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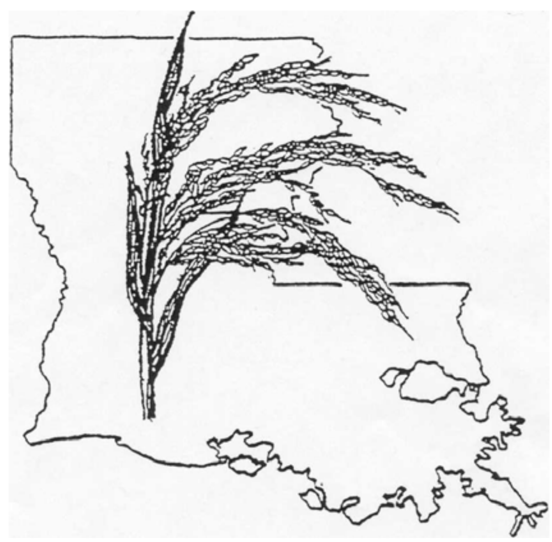
PROCEEDINGS. . .

Thirtieth Rice Technical Working Group

New Orleans, Louisiana: February 29 – March 3, 2004



The Agricultural Experiment Stations and Agricultural Extension Services of Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas; and the Agricultural Research Service, the Economic Research Service, the Cooperative State Research, Education, and Extension Service, and other participating agencies of the U.S. Department of Agriculture; and cooperating rice industry agencies

Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station
Southwest Region
Rice Research Station
Crowley, Louisiana 70526

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Proceedings ... Thirtieth Rice Technical Working Group **New Orleans, Louisiana: February 29 – March 3, 2004**

Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station
Southwest Region
Rice Research Station

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PROCEEDINGS ... THIRTIETH
RICE TECHNICAL WORKING GROUP

RICE TECHNICAL WORKING GROUP

Organization and Purpose

The Rice Technical Working Group (RTWG) functions according to an informal memorandum of agreement among the State Agricultural Experiment Stations and the Agricultural Extension Services of Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, and the Agricultural Research Service, the Economic Research Service, the Cooperative State Research, Education, and Extension Service and other agencies of the United States Department of Agriculture. Membership is composed of personnel in these and other cooperating public agencies and participating industry groups who are actively engaged in rice research and extension. Since 1960, research scientists and administrators from the U.S. rice industry and from international agencies have participated in the biennial meetings.

Pursuant to the memorandum of agreement, the Association of Agricultural Experiment Station Directors appoints an administrative advisor who represents them on the Executive Committee and in other matters. The administrator of the USDA-ARS designates a representative to serve in a similar capacity. The Directors of Extension Service of the rice growing states designate an Extension Service Administrative Advisor. The Publication Coordinator also is on the Executive Committee.

Other members of the Executive Committee are elected biennially by the membership of the RTWG; they include a general chair who has served the previous term as secretary, a secretary-program chair, a representative from each of the seven major rice-growing states (Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas), the immediate past chair, and an industry representative. The rice industry participants elect an Executive Committee member, on a rotational basis, from the following areas: (1) chemical, (2) seed, (3) milling, (4) brewing industries, (5) producers, or (6) consultants.

Several weeks prior to the biennial meeting, panel chairs solicit and receive titles and interpretative summaries of papers to be presented. They work with the secretary-program chair in developing the program, including joint sessions as desired. Program development includes scheduling of papers and securing persons to preside at each panel session. Each panel chair is in charge of (1) election of a successor and (2) updating of the panel recommendations.

Committees, which are appointed by the incoming chair, include Nominations, Location and Time of Next Meeting, and Resolutions Committee. Members of the Nominations and the Location and Time of Next Meeting Committees are usually selected to represent the different geographical areas. The Resolutions Committee is responsible for the resolutions pertaining to the current meeting and for a necrology report when appropriate.

The RTWG meets at least biennially to provide for continuous exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by the States, Federal Government, and cooperating agencies. It develops proposals for future work, which are suggested to the participating agencies for implementation.

