors in the representation of the logic for diagnosing zinc deficiency. These will be corrected prior to the pilot testing.

A harvesting expert system, RiceHarvest, has been designed, and initial computer coding has been completed. The prototype system will allow a grower to select an optimal time 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 newest technology in harvest research to growers who are interested in optimizing the harvested value of their crop.

Preliminary planning for a rice disease management expert system has begun. Initially, the efforts will focus on sheath blight. Experiments were conducted in 1991 and will be continued in 1993 to refine the database regarding the rate of development of the disease as a function of environment. One goal of the research is to verify or modify a predictive model developed in Japan for sheath blight development and yield impact.

A prototype electronic calendar program, RiceManager, has been developed. The program will help identify conflicts in scheduling, improve planning and facilitate pesticide usage record-keeping. Software testing is in the early stages. The concept for this software came from rice growers requesting help in logging pesticide usage. RiceManager will also provide a gateway to all the other expert system modules via a main menu.

SIGNIFICANCE OF FINDINGS

Testing and continued refinement of expert systems software for rice growers has shown that this new technology is capable of delivering benefits in the real world. More effort is now needed to promote the use of the software and train new users. With proper training, new users such as county agents, consultants and individual growers will be able to utilize these tools as a source of consolidated and current information. Special information, such as the economics of weed management alternatives, cannot be accessed from any other medium. These 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.

FURROW-IRRIGATED RICE STUDIES IN 1992

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

ABSTRACT

Previous studies on furrow irrigation for rice did not compare furrow to flood in terms of both grain yields and water usage. A study comparing furrow-irrigated and flooded rice was conducted in 1992 (the third year of a three-year study) at the Northeast Research and Extension Center (NEREC), Keiser, Arkansas. Grain yields for flooded and two furrow-irrigated treatments were 7170, 6110 and 6040 lb/acre, respectively. We were unable to identify the causes of the yield reduction through study of nitrogen (N) and water treatments. However, water use for the two furrow-irrigated treatments was more than 30 in. less than the flooded treatment after adjusting for levee seepage.

A study addressing the feasibility of producing furrow-irrigated rice behind wheat began with the fall 1991 wheat crop. Wheat was raised on bedded soil and yielded 3440 lb/acre. Rice was seeded on the same soil beds on 20 June 1992. The rice crop developed slowly and was not harvested until 6 November. Yields averaged 3450 lb/acre and were not significantly affected by pre-plant treatments.

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). Potential benefits of furrow irrigation over a continuous flood on rice include 1) water and associated energy savings through reduced deep percolation and lack of levee seepage; 2) simplified flushing of the soil early in the growing season; 3) savings from not having to construct and destroy levees; and 4) easier harvests due to quicker soil drying and freedom from levees. In northeastern Arkansas, many of the clay soils have a very low infiltration rate once they are saturated. However, most contain varying amounts of highly permeable areas (sand blows) that can lead to increased water requirements. The objectives of this research were to compare flooded and furrow-irrigated rice and investigate the feasibility of producing furrow-irrigated rice following wheat.

PROCEDURES

Flood/Furrow Comparison

Water-management plots were established at the Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, on a Sharkey silty clay precision graded to 0.15% slope and no cross slope. Three treatments consisted of flood irrigation, furrow irrigations twice per week and furrow irrigations when the soil water deficit (SWD) reached 0.75 in. The furrow-irrigation plots were seeded on 16 38-in. beds with 1200-ft row lengths. The flooded plots were eight sequentially flooded bays. Each bay was 50 ft wide by 135 ft long for a total length of 1080 ft. There were three replications of the treatments. Water introduced to each water-management plot was monitored with a flowmeter. The water measured with the flowmeters included water that seeped out through the levees. Because of the size of the experimental plots, a larger proportion of the water applied was lost by seepage through the outside levees than would occur in a production field. Since no measurements of seepage were made, the amount of seepage was estimated from the work of Ferguson et al. (1986). Water loss from the flooded plots as tailwater was minimal (i.e., the plots were watched, and water was shut off in time to avoid tailwater loss).

'Tebonnet' rice was drill seeded (6-in. spacing) on 17 April 1992. Seeds were treated with gibberellic acid (Release) to facilitate a rapid, uniform emergence. All plots were fertilized at the recommended rate of 110 lb N/acre. The N was split among preflood, internode elongation (IE) and IE+2 weeks applications. Herbicide applications were the same for all water treatments. All plots were flushed twice before the initiation of flood.

To determine if the N response was consistent among water treatments, N subplots were added to each water-management plot, with rates of 0, 25 and 50 lb N/acre (above the 110 lb N/acre applied to all plots). The additional N was applied to the subplots approximately two weeks before the IE application.

Areas of 2 ft by 20 ft were harvested with a small-plot rice combine. Harvests were taken in each of the eight sequential bays and at equivalent positions down the row in the furrow-irrigated plots. Harvests were also taken in each N subplot. Moisture content was determined for each harvest sample, and grain yields were adjusted to 12% moisture content.

Wheat/Rice Doublecrop

'Cardinal' wheat was seeded on 4 October 1991 on 38-in. beds with 500-ft row lengths. Wheat was harvested on 19 June 1992. The rice study was conducted as a randomized complete block with four replications. The two pre-plant treatments were 1) burning the wheat stubble before seeding rice and 2) seeding rice into standing wheat stubble. No tillage was used on any of the plots between the wheat harvest and rice planting. Rice plots were 19 ft wide (six 38-in. beds) by 400 ft, with a 19-ft buffer between adjacent plots. 'Alan' rice was drill seeded (8-in. spacing) on 20 June 1992. Seeds were treated with gibberellic acid (Release) to facilitate a rapid, uniform emergence. All plots were fertilized at the rate of 174 lb N/acre. The N was split among early-season (10 July), IE and IE+2 weeks applications. A "burndown" herbicide application (20 oz/acre Roundup D-Pak) was made on the non-burned plots prior to seeding. All subsequent herbicide applications were the same for all treatments. All plots were flushed twice per week.

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

RESULTS AND DISCUSSION

Flood/Furrow Comparison

Grain yields and water use for the water-management plots with 110 lb N/acre are included in Table 1. The mean yields for the two furrow-irrigated treatments were not significantly different from each other but were significantly lower than for the flooded treatment. The yield reduction associated with furrow-irrigated production was consistent with observations from previous years of the study (Vories and Counce, 1992). The yield was not significantly affected by location in the field or by the addition of supplemental N.

Ferguson et al. (1986) reported from measurements made for two years at NEREC that levee seepage on the Sharkey silty clay averaged 2.66 gal/day/ft of outside levee. Based on those findings, 10 in. of the water applied to the flooded plots was assumed to have been levee seepage and was not used in the comparison. With the frequent rains in 1992, there was not a significant difference between the amounts of water applied to the two furrow-irrigated treatments. However, over

30 in. more water was applied to the flooded plots, even after accounting for levee seepage (Table 1).

Wheat/Rice Doublecrop

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. Problems with the grain drill were observed when planting the fourth replication of the rice study. Although plots were harvested from the fourth replication, yields averaged over 1000 lb/acre less than yields from the other replications. Therefore, only data from replications 1 through 3 were included in the analysis and the yields reported in Table 2.

Because the soil beds would not be reworked between the wheat harvest and the planting of rice, the beds had to be firm enough to support the combine without rutting. Therefore, the frequent rains in late May and early June led to an extremely late (20 June) planting for rice. The weather that followed led to slow development of the rice crop, with grain filling and maturation periods delayed until fall. The results were a very late harvest (6 November) and low yields (Table 2).

SIGNIFICANCE OF FINDINGS

Grain yields were reduced by 15% with furrow irrigation as compared to flood. The reduction was consistent with data from previous years and does not appear to be affected by different irrigation scheduling or additional nitrogen. The potential for water savings does appear to be significant for the Sharkey soil.

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. As shorter-season rice cultivars are developed, some of the risks may be reduced.

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Table 1. Grain yields and water use from 1992 furrow-irrigated/flooded rice comparison study at Northeast Research and Extension Center, Keiser, Arkansas.

Irrigation Treatment	Grain Yield	Water Use
	lb/acre @ 12% moisture	in.
Furrow irrigated:		
twice weekly	6040 a	21 a
@ 0.75 in. SWD	6110 a	18 a
Flood irrigated	7170 b	56[z] b
LSD(0.05)	810	8

[z]Adjusted to allow for 10 in. of levee seepage.

Table 2. Rice grain yields from 1992 wheat/furrow-irrigated rice study at Northeast Research and Extension Center, Keiser, Arkansas.

Seedbed Treatment	Grain Yield
	lb/acre @ 12% moisture
Burn wheat stubble and seed rice	3580
Seed rice into standing wheat stubble	3310
LSD(0.05)	n.s.

PERFORMANCE TESTING OF RICE IRRIGATION PUMPING PLANTS

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

ABSTRACT

Preliminary work conducted by the Cooperative Extension Service reveals that the average irrigation pumping plant is operating at less than 70% of optimum efficiency. 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.

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.

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 performance and selection.

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

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

This specific information is then evaluated to determine what recommendations 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 somewhat 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

Additional pumping plant evaluation equipment was purchased, and testing was continued during the 1992 growing season. The new equipment was field calibrated so that it provided more specific information on the power unit's performance. Eighteen tests were conducted on 14 different wells in six counties: Chicot, Cross, Crittenden, Lincoln, Poinsett and Woodruff. The average pumping efficiency of the irrigation systems evaluated was less than 70%, which adds $3 to $6/acre-ft of water pumped. Eleven of the evaluations were on diesel-powered wells, six on electric-powered and one on a propane-powered well. Useful information on pumping capacity and fuel consumption was provided to the producers. A summary of this information is presented in Table 1 with a more complete presentation of the data in Table 2.

SIGNIFICANCE OF FINDINGS

In nearly every case, the producer thought the well was pumping more water than was actually measured during the evaluation. The new testing equipment made it possible to better inform the producer about the power unit performance. Calculations on the propane unit indicated that a fuel cost savings of $1000 to $1200/year might be realized by converting to a diesel-powered unit. The producer planned to use this information to determine if he wanted to make this conversion.

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.

Table 1. 1992 test results summary.

Energy Source	No. of Tests	Pumping Capacity Range (GPM)[z]	Fuel consumption Range	Seasonal Fuel Consumption Range[w]
Electric	6	565-2225	7-21 KWH/acre-in.[y]	212.4-621 KWH/acre[v]
Diesel	11	1165-2630	0.55-1.45 gal/acre-in.[x]	16.5-43.5 gal/acre[u]
Propane	1	1480	1.58 gal/acre-in.	47.4 gal/acre

[z]GPM - Gallons per minute
[y]KWH/acre-in. - Kilowatt hours of electricity per acre-in. of water pumped
[x]gal/acre-in. - Gallons of fuel per acre-in. of water pumped
[w]Assumes 30 in. pumped per acre
[v]KWH of electricity/acre
[u]Gallons of fuel/acre

Table 2. 1992 complete test results.

System Type[z]	Power Unit	Pump	Flow	Fuel Use	Fuel Use	Seasonal Fuel Use
	RPM[y]	RPM	GPM[x]	gph[w]	gal/acre-in.[v]	gal/acre[u]
Propane-LST	1100	1650	1480	5.2	1.58	47.4
Diesel-LST	2280	1900	1500	4.82	1.45	43.5
Diesel-LST	2000	1670	1500	3.42	1.03	30.9
	2120	1760	2050	4.31	0.95	28.5
Diesel-LST	2060	–	1880	3.63	0.87	26.1
	2180	–	2000	4.27	0.96	28.8
Diesel-LST	1800	1500	1165	2.01	0.77	23.1
	2160	1800	1590	3.16	0.895	26.85
Diesel-LST	1910	1910	1525	3.4	1.0	30.00
Diesel-LST	2120	1750	2630	3.76	0.64	19.2
	1820	1500	1850	2.26	0.55	16.5
Diesel-LST	1700	1700	1750	2.4	0.62	18.6
				KWH	KWH/acre-in.	KWH/acre
Electric-LST	--	--	1350	21.25	7.08	212.4
Electric-SUB	--	--	565	26	20.7	621.0
Electric-LST	--	--	2225	53.5	10.8	324.0
Electric-LST	--	--	2150	42	8.8	263.7
Electric-LST	--	--	2020	46	10.2	306.0
Electric-LST	--	--	1300	25	8.6	258.0

[z]LST - Line shaft turbine; SUB - submersible
[y]RPM - Revolutions per minute
[x]GPM - Gallons of water per minute
[w]gph - Gallons of fuel per hour; KWH - Kilowatt hours
[v]gal/acre-in. - Gallons of fuel per acre-in. of water; KWH/acre-in. - KWH of electricity per acre-in. of water
[u]gal/acre - Gallons of fuel per acre; KWH/acre - KWH of electricity per acre. Assumes 30 in. pumped per acre.

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

Joel T. Walker and Dennis R. Gardisser

ABSTRACT

Eight aircraft calibration workshops including almost 400 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. Investigation of particle properties with a granular herbicide indicated the need for adjustment for granule size in order to achieve uniform distribution with current aerial equipment. Blending of larger granules would allow pilots to apply the herbicide at low rates without costly and difficult adjustments to equipment.

INTRODUCTION

This project was designed to satisfy the following objectives: 1) To determine the accuracy with which fertilizers, seeds and other granular materials are being applied to fields by typical Arkansas agricultural aviators; 2) To determine problems with accurate distribution of granular materials that may be associated with certain aircraft/spreader combinations, application methods and the material; 3) To determine the relative significance of factors affecting accuracy with which fertilizers, seeds and other granular materials are being applied to fields by typical aerial equipment in Arkansas; 4) To model the distribution and transport of particles to the point of deposition using actual field measurements to verify equations; 5) To develop recommendations for practical field application of granular materials and work with particular popular aircraft/spreader combinations in determining initial equipment settings that provide good material distribution.

MATERIALS AND METHODS

The objectives have been largely accomplished through a cooperative effort between research and extension. The principle investigators have developed and continue to use equipment and procedures (Gardisser et al., 1985) for measuring the dispersion, transport and deposition of particles from aerial equipment. For the past eight years, this equipment has been used at workshops to calibrate and adjust aerial equipment while gathering valuable data. These workshops are performed at the request of the pilots who spend valuable time away from their businesses operating expensive aircraft during the workshops. County Extension personnel assist in workshop operation.

An investigation of the effects of particle size on the distribution pattern was continued (Barnes and Walker, 1991). Ordram 10G and 15G are being applied by aircraft, but a need for improved application efficiency has been noted. These materials are typically applied at dosages of 15 to 30 lb of formulated product per acre. The systems used on most aircraft in rice-producing areas were designed to apply fertilizer with the most common application rate being approximately 100 lb/acre. Pesticide formulations that closely approximate the particle size characteristics and flow rates of urea fertilizer should result in the most uniform application. This assumes that the pilot will not make substantial changes to his craft when changing from one material to the other and that the aircraft has been properly adjusted for fertilizer applications. This experiment was originally set up to include four dry materials: 1) Ordram 10G, 2) Kaolin clay having a particle size the same as that of Ordram 10G, 3) #10 granule blank and 4) #10 granule labeled ALT. Table 1 gives properties of some of these materials. The #10 granule particles were much larger than regular Ordram particles. Urea at an application rate of 100 lb/acre was used as a reference. These materials were tested on 1 September 1992. On 22 September 1992 two additional #10 granule materials were tested. Data collections were replicated three times for each material type.

The potential of rotary spreaders was evaluated through adaptation of previous modeling work (Walker et al., 1992). A simple model of particle velocities exiting a rotary spreader disk was developed. These velocities were entered into a model of particle trajectory to the ground developed previously (Walker and Gardisser, 1988 and 1989) and adapted to the rotary data.

RESULTS AND DISCUSSION

Significant improvement in deposition uniformity has been measured from aircraft as a direct result of the adjustments made at these workshops (Walker and Gardisser, 1987). 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). Both pilots and rice farmers appreciate the workshops. Eight workshops were held this year with nearly 400 analyses being performed.

Particle size had a significant impact on distribution pattern uniformity and effective swath widths when spread by agricultural aircraft. Both the distribution uniformity and the effective swath width were more desirable with #10 granules than with regular Ordram. The uniformity of current Ordram 10G particles is not as good as would be expected if a larger particle size was adopted as a carrier. The effective swath width of #10 granule particles (larger particles) would more closely approximate widths commonly used by aerial applicators during their fertilizer applications. This should make it less confusing when trying to flag passes in the field. Both standard Ordram and DPG-treated particles seemed to have about the same flow rate or application rate and should result in the same dosage. Very little difference was noted between two different samples of a larger particle size. This would indicate that particle size influences the distribution much more than slight bulk density changes. Larger particles may be applied within an acceptable CV level of 15%. The CV average for all the smaller particles is 22.2% and for the larger particles is 9.3%, a substantial improvement in uniformity with the larger particles. Formulations that more closely exhibit the qualities of fertilizer or products to which the aerial applicators are accustomed and for which they have their equipment adjusted should result in the most uniform field applications. The investigators will continue to work with the chemical manufacturer to determine ideal particle size.

Adaptation of rotary equipment to fixed-wing aircraft does not appear to be practical due to the increased aerodynamic drag, auxiliary power requirements and likelihood of a poor pattern.

SIGNIFICANCE OF FINDINGS

The aerial application industry is changing rapidly with the addition of turbine engines, recommendations for high rates of fertilizer application and the introduction of granular herbicides requiring low (10-20 lb/acre) application rates. The investigators wish to continue the workshops so that data for these types of applications can be gathered. Also, the investigators feel that sufficient data on air flow (Gardisser and Walker, 1991), particle properties and the distribution process is in hand to begin design and development of a spreader that will perform well with modern aircraft, have adjustments for fine tuning and be able to work satisfactorily with both low rates of herbicides and high rates of fertilizer.

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Table 1. Properties of granular materials used in investigation of distribution of low-rate herbicide. Ordram Testing - Pine Bluff 1992.