Location and Time of the 2004 Meeting

The 30th RTWG meeting was hosted by Louisiana and held at the DoubleTree Hotel in New Orleans, Louisiana, from February 29 to March 3, 2004. The Executive Committee, which coordinated the plans for the meeting, included Rick Norman, Chair; Don Groth, Secretary; and Mark Kurtz, Immediate Past Chair. Geographic Representatives were Chuck Wilson (Arkansas), Jim Thompson (California), Christopher Deren (Florida), Johnny Saichuk (Louisiana), Dwight Kanter (Mississippi), Bruce Beck (Missouri), and Christine Bergman (Texas). Administrative Advisors were William Brown (Experiment Station), Mike French (Extension Service), and J. Neil Rutger (USDA-ARS). Publication Coordinators were Pat Bollich and Don Groth. The Industry Representative was Dave Jones. The Local Arrangements Chair was Steve Linscombe.

Location and Time of the 2006 Meeting

The Location and Time of the 2006 Meeting Committee recommended that the 31st RTWG meeting be held by the host state Texas, at the Woodlands Waterway Marriott in Houston, Texas, from February 26 to March 1, 2006.

2004 RTWG Awards

The Distinguished Rice Research and Education Award honors individuals achieving distinction in original basic or applied research, creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills, which advance the science, motivate the progress, and promise technical advances in the rice industry. Only one individual and team award can be given at an RTWG meeting. The individual award was presented to Dr. R.D. Cartwright for his contributions to the control of rice diseases. The team award was presented to Drs. F.N. Lee, M.A. Marchetti, and K.A.K. Moldenhauer for their contributions to the control of rice blast through resistance.

The Distinguished Service Award honors individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, and industrial rice technology. This award usually requires a whole career to achieve, and thus, it can be argued it is our toughest award to win. But, since more than one can be given at an RTWG meeting, it is our fairest award granted to all worthy of such distinction. This award was presented to Drs. P.K. Bollich, W.H. Brown, A.D. Klosterboer, F.N. Lee, J.A. Musick, J.E. Street, J.F. Williams, and S.L. Wright, III.

Publication of Proceedings

The LSU AgCenter's Rice Research Station published the proceedings of the 29th RTWG meeting. Professors Patrick Bollich and Donald Groth of Louisiana served as the Publication Coordinators for the 2002 proceedings. They were assisted in the publication of these proceedings by Darlene Regan.

Instructions to be closely followed in preparing abstracts for publication in the 31st RTWG (2006 meeting) proceedings are included in these proceedings (pp. 204-205).

Committees for 2006

Executive:

Chair:	Don Groth	Louisiana
Secretary:	Garry McCauley	Texas

Geographical Representatives:

Rick Cartwright	Arkansas
Randall Mutters	California
Andrew Bennett	Florida
Bill Williams	Louisiana
Tim Walker	Mississippi
Gene Stevens	Missouri
Bob Fjellstrom	Texas

Immediate Past Chair:

Rick Norman	Arkansas

Administrative Advisors:

David Boethel	Experiment Station
Mike French	Extension Service
J. Neil Rutger	USDA-ARS

Publication Coordinators:

Don Groth	Louisiana
Mike Salassi	Louisiana

Industry Representative:

Dave Jones	California

2006 Local Arrangements:

Anna McClung, Chair	Texas

Location and Time of 2008 Meeting:

Jim Hill	California
Randal Mutters	California
Tim Walker	Mississippi

Nominations:

Jim Hill (Chair)	California
John Bernhardt	Arkansas
Andrew Bennett	Florida
Eric Webster	Louisiana
Mark Kurtz	Mississippi
Gene Stevens	Missouri
Lee Tarpley	Texas
Dave Jones	Industry

Rice Crop Germplasm:

Karen Moldenhauer, Chair	Arkansas
Jim Correll	Arkansas
Georgia Eizenga	Arkansas
Robert Fjellstrom	USDA-ARS
James Gibbons	Arkansas
Farman Jodari	California
Dwight Kanter	Mississippi
Jim Oard	Louisiana
Mo Way	Texas
Fangming Xie	Texas
Ex Officio:	
Harold Bockleman	USDA-ARS
Mark Bohning	USDA-ARS
David Marshall	USDA-ARS
J. Neil Rutger	USDA-ARS
Kay Simmons	USDA-ARS
Allan Stoner	USDA-ARS

National Germplasm Resources Laboratory:

Mark Bohning	USDA-ARS
Allan Stoner	USDA-ARS

Resolutions:

Carl Johnson	California
Richard Dunand	Louisiana

Rice Variety Acreage:

Johnny Saichuk, Chair	Louisiana
Chuck Wilson	Arkansas
Kent McKenzie	California
Curtis Rainbolt	Florida
Tim Walker	Mississippi
Bruce Beck	Missouri
Jim Stansel	Texas

2006 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:
Shannon Pinson Texas
Economics and Marketing:
David Anderson Texas
Plant Protection:
Mo Way Texas
Processing and Storage:
Cherly Earp Texas
Rice Culture:
Lee Tarpley Texas
Rice Weed Control and Growth Regulation:
J. Mike Chandler Texas

RESOLUTIONS
30^TH RTWG - 2004

The 30^th meeting of the RTWG held at New Orleans, Louisiana, Feb. 29 – March 3, has provided the time and location for the exchange of information among rice research and extension scientists, rice growers, representatives of the rice industry, and users of rice products. This exchange of knowledge has been beneficial to all concerned and has accomplished the aims of the RTWG.

Therefore, the resolutions committee, on behalf of the RTWG, expresses its appreciation to the following individuals and organizations that have contributed to the success of the 30^th meeting.

1. Rick Norman, RTWG Chair, and all other members of the Executive committee who organized and conducted this very successful meeting. We recognize Don Groth and his cooperating staff for the timely completion of organizational details to include notification correspondence, program preparation, specific paper presentation standards, and all other tasks involved with the RTWG.

2. The staff of the New Orleans DoubleTree Hotel (particularly Andrew Acthley and his staff) for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The Local Arrangements committee, chaired by Steve Linscombe. To Karen Bearb and Darlene Regan for conducting all aspects of pre-registration and for handling many other details of planning the meeting. To Karen Bearb, Darlene Regan, Kimberly Guidry, and Patricia Bollich for conducting all aspects of on-site registration. To Richard Dunand, Don Groth, and Steve Linscombe who contacted donors and solicited donations. We appreciate all the aforementioned efforts to make sure everything was in place so the meeting ran smoothly.

4. To all other Rice Research Station faculty and staff who contributed time and effort to make sure this meeting was a success. Special recognition to the Rice Research Station research associates who assisted with A/V in all concurrent sessions. Also, to Davis Dautreuil for his time and expertise in all computer-related aspects of the meeting.

5. The Panel Chairs (Qi Ren Chu, Michael Salassi, Nathan Childs, Michael Stout, Elaine Champagne, Jim Oard, Eric Webster, and Bill Williams) and moderators for planning, arranging and supervising the technical sessions. Special recognition is due for the efforts of the chairs and Don Groth to collect, organize, and edit abstracts for the Website, posting, and final publication.

6. The paper/poster presenters for sharing results and new ideas at the meeting.

7. The General Session speakers for sharing their knowledge and wisdom:

Bill Brown – Vice Chancellor and Director, LSU AgCenter, Louisiana Agricultural Experiment Station
"Welcome to Louisiana/Update on Louisiana Agriculture and LSU AgCenter Programs."

Ben Noble – Vice President, Government Affairs, USA Rice Federation
"Rice Industry Issues – Today and in the Future."