Material Code	Material Description	Bulk Density	Recom-mended Swath	CV @ Rec. Swath	75 ft Application Rate	75 ft CV
Urea	Urea	48	81	12	89	15
			84	9	91	17
			81	10	95	14
OR10GACT	Ordram 10G	56.7	57	15	20	20
			63	14	49	22
			63	24	18	29
OR10GDPG	Kaolin Clay	50.7	69	20	18	23
			69	21	18	23
			69	21	18	22
10GRACTW	#10 Granule ALT - 1st Sample	49	78	5	28	7
			75	7	28	7
			75	15	25	15
10GRDPGW	#10 Granule Blank - 1st Sample	50	81	8	26	11
			81	5	26	7
			78	8	28	10
10GRACT	#10 Granule ALT - 2nd Sample	49	75	11	21	11
			75	8	22	8
			72	6	20	8
10GRDPG	#10 Granule Blank - 2nd Sample	45.3	78	9	22	10
			78	5	19	6
			72	13	23	16

EVALUATION OF THE HARVESTING PERFORMANCE OF THE SHELBOURNE REYNOLDS STRIPPER HEADER

Terry Siebenmorgen, Earl Vories, Andy Mauromoustakos, Dennis Gardisser and Kelvin Bennett

ABSTRACT

Harvesting tests were conducted with a Shelbourne Reynolds stripper header in September 1992 in commercial rice fields near Keiser, Arkansas. Harvesting speeds of 1, 2, 3 and 4 mph were evaluated in 'Newbonnet' and 'Millie' rice fields, encompassing a wide range of moisture contents. Although the analysis of these data is incomplete at this time, preliminary results seem to indicate that harvest loss rates increase at speeds of 3 mph and above. In addition, harvest loss rates were higher in Millie than in Newbonnet for equivalent harvesting speeds.

INTRODUCTION

The technology of stripping grain was developed and patented by the British Technology Group (BTG). Shelbourne Reynolds Engineering Ltd. of Suffolk, England, received the first patent on a stripper header and currently markets stripper headers in Europe and the United States. The stripper header, which mounts to most modern self-propelled combines, is designed to strip small grain heads (i.e. rice, wheat, oats, barley) from their stalks and deliver the grain to the combine feeder housing. This stripping process is achieved by eight rows of finger-like teeth spread evenly around 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.

Preharvest, header and combine losses all contribute to the total crop loss. Material feedrate, which is directly related to crop density and harvesting speed, significantly affects combine and header loss rates. Grain moisture content at harvest has also been found to significantly affect grain quality.

Unfortunately, little research has been published on rice harvesting losses induced by header and combine operating parameters. This limited research is almost obsolete with the advent of improved harvesting methods and new rice varieties. In addition, published research on fuel consumption requirements and combine harvesting effects on grain quality from the mid-South is almost nonexistent for modern rice varieties.

The main objective of this project was to determine the rice harvesting effects of the Shelbourne Reynolds stripper header on harvest loss, grain quality and fuel consumption.

PROCEDURE

Two Case/IH 1680 self-propelled axial-flow combines were used for testing. One combine was equipped with a Shelbourne Reynolds SR6000 stripper header (this combine and header will be referred to as the "stripper combine" throughout the remainder of this report). The other combine carried a conventional Case/IH model 1010 rigid grain header (this combine and header will be referred to as the "conventional combine"). Both headers were 6.1 m (20 ft) wide.

A few modifications listed in the Shelbourne Reynolds owner's manual were necessary for the stripper combine. Although both combines had a closed tube specialty rotor, four impeller blades were mounted on the front of the stripper combine's rotor while the conventional combine's rotor contained the standard two impeller blades. The three rear grates were replaced with Shelbourne Reynold's special modified grates of type KIT-00903. The three front concaves had the 3/8-in. steel bar wires fitted in every other hole. The stripper combine's clean grain and tailings auger handling capacities were increased by replacing the 25-teeth chain drive gears with 30-teeth gears. The front roller on the feeder housing was raised and locked into its top position to allow for even material feed.

The experimental design consisted of testing field harvesting speeds of 1, 2, 3 and 4 mph. The tests were conducted over a 29-day period during September 1992 in laser-leveled, commercial rice fields near Keiser, Arkansas. The two varieties tested were Newbonnet, a mid-season, short-statured, long-grain variety, and Millie, a short-season, long-grain variety. Harvesting tests in both varieties encompassed a wide range of moisture contents. Therefore, four experimental variable test combinations were conducted for each rice variety and moisture content. Each field speed/moisture content/variety test combination was replicated several times.

Optimum combine and header settings were determined prior to the actual tests by an experienced field harvesting technician representing Wallace Equipment, Inc., a distributor for Shelbourne Reynolds Engineering. The optimum stripper combine operating parameters as determined by this technician were held constant throughout all of the tests. These parameters 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.

One replication of each experimental variable combination was performed within each bay of rice. The rice bay's average length was approximately 1000 ft. Both combines were warmed up at the beginning of each test day by harvesting a minimum of 200 bu of rice. A test run consisted of harvesting a full header's width of rice with both the stripper and conventional combines immediately adjacent to each other down the entire 1000-ft length of the rice bay. The stripper combine harvested rice at one of the four randomly selected harvesting speeds. The conventional combine served as a control and always harvested at optimal settings (harvesting speed = 1 mph, fan speed = 800 rpm, rotor speed = 850 rpm and concave clearance = 7/8 in.).

The total weight of harvested rice for each combine was measured in a weigh wagon upon the completion of each test run. Any differences between the weight of grain in the grain tank of the two combines were assumed to represent the harvesting loss or gain associated with harvesting with a stripper header. The elapsed test time was recorded with a stopwatch in order to verify harvesting speeds. Fuel consumption and fuel temperature data were also recorded for each test. Samples from the grain tank of both combines were collected for moisture content and head rice yield determinations. In addition, in an effort to minimize any mechanical damage imparted to the rice kernels, hand harvested samples were collected alongside each cut made by the stripper combine.

RESULTS AND DISCUSSION

All of the harvesting data have been collected; however, since the project was not completed until late fall, some of the data have not yet been analyzed.

Preliminary results seem to indicate that there were no significant differences in harvest loss of the stripper header between 1 and 2 mph. However, loss appears to increase quadratically at and above 3 mph. A maximum harvesting speed of 3 mph was attained in Newbonnet since harvesting speeds above 3 mph appeared to overload the shoe and cause the clean grain and tailings augers to "choke up." The average yield of Newbonnet was slightly over 200 bu/acre. A maximum harvesting speed of 4 mph was achieved in Millie before the same "choking" problems were experienced. The average yield of Millie was approximately 175 bu/acre.

Preliminary comparisons of the stripper combine loss rate to that of the conventional combine traveling at speeds of 1 mph or less and set at optimal conditions showed that stripper combine loss rates at 1 and 2 mph were near zero for Newbonnet but were much higher for Millie. The analysis of these data is not complete at this time, but investigations of possible varietal differences that could have caused this are pending.

Fuel consumption and grain quality data are currently being analyzed. Graphs illustrating fuel consumption versus harvesting speed and moisture content will be constructed. In addition, the effects of the stripper header on the quality of harvested rice will be evaluated upon completion of the milling tests.

EVALUATION OF NUCLEAR MAGNETIC RESONANCE FOR RICE DRYING RESEARCH

T.J. Siebenmorgen, V.K. Bhumbla and K.A.K. Moldenhauer

ABSTRACT

Use of nuclear magnetic resonance (NMR) techniques to determine moisture content of various rice fractions was investigated. Newbonnet rice at an initial moisture content of 17.9%, wet basis, was dried to a final moisture content of 9.9%, wet basis, and samples taken at intervals of 1 percentage point change in moisture content. Dried rough rice was rewetted to obtain samples from moisture content of 10.65%, wet basis, to 17.81%, wet basis, at intervals of approximately 1 percentage point in moisture content. All the samples were milled to obtain brown rice, white rice and rice hulls, which were tested for moisture content by using NMR.

Moisture content of freshly harvested rough rice under different conditions of drying air temperature and relative humidity at different intervals of drying was obtained using NMR and other more traditional moisture measurement techniques. Results compared very favorably with the standard oven method. Free induction decay curves for rough rice were also obtained.

INTRODUCTION

Moisture content is regarded as the single most important quality-related property of grains. Rapid determination of moisture content in grains has long been a concern; nuclear magnetic resonance (NMR) is a potentially significant technique for rapid determination of moisture content in rice. The primary objective of this study was to explore the applicability of NMR in determining the moisture content of rough rice and rough rice fractions, viz., brown rice, white rice and rice hulls.

PROCEDURE

Cleaned rough rice ('Newbonnet') at an initial moisture content of approximately 17%, wet basis, was dried to a final moisture content of approximately 10%, wet basis, under room temperature conditions in a single layer. Rough rice moisture was continually measured and samples taken roughly at every 1 percentage point change in moisture content. The dried rough rice was rewetted to obtain samples at 1 percentage point moisture change to a moisture content of approximately 18%, wet basis. Rough rice samples were subsequently milled to obtain brown rice, white rice and hulls. A minispec NMR analyzer was used to obtain the moisture content of the rough rice, brown rice, white rice and hulls. The moisture contents so obtained were compared with those obtained using the standard air oven drying method, and the results were compared.

Table 1 shows the parameters of the NMR equipment that were used in developing the regression equation and subsequent moisture measurement.

In order to evaluate measurement of rough rice moisture content immediately after drying, Newbonnet rice harvested at a high moisture content (approximately 18%) was dried under controlled conditions of temperature and relative humidity. Rough rice samples were taken at intervals of 15 min, 30 min, 45 min, 1 hr, 1.5 hr, 2.0 hr, 2.5 hr, 3.0 hr, 3.5 hr and 4 hr. Free induction decay (FID) curves for the rice samples were obtained immediately after drying for different drying times. Moisture content of the samples was also obtained using NMR, single kernel moisture meter, Motomco moisture meter and the standard air oven technique.

RESULTS

Table 2 compares the results obtained for the rough rice using the standard air oven technique and the NMR technique. The moisture contents obtained using NMR correlated very well to those from the standard air oven technique, and in all cases the error involved was less than 1.5%. In the case of brown rice, white rice and hulls, similar errors were less than 2.5%, 3.93% and 3.10%, respectively. Fig. 1 shows a typical curve comparing moisture contents during drying obtained using different moisture measurement techniques. From the figure it can be seen that moisture contents obtained using NMR follow the oven moisture contents closely.

SIGNIFICANCE OF FINDINGS

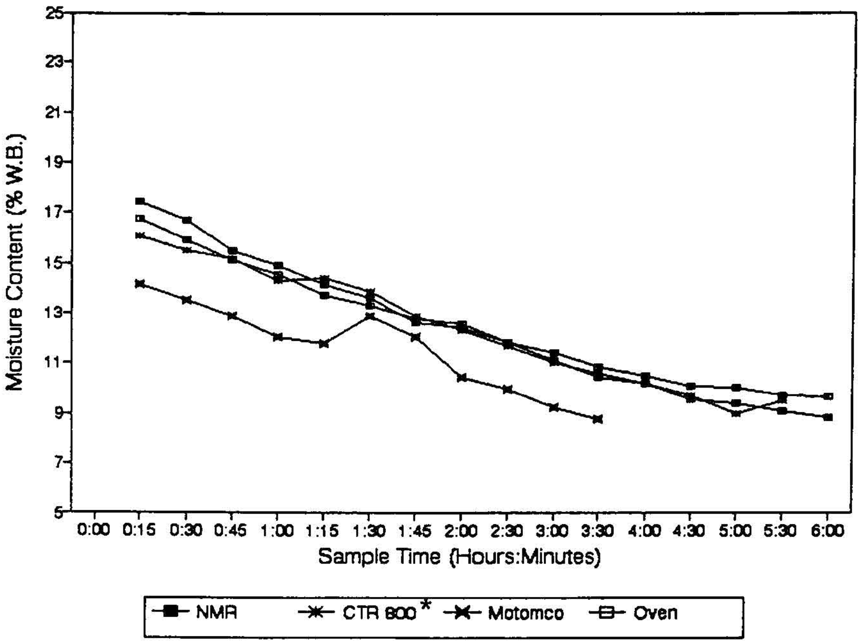
The experimental results obtained show that NMR provides a quick, reliable and nondestructive technique for measuring moisture content of rough rice, brown rice, white rice and rice hulls under equilibrated conditions. Measurement of moisture content during drying of rough rice indicates that NMR is a viable moisture content measurement technique in samples where the moisture profiles have not yet stabilized.

Table 1: NMR parameters used in developing the regression equation for moisture measurement of rough rice fractions

NMR Parameter	Value
Dur 01	30 μs
Dur 02	70 μs
Offset	0.011
Enhancement	25
Attenuation	29
Relaxation delay	1.00s
Band Width	High
Mode	Diode

Table 2: Comparison of moisture content of rough rice obtained using NMR and standard air oven method.

Sample No.	Sample weight, g	NMR mc, %wb i	Oven mc,% wb ii	error % (i-ii)/ii* 100
1	3.0974	17.96	17.91	0.30
2	2.9659	17.36	17.49	0.77
3	3.1134	16.49	16.47	0.11
4	2.9489	15.68	15.51	1.07
5	3.1151	14.35	14.24	0.74
6	3.1393	12.87	12.83	0.28
7	3.0741	12.03	12.02	0.07
8	2.9635	10.46	10.52	0.53
9	2.9396	9.74	9.88	1.41



*CTR 800 and Motomco are single kernel and batch testers, respectively.

Fig. 1. Comparison of moisture conent of rough rice dried at 49°C and 20% relative humidity using different moisture measurement techniques.

DETERMINING OPTIMAL HARVEST MOISTURE CONTENT: MODELING OF RICE FIELD MOISTURE CONTENT

Terry J. Siebenmorgen, Renfu Lu, Thomas A. Costello, Edward O. Fryar and Robert H. Dilday

ABSTRACT

A mathematical model was developed to predict rice grain moisture content (MC) during the harvest season. The effects of dew and rain on rice grain MC change were predicted by the model. Simulations were conducted using the hourly field meteorological data for the harvest seasons from 1988 to 1990 at Stuttgart and Keiser, Arkansas. The model-predicted grain MCs compared reasonably well with the experimental data for the three harvest seasons. Relatively large prediction errors (up to 5 percentage points) were sometimes obtained for the early harvests or when rice was harvested shortly after rain. The occurrence of rain caused dramatic increases in rice grain MC, but the rice grain also lost the absorbed moisture rapidly soon after rain. The presence of dew could cause up to a 4-percentage-point increase in rice grain MC overnight.

INTRODUCTION

Time of harvest is one of the most critical operations in rice production and can significantly affect rice field yield, milling quality and drying costs and, therefore, a producer's final income. This is largely due to proper moisture content (MC) of the grain at harvest. If rice grain MC in the field could be accurately predicted, proper harvesting schedules could in turn be made to maximize economic return to the producer.

Variation in rice grain MC during the harvest season is a dynamic process that is closely related to environmental conditions. Temperature, relative humidity, wind and solar radiation are the primary variables. Rain or dew causes an increase in rice grain MC and can also delay harvesting. A model for accurately predicting rice grain MC in the field should take into account these weather factors. This report summarizes results of model development for predicting rice grain MC throughout the harvest season and model validation using meteorological and field MC data collected from 1988 through 1990. A detailed description of the mathematical model and its implementation can be found in Lu and Siebenmorgen (1992, 1993).

PROCEDURE

In the field, three drying/rewetting modes are expected to take place in a rice kernel on a panicle: 1) drying/rewetting by the ambient air without the presence of rain or dew; 2) rewetting by dew; and 3) rewetting by rain. In addition, the rice plant will continue to supply water to the panicles until senescence. This can significantly influence the rice grain MC change during the early part of the harvest season.

Mathematical equations were developed to predict the change in rice grain MC in the field under each of the three weather conditions. The drying/rewetting of rice in the field was considered a process of simultaneous heat and mass transfer. In order to accurately predict the change in rice grain MC, the effects of radiation, evaporation/condensation and convection on the heat flow at the kernel surface were considered in the heat transfer equations. The incidence and duration of dew on the kernel surface and the effects of rain events on rice grain MC were predicted by the model.

A computer program was developed to implement the model for predicting rice grain MC during the harvest season. Meteorological data were obtained from the University of Arkansas Rice Research and Extension Center (RREC) at Stuttgart, Arkansas, in 1988 and 1989 and the Northeast Research and Extension Center (NEREC) at Keiser, Arkansas, in 1989 and 1990. An automated weather station positioned 2.0 m above the ground was used to record hourly air temperature, relative humidity, total solar radiation, rain amount and duration and wind velocity, which were used as inputs in simulation runs. Field grain MC data for two long-grain varieties, 'Newbonnet' and 'Tebonnet', in the harvest seasons from 1988 to 1990 were used to validate the modeling results.

RESULTS AND DISCUSSION

In 1988, the model predictions of rice grain MC compared well with the experimental data, particularly after rice grain MC decreased to about 20% (Fig. 1). The average absolute prediction error over the entire harvest season was 1.5 percentage points. The occurrence of rain events caused rapid increases in rice grain MC. However, the rice grain also lost the absorbed moisture rapidly after rain. In the early harvest season, the rice grain MC decreased steadily, and this trend was disrupted only by rain events. The model did not predict any dew incidence on the kernel surface during the 1988 harvest season at Stuttgart.

Figure 2 shows the comparison of experimental data and the model predictions of rice grain MC for Newbonnet grown at Stuttgart in 1989. Predicted grain MCs compared well with the experimental data over the entire harvest season. The average absolute prediction error was about 1.2 percentage points. Relatively larger prediction errors (up to 3.6 percentage points) were obtained from the two harvest dates in which rice was harvested shortly after rain.