8. The Mini-Symposium on Risks of Introduced Pests speakers:

Mo Way – Research Entomologist, Texas A & M University
"Insects"

Rick Cartwright – Plant Pathologist, University of Arkansas
"Diseases"

Dearl Sanders – Weed Scientist, LSU AgCenter
"Weeds"

Gary Cave – Entomologist/Senior Risk Analyst – USDA, APHIS, PPQ.
"CPHST, PERAL, International Trade and Invasive Plant Pests"

9. Pat Bollich and Don Groth, LSU AgCenter, assisted by Darlene Regan, in publishing the RTWG proceedings.

10. The RTWG wishes to recognize the following sponsors whose generous donations helped to make the 30th RTWG meeting a success:

JAZZ

BASF
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Riceland Foods Foundation
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The Hlavinka Equipment Company/Case IH
Horizon Ag, LLC
Lockeby Rice and Grain
Quality Equipment Company
RiceCo
Supreme Rice Mill, Inc.
Sweetlake Land and Oil Company
Terral Seed, Inc.

Distinguished Rice Research and/or Education Award

Richard D. Cartwright

This scientist has made significant contributions to both applied research and the extension service for controlling diseases in rice. He is recognized widely throughout the southern region and the United States as a leading authority on the epidemiology of rice diseases and control of diseases in rice production.

He conceived and developed a rice disease monitoring system in Arkansas to define risk areas for prevalent diseases and to detect new diseases and new races of pathogens. This is the first statewide rice disease monitoring system that has been established in the United States, and it has made significant contributions to the current knowledge on the prevalence of rice diseases in Arkansas and their incidence and severity on the various rice cultivars we grow. This program has been widely used to educate and provide “hands on training” in identifying diseases to growers, county extension agents, rice consultants, and others. This program serves as a model for the regional rice pest survey conducted by cooperating agencies and universities. His weekly newsletters on the rice disease situation during the growing season are eagerly read by growers, county agents, consultants, scientists, commodity traders, and government officials because they are so informative.

His fungicide efficacy studies resulted in the recommendations for use of propiconazole on rice cultivars susceptible to kernel smut and false smut diseases. His work has provided for the proper uses of Quadris and other sheath blight fungicides at rates and timings appropriate to control sheath blight. This has resulted in the overall use of less fungicide per acre without losing yield or quality and maximizing profit to the grower. His fungicide tests have led to new scouting procedures and threshold treatment levels for rice diseases. In addition, he has defined the impact of potassium and the severity of stem rot and brown spot on southern rice cultivars and the impact of nitrogen timing and rate on sheath blight, kernel smut, and false smut of rice.

Distinguished Rice Research and/or Education Award

Fleet N. Lee, Marco A. Marchetti, and Karen A.K. Moldenhauer

These two pathologists, Fleet Lee of the University of Arkansas and Tony Marchetti of the USDA-ARS, and a rice breeder, Karen Moldenhauer of the University of Arkansas, teamed together in the discovery, characterization, and utilization of novel blast resistance genes in southern U.S. rice germplasm and characterization of the population of the rice blast pathogen in the southern United States.

Five popular rice cultivars have been released as a result of their work and equally as important as the release of these cultivars are the contributions these cultivars have made as parents in U.S. rice breeding efforts.

The race characterization of the rice blast pathogen population in the United States by the pathologists of this team has formed the basis for much of our current understanding of the evolution of this fungus in the South, and other blast researchers have been and are currently using the information worldwide.

Distinguished Service Award

Patrick K. Bollich

This rice agronomist of the LSU AgCenter was committed to the promotion of the rice industry in Louisiana through his contributions and achievements in rice culture and soil fertility research, education, and extension.

His work in the area of rice fertility and rice culture helped to improve the soil fertility and cultural management packages for producers in the southern growing region. He gave considerable research effort in improving rice ratoon yields, which is very important to rice production in southern Louisiana.

He was a leader in the south in research and implementation of conservation tillage in rice. This helped with water quality in Louisiana by mitigating problems associated with runoff from production fields. The National Cotton and Rice Conservation Tillage Conference recognized him for his innovation in conservation tillage with their Conservation Tillage