Figure 3 shows the comparison of predicted and observed grain MCs of Newbonnet long-grain rice for 1989 at Keiser. The model predicted the rice grain MCs reasonably well with an average absolute error of 1.3 percentage points. A larger prediction error (3.8 percentage points) was obtained for the last harvest date when the rice was harvested a few hours after rain. In 1990, it rained on approximately one-fourth of the harvest season days (Fig. 4), causing dramatic changes in rice grain MC. The model predictions of rice grain MC did not compare well with the experimental data when rice grain MC was above 25% (the maximum prediction error was about 5 percentage points). The measured grain MC decreased by only about 4 percentage points during the first 14 days, which was abnormally low. After the rice grain MC decreased to about 20%, the rice kernel experienced the daily cyclic changes of diurnal drying and nocturnal rewetting if rain events were not present. The model predictions of rice grain MC compared well with the experimental data except for the last two harvest dates. Larger prediction errors for the last two harvest dates (4.3 and 2.8 percentage points) are speculated to be due to the fact that the air temperature for that time period dropped to about 1°C, which is beyond the normal temperature range that the drying model applies.

Dew incidence on the kernel was predicted for eight days out of the 58-day harvest season in 1990 at Keiser. The modeling results showed that the kernel MC could be increased by 3.7 percentage points when dew lasted about 9 hours. No dew was predicted by the model for the 1988 and 1989 harvest seasons at Stuttgart and Keiser.

Overall, the model adequately predicted rice grain MC in the field during the three harvest seasons. Relatively large prediction errors were sometimes obtained when rice was harvested at high grain MCs

(> 25%). Reasons for this include the fact that nonuniformity in the field was more pronounced at higher grain MCs. Also, grain MC measurement errors would be expected to be greater at higher grain MCs. As the average grain MC decreased, the individual kernel MCs became less variable on a panicle and among panicles for different field plots. Hence the model is expected to give a better prediction late in the harvest season than early in the harvest season.

SIGNIFICANCE OF THE WORK

The mathematical model developed in this study was shown to be appropriate for predicting rice MC in the field during the harvest season. The model, in conjunction with available weather information and a previous, related study on modeling rice field yield and milling quality (Lu et al., 1992a, 1992b), can be used to determine the optimal time to harvest rice. Further work will be conducted to incorporate the results of this study into an expert system to assist the producers in making time of harvesting decisions.

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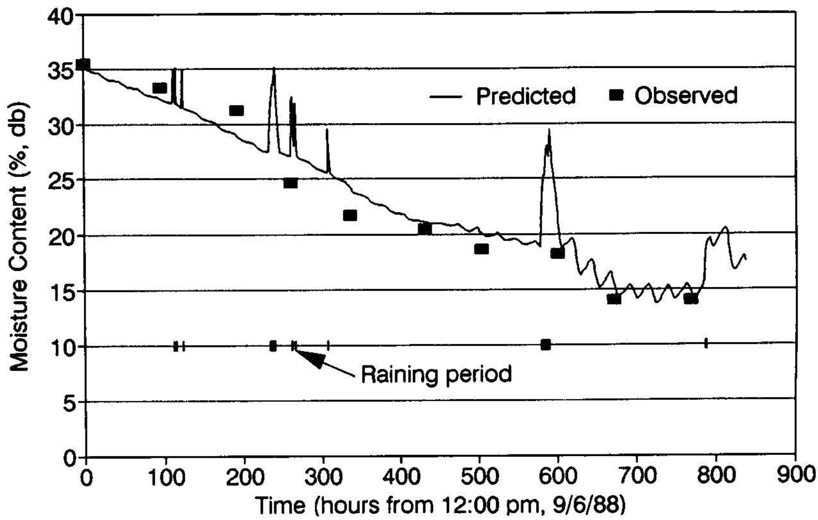

Fig. 1. Predicted and observed moisture contents of 'Newbonnet' long-grain rice in 1988 at Stuttgart, Arkansas.

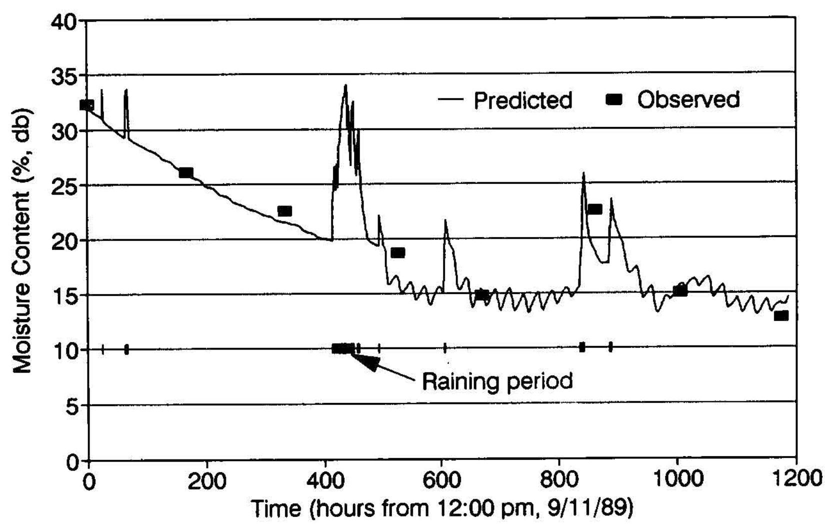

Fig. 2. Predicted and observed moisture contents of 'Newbonnet' long-grain rice in 1989 at Stuttgart, Arkansas.

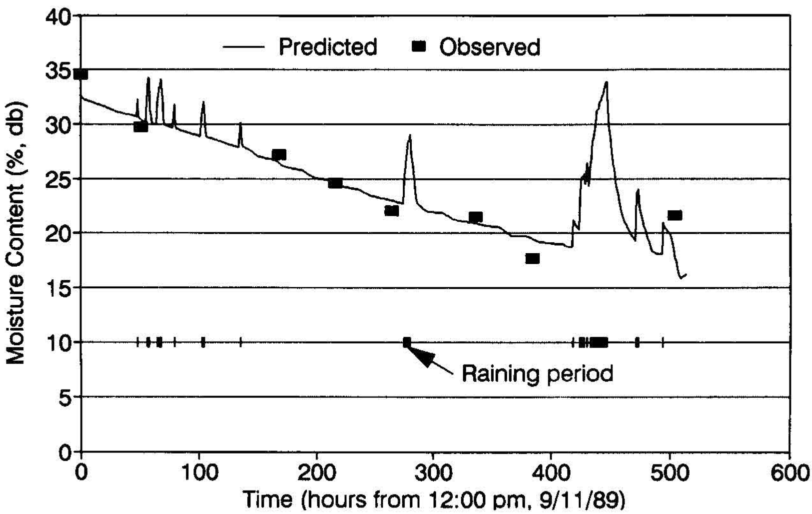

Fig. 3. Predicted and observed moisture contents of 'Newbonnet' long-grain rice in 1989 at Keiser, Arkansas.

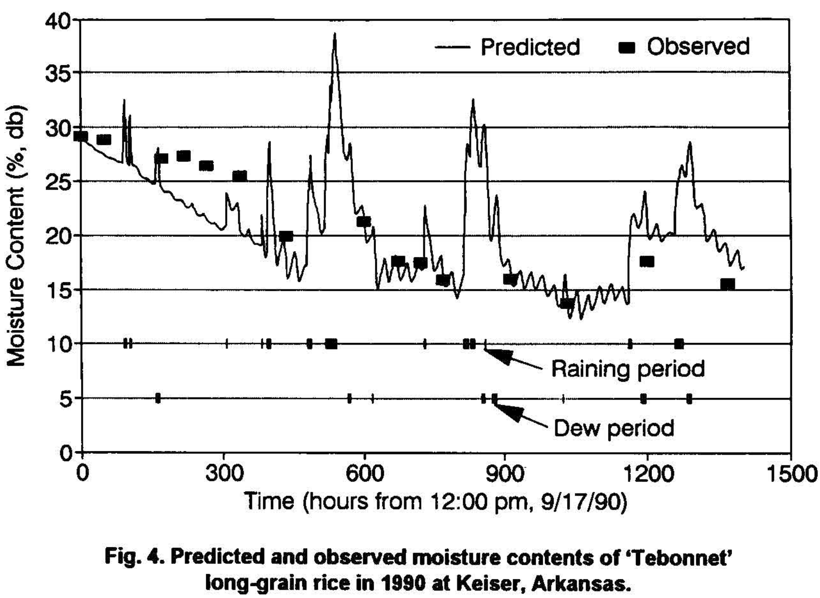

Fig. 4. Predicted and observed moisture contents of 'Tebonnet' long-grain rice in 1990 at Keiser, Arkansas.

MOISTURE ADSORPTION RATES AND KERNEL MOISTURE CONTENT EFFECTS ON HEAD RICE YIELDS AT HARVEST

Terry J. Siebenmorgen, Renfu Lu and Paul A. Counce

ABSTRACT

Time of harvest experiments were conducted in 1989 and 1990 to measure head rice yield (HRY) and individual kernel moisture content (MC) distributions for 'Newbonnet', 'Lemont' and 'Tebonnet' long-grain varieties. Individual kernel MC frequency distributions for the three rice varieties showed two or three modes for the early harvest dates. As time progressed, the high-MC modes gradually diminished, and only one mode was shown in the kernel MC frequency distributions for the late harvest dates. HRYs of the three varieties did not change significantly when the average rice MC at harvest ranged from 15 to 22%. HRY reductions occurred as a result of rapid rewetting by rain after the MC decreased to 15% or lower prior to rain. The HRYs obtained from the harvest dates after rain were most significantly correlated with the percentage of kernels with MCs above 10.5% for Newbonnet, 13.5% for Lemont and 12.5% for Tebonnet, as measured on the harvest dates before the rain.

INTRODUCTION

The value of rice is largely determined by the head rice yield (HRY), which is defined as the weight percentage of rough rice that remains as head rice (whole kernels) after complete milling. HRY is influenced by many factors, including variety, cultural practices, grain MC at harvest and postharvest drying and storage operations. Among these factors, the influence of harvest MC on HRY has been extensively reported. Harvesting at high or low MCs can result in significant HRY reductions. Studies have shown that reductions in HRY at the late stages of harvest are mainly attributed to kernel fissuring, which is caused by rapid moisture adsorption. Rice kernels will fissure when rapidly rewetted if the initial MC is below a critical level of 12 to 15%.

This critical MC level may vary with variety and environmental conditions. As rice dries in the field, an increasing number of kernels fall below the critical MC level. It has been speculated that preharvest HRY reductions are correlated with the percentage of kernels that dry below the critical level and are subsequently rewetted. The objective of this study was to measure HRYs and kernel MC frequency distributions throughout harvest and to determine possible relationships between HRY and the kernel MC distributions.

PROCEDURE

Time of harvest experiments were conducted at the University of Arkansas Northeast Research and Extension Center (NEREC) at Keiser, Arkansas. The long-grain variety, Newbonnet, was used in 1989, and two long-grain varieties, Lemont and Tebonnet, were used in 1990. The experiments were randomized complete block designs, 7 x 23 ft plots with four replications, and the treatments were time of harvest.

Rice was hand-harvested around noon and threshed with a stationary combine. Immediately following each harvest, individual kernel MCs were measured using a Shizouka Seiki, CTR-800A individual kernel moisture meter. Ten 200-kernel samples were used for MC measurements from each of four replications. Samples for HRY determination were double bagged in Zip-loc plastic bags and refrigerated at approximately 1°C until time of milling. Two 150-g subsamples from each replication were dried to 12.5% MC and milled for 30 sec using a McGill No. 2 mill to determine HRY. A detailed description of the experimental procedure is given in Siebenmorgen et al. (1992a, 1992b).

RESULTS AND DISCUSSION

Fig. 1 shows typical kernel MC frequency distributions for Tebonnet at three selected harvest dates representing the early, middle and late part of the harvest season. A tri-modal pattern in kernel MC frequency distributions was observed on the early harvest date. As harvest time progressed, the high-MC mode decreased and the low-MC mode increased. Only a single mode was shown in the MC frequency distributions for the late harvest dates. The trends in MC frequency distribution patterns for all three varieties were similar and were in agreement with those found in an earlier study.

Average MCs, HRYs and the occurrence of rain throughout the harvest seasons for the three varieties are shown in Fig. 2. HRY for Newbonnet increased steadily as the MC decreased to 22% (Fig. 2a). No significant change in HRY was measured at harvest MCs between

15 and 22%. Approximately 0.4 in. of rain fell when the average rice MC for Newbonnet was about 18%. At this high MC, HRY was not affected when rice was harvested two days after the rain. However, rain did cause a significant two-percentage-point reduction in HRY when the Newbonnet rice was harvested on October 2 (day of year (DOY) 275), five days after DOY 270 when the average MC was about 15%. It appears that HRY began to decrease as MC decreased below 15%. However, no dramatic reduction in HRY was observed for the Newbonnet variety in 1989. It is speculated that this was because harvest was ended before a large number of kernels dried to critically low MC levels, thereby preventing HRY reduction due to rewetting.

In 1990, there was no significant change in HRY at MCs ranging from 22 to 15% for Lemont and Tebonnet (Figs. 2b and 2c, respectively). Dramatic HRY reductions occurred for both Lemont and Tebonnet rice harvested after rain had rewetted rice that had dried to 12% MC. Lemont HRY dropped 37.5 and Tebonnet 23.1 percentage points over a time interval of seven days after rewetting rain, which began on DOY 308. Figs. 2b and 2c show that rain had not occurred for several days just prior to the dates when the Lemont and Tebonnet MC reached 12%, and HRYs for both Lemont and Tebonnet did not decrease dramatically. The weather data show that the first frost in 1990 occurred on October 11 (DOY 284). There was a heavy, killing frost on October 26 (DOY 299). Therefore, it appears that dew or frost did not fissure a large percentage of the rice kernels.

Individual kernel moisture data (Siebenmorgen et al., 1991, 1992a) reveal that HRYs from harvest dates immediately after rain were correlated with the percentage of kernels at harvest that had MCs above given levels on the corresponding dates before rain for each variety. HRY after rain rewetting was most significantly correlated with the percentage of kernels with MCs above 10.5% for Newbonnet (R^2 = 0.991), 13.5% for Lemont (R^2 = 0.992) and 12.5% for Tebonnet (R^2 = 0.998). This indicates that if, for example, an individual Tebonnet kernel dried to below 12.5% and was subsequently rewetted by rain, sufficient fissuring would occur to break the kernel during milling. With the variability associated with individual kernel MCs about the mean MC (Fig. 1), a bulk sample with an average MC above the critical level may include a large number of kernels that are below the 12.5% level, and thus some of the kernels would be susceptible to fissuring by rain. Because of relatively few data points used in the regression analysis, the MC level corresponding to the maximum correlation coefficient may differ from the critical MC level. However, these preliminary results did indicate that a linear relationship exists between HRY and the percentage of kernels with MC above or below a given level. Lemont rice appeared to have a higher critical MC level, under which rice would fissure when subjected to rapid rewetting, than did Newbonnet and Tebonnet rice.

SIGNIFICANCE OF THE WORK

Head rice yield reduction in the three rice varieties appears to have been caused mainly by rewetting of rice kernels by rain after the MC had been reduced below a critical level dependent on the variety. Rain had no discernible effect on HRY when the average rice MC was above 15% at the time rainfall occurred. Severe HRY reductions occurred as a result of rewetting by rain after the average rice MC decreased to below 15%. These results suggest that these three varieties of long-grain rice grown in Arkansas may be harvested at MCs as low as 15% without a significant loss to the HRY if conditions are similar to those in these tests.

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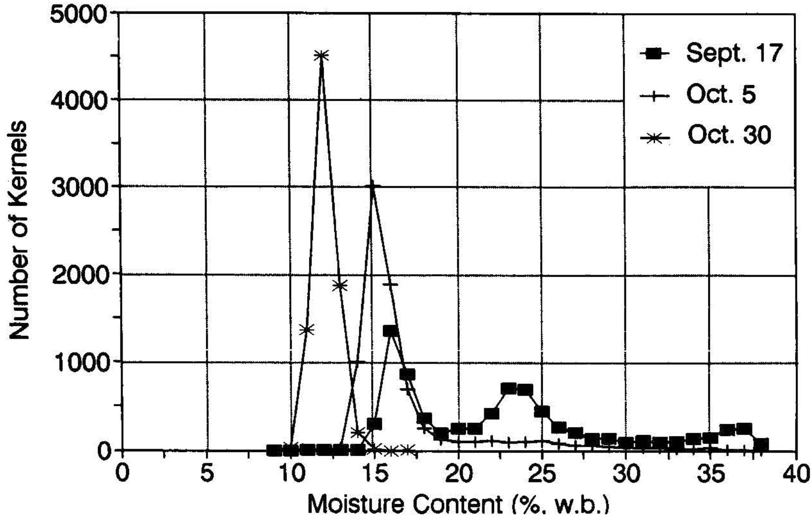
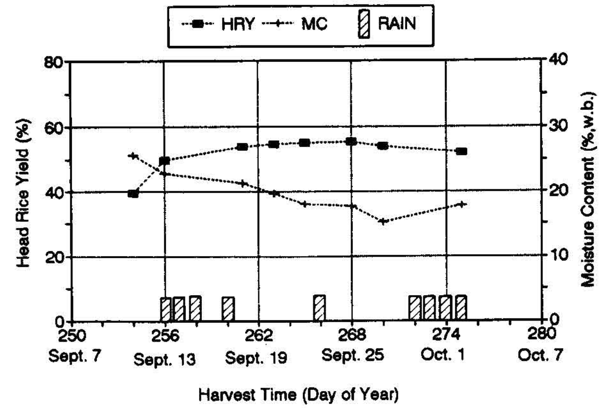
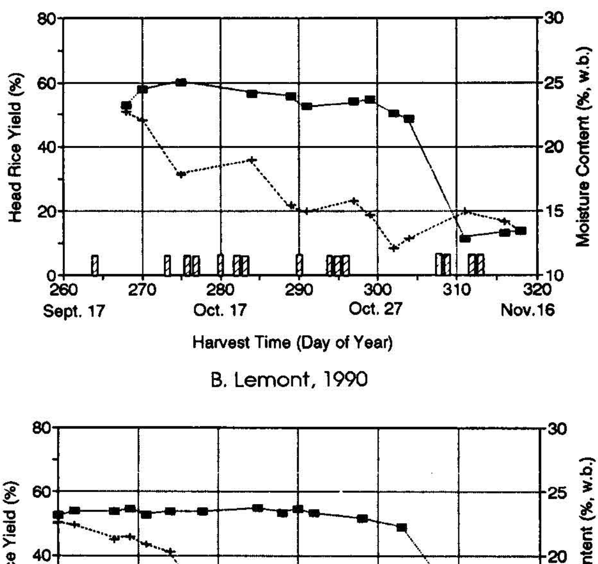


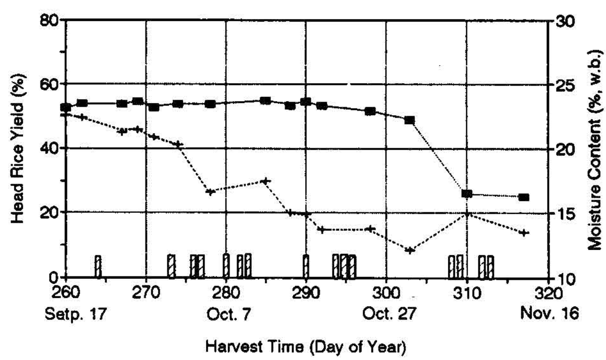
Fig. 1. Kernel moisture content frequency distributions at three selected harvest dates for 'Tebonnet' in 1990.



A. Newbonnet, 1989



B. Lemont, 1990



C. Tebonnet, 1990

Fig. 2. Head rice yield and average MC on each harvest date, and the incidence of rain for (a) 'Newbonnet' in 1989, (b) 'Lemont' in 1990, and (c) 'Tebonnet' in 1990.

UTILIZATION OF RICE BRAN PROTEINS IN FOODS

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ABSTRACT

Rice bran protein concentrates (RBPC) containing 47% and 56% protein were produced by extracting proteins in water or dilute alkali (pH 10) solutions, respectively. When analyzed for nutritional qualities, the RBPC had favorable amino acid profiles and high (90%) digestibility. When compared with the 1.0 score of a reference protein for 2- to 5-year-old children recommended by the Joint FAO/WHO Expert Consultation on Protein Quality, the water- and alkali-extracted RBPCs had protein digestibility-corrected amino acid scores of 0.96 and 0.86, respectively. Scores compared to the reference protein for infants were higher than that of soy protein isolate, which is used as a protein source for infant formulas. In addition, the water-extracted RBPC showed possible hypoallergenic properties. Protein concentrates and isolates from rice bran may have potential in the manufacture of value-added products that are hypoallergenic.

INTRODUCTION

The current primary use of rice bran is as a component in animal feed. It contains 12-16% protein (Saunders, 1990) and is higher in the essential amino acid lysine than other cereal brans. The protein is easily extracted from unheated bran and, as a concentrate or isolate of greater than 70% or 90% protein, respectively, may be a potential source of high-quality protein for human consumption. Several researchers have prepared rice bran protein concentrates (RBPCs) (Chen and Houston, 1970; Connor et al., 1976; Lew et al., 1975; Houston et al., 1969; Lynn, 1969; Mitsuda et al., 1970; and Maki and Misao, 1983). Saunders (1990) prepared a concentrate and reported digestibility of greater than 90%, which was superior to the 73% value found for raw rice bran.

The Joint FAO/WHO Expert Consultation on Protein Quality Evaluation (1990) recommended the use of an amino acid scoring procedure adjusted for digestibility. A hypothetical reference protein derived from the amino acid requirements for the 2- to 5-year-old child was designated as the standard of comparison for food proteins. It was desirable to evaluate the protein quality of two RBPCs produced by water (WE-RBPC) or alkali extraction (AE-RBPC) methods. Protein quality of the two RBPCs was compared to that of a soybean protein isolate (SPI), casein and the Joint FAO/WHO/UNU (1985) reference proteins for infants and 2- to 5-year-old children.

Rice has been regarded as hypoallergenic. A food is considered allergenic if it causes production of class E antibodies, which cause an allergic reaction. Therefore, hypoallergenic describes a material that does not cause an allergic reaction. A substance is antigenic if it causes production of antibodies of any class. Antigenicity of a protein is sometimes used to indicate allergic potential. Very little has been reported concerning the allergenic and antigenic properties of rice and rice bran. Matsuda et al. (1988, 1991) identified a protein of about 16,000 daltons molecular weight that was responsible for allergic symptoms in three individuals. The allergenic protein was contained primarily in the milled rice, but a small amount was present in bran.

It was desirable to study the immunological properties of rice bran to determine if it might have potential as a hypoallergenic protein source. Antibodies to RBPC, soybean protein isolate and non-fat dry milk were developed in rabbits and the quantities compared. Antigenic proteins in the RBPC were identified.

PROCEDURES

Preparation of RBPC. Commercial rice bran was defatted with petroleum ether and dried. The bran used for preparation of the AE-RBPC was washed in 50% ethyl alcohol and mixed with dilute alkali solution (pH 10) for 1 hr. The slurry was centrifuged and the liquid containing the dissolved proteins retained. The pH of the liquid was adjusted with HCl to 4.5 where the proteins precipitated. After centrifugation, the proteins were freeze dried. Water extracted-RBPC was prepared in the same way except that it did not undergo the alcohol wash and was extracted in water rather than in alkali solution.

Digestibility studies. *In vivo* digestibility was determined by the method recommended by the Joint FAO/WHO Expert Consultation on Protein Quality Evaluation (1990). Rats were fed weighed diets with the RBPCs, which had been autoclaved to remove residual petroleum ether. Feces were collected and the amount of protein retained calculated. Chemical (*in vitro*) digestibility was determined for SPI and milk according to Pedersen and Eggum's (1983) method.

Amino acid analyses. Samples of the RBPCs were sent to the University of Missouri-Columbia Experiment Station Chemical Laboratories for amino acid analyses. Protein Technologies, Inc. (St. Louis, MO) provided analysis for the SPI.

Protein Digestibility-Corrected Amino Acid Scores (PDCAAS). These values were computed as recommended by the Report of the Joint FAO/WHO Expert Consultation on Protein Quality Evaluation (1990). Reference patterns used were from the FAO/WHO/UNU (1985).

Antigenic and allergenic studies. Antibodies were developed by injecting rabbits with soybean protein isolate PT710 (Ralston Purina), non-fat dry milk or the AE-RBPC, which contained all the proteins extracted by both the alkali and water treatments. The blood serum levels were measured by enzyme linked immunosorbent assay (Bhunia et al., 1991). To identify antigenic proteins, separation was done by sodium dodecyl polyacrylamide gel electrophoresis followed by Western blot analysis.

RESULTS AND DISCUSSION

The WE- and AE-RBPCs had protein contents of 47% and 56%, respectively. The protein in the RBPCs was 90% digestible, which was lower than the 100% and 96% values for milk and SPI, respectively. Rice bran protein concentrate fed to the rats had been autoclaved to remove solvent residue from the defatting process. Rice bran protein concentrate produced without extensive heat treatment would be expected to have higher digestibility. The 90% digestibility value was, however, improved over the 73% for rice bran reported by Saunders (1990).

Amino acids were corrected for digestibility and scored (Table 1). A score of 1.0 or greater indicates that the requirement was met for that amino acid. When compared to the reference protein for children ages 2 to 5, WE-RBPC was slightly deficient in lysine (0.96). Alkali-extracted-RBPC was also deficient in lysine (0.86), and the threonine content was marginal (1.00). Soy protein isolate was marginal in the sulfur-containing amino acids methionine and cystine (1.00). When compared to the requirements for infants, WE-RBPC, AE-RBPC and SPI were all deficient with respective scores (and limiting amino acids) of 0.70 (tryptophan), 0.76 (lysine) and 0.60 (methionine and cystine). Although quite deficient in the sulfur-containing amino acids, SPI is currently used as the protein source in many infant formulas. Both the RBPCs had better scores than the SPI and may be potential protein sources for similar products. Use of bran proteins would be particularly desirable if RBPC proves to be hypoallergenic, since soy is a common allergen. However, more work needs to be done to improve the protein content of the RBPCs to > 90%, as is required in a protein isolate. The alcohol wash improved the protein content of the AE-RBPC and should have a similar effect when applied to the WE-RBPC.

Rice bran protein concentrates, cow's milk and SPI were tested for antigenic properties by development of polyclonal antibodies in rabbits, and the respective serum antibody levels were 653,000, 27,300 and 21,845,000. The relatively low level for milk was unexpected since both milk and SPI are known to be very allergenic in some humans. Dr. Ralph Knight of New Zealand Milk Products told us that New Zealand white rabbits do not develop high blood antibody levels to milk (personal communication, Dallas, Texas, June 1991). The antibody level was significantly lower for rice than for soy. The blood serum containing the antibodies against rice was reacted against rice proteins (Western blot analysis) to determine specifically antigenic proteins. Preliminary results confirmed the work of Matsuda et al. (1988, 1991). However, these proteins were not found in the WE-RBPC. The water-extracted concentrate may have hypoallergenic qualities, even if the AE-RBPC does not.

When infants are allergic to the milk or soy proteins in a formula, class E antibodies are formed in the intestine. These are different from the class G antibodies produced in the rabbit blood during this study. Further testing needs to be done to determine if rice bran proteins cause allergic reactions in the gut or if they have hypoallergenic properties.

SIGNIFICANCE OF FINDINGS

Rice bran proteins are highly digestible and of good nutritional quality. The proteins that may cause allergy to rice do not appear to be extracted in water. Therefore, a potential exists to manufacture a hypoallergenic RBPC that might have application in value-added food products and infant formulas. Rice bran could become a much more valuable commodity with protein concentrates and isolates bringing prices of $0.50 to $2.50 as opposed to current prices for rice bran of $0.03/lb.

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Table 1. Protein digestibility corrected amino acid scores for rice bran protein concentrates and soy protein isolate as compared to the FAO/WHO/UNU reference proteins (1985).

	2- to 5-year-old child			Infant		
Amino Acid	WE-RBPC	AE-RBPC	SPI	WE-RBPC	AE-RBPC	SPI
Histidine	1.63	1.68	1.32	1.19	1.23	0.96
Isoleucine	1.43	1.36	1.68	0.87	0.83	1.02
Leucine	1.12	1.09	1.20	0.80	0.77	0.85
Lysine	**0.96**[z]	**0.86**	1.05	0.85	**0.76**	0.92
Methionine & Cystine	1.36	1.36	**1.00**	0.81	0.81	**0.60**
Phenylalanine & Tyrosine	1.25	1.25	1.38	1.10	1.10	1.21
Threonine	1.06	1.00	1.09	0.84	0.79	0.86
Tryptophan	1.09	1.27	1.09	**0.70**	0.82	0.70
Valine	1.77	1.74	1.37	1.13	1.10	0.87

[z]values in **bold** print indicate protein digestibility-corrected amino acid score.

DEVELOPMENT OF TESTS TO MAKE SPECIFICATIONS FOR RICE FLOUR AND STARCH

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ABSTRACT

The central focus of this research was to develop tests that predict how rice flour/starch will function as a food ingredient. From previous work we know that gelatinization influences functionality. Two assays, water uptake and swelling potential, were used to determine how much water was in the starch granule when gelatinization takes place. Results indicated that short- and medium-grain varieties take on more water than long-grain varieties, with a few exceptions. Gel electrophoresis was performed on 12 varieties to obtain a protein profile. Cooked rice flour pastes were analyzed using a texture analyzer to develop a method for measuring low shear viscosity. The swelling potential assay along with the low shear viscosity and/or gel strength test using the texture analyzer have potential for being developed as screening tests in breeding programs or specification tests for rice processors.

INTRODUCTION

Consumption of rice in the U.S. has consistently increased over the past few years. More recently, rice flour and, to some extent, rice starch are being used as ingredients in further processed foods. This is good for the rice industry, but there are problems in predicting the functional properties of flour from different varieties and within a variety grown under different conditions. This variability makes it difficult for rice processors to predict the behavior of flour and starch and also makes it difficult to write specifications for buyers. The important factors in marketing rice are its cooking, eating and processing qualities, which include texture (firmness, stickiness, etc.), flavor, integrity and appearance of the cooked grain. These traits are primarily governed through inherited traits, and breeding for food quality characters could expand rice markets. The screening tests being conducted by the USDA/ARS Rice Quality Laboratory at Beaumont, Texas, are very effective for defining typical grain-type cooking quality of southern rice varieties. At present, there are no routine tests in use for defining flavor or texture for whole grain rice or for rice flour and starch.

When studying the cooked rice texture and/or the cooking and eating qualities of rice, many factors and many tests need to be included. Stickiness can be measured on cooked whole kernel rice; viscosity is normally measured when flour/starch paste is cooked. When rice kernels or rice flour/starch pastes are cooked, gelatinization takes place. During gelatinization, water is taken into the starch granule, and it becomes swollen. The amount of water that is absorbed influences how sticky the kernel will be or how viscous the paste will be. The water uptake, swelling potential, dispersibility of the granule and amount of water left in intergranular spaces influence stickiness and paste viscosity. Gelatinization, then, influences the functionality of the flour/starch as it is used in food processing.

The protein content of rice is very small, about 7% on the average, and it was never considered to be an indicator of cooking and eating quality in rice. But in other cereal grains, such as wheat, protein is a major factor in determining texture. With this in mind, we directed some of our studies to determine if this were true for rice. In some of our previous work (Hamaker et al., 1991), we correlated a 60-Kdal protein with the amylose content of rice. Since amylose content and other traits are determining factors in cooking and eating quality of rice, we concluded that this protein correlates to rice texture. And in another study (Hamaker and Griffin, 1990) we found that when a reducing agent was added to the solution/suspension of rice/rice flour to disrupt the protein, the stickiness/viscosity increased. As our work progressed (Hamaker and Griffin, 1993) we found that by adding the reducing agent to disrupt the protein, the gel strength was affected and the degree of gelatinization increased. A conclusion was made that a starch granule-associated protein appears to influence the functional properties of the flour/starch paste as well as the texture of the cooked whole grain. The studies conducted for this project are designed to better understand the texture of cooked rice and rice flour and starch and to develop better methods that predict functional properties of flour and starch.

PROCEDURES

1. To determine how much water was in the starch granule when gelatinization takes place, we developed a method for water uptake. Flour (1 g) was placed in a large test tube with 30 ml water and incubated for two hours at the temperatures of 25, 50, 60, 70 and 80°C. Next it was centrifuged and the supernatant discarded. The weight was recorded and the tube placed in a 105°C oven overnight. After cooling, the weight was recorded again, and the difference obtained was recorded as water uptake.
2. The swelling factor of starch granules was measured using a revised method of Tester and Morrison (1990). A reducing agent was added to one set of flour. Rice flour (100 mg) was placed in a test tube with 10 ml water and placed in a waterbath at the appropriate temperature (50, 60, 70, 80 or 90°C) for 30 min. Blue dextran (mol. wt. approximately 2,000,000 daltons) was added, the tubes centrifuged and the supernatant read at 640 nm. The absorbance readings were inserted into a fixed formula and the numbers recorded as swelling factor. Results with and without a reducing agent further strengthened our findings that a starch granule-associated protein has influence on rice texture.
3. Proteins from 12 varieties were extracted and analyzed by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) according to the method of Laemmli (1970). The approximate molecular weight and amount of protein in the bands can be determined after this assay is performed. Since we previously found a 60-kdal protein to correlate with stickiness, work is in progress to determine if there is another protein to correlate to texture.
4. The Universal TZ-XT2 Texture Analyzer was used to determine the strength of the gelatinization paste of 10 flours. A beaker with rice flour (8 g) and 100 ml water was placed in a boiling water bath and stirred approximately 20 revolutions/min with a Teflon-coated rod to keep the flour particles in suspension for 15 min. A minimum amount of shear was introduced to the mixture to keep from breaking the swollen granules. The hot paste was cooled to 70°C, and gel strength was recorded as the amount of force needed to remove the probe from the paste.

RESULTS AND DISCUSSION

Water uptake amounts needed to be established to determine how much water is in the starch granule when gelatinization takes place. The overall pattern showed that short- and medium-grain rices take up water faster and also take on more water than long-grain varieties. With the overnight drying, this test is more time-consuming than the swelling factor assay.

The difference between the water uptake and the swelling factor is that we can determine the true amount of water inside the starch granule. This is because the blue dextran with its large molecular weight size cannot enter the swollen granule. It stays in the water surrounding the granule. Results from this assay indicate that short- and medium-grain rices were generally found to have higher swelling factors than long-grain rices. This indicated a more immediate and complete swelling of the starch granules of short- and medium-grain rice grains during gelatinization. When a reducing agent was included in the procedure, all the rice varieties but one showed an increase in swelling where the protein had been broken away from the molecule to let the starch granule absorb more water. This assay, since it is relatively simple and fast, is one we want to develop as a predictive test for rice flour texture. This would be useful as a specification test for rice processors or a screening test in a breeding program.

Preliminary tests performed on 12 cooked rice flour pastes using the Universal TA-XT2 Texture Analyzer showed promise of developing a low shear viscosity test. If this could be done, it would be comparable to the Instron Universal Tester and Brabender Visco/Amylograph to determine textural properties. And a method to determine a texture profile of a gel that was made from a cooked rice flour slurry is also underway.

SIGNIFICANCE OF FINDINGS

By using the water uptake method and the swelling factor assay, with and without a reducing agent, we further concluded that a starch granule associated-protein is involved in understanding rice texture. The swelling factor assay may be effective as a screening test to predict flour pasting properties. There is a present need to improve specifications for rice flour now that it is being used more by the food industry.

Our previous work suggested that cooked rice stickiness is influenced by proteins as well as by starch. The flour paste viscosity studies indicated that proteins associated with starch granules seemed to control the extent that granules swell and gelatinize.

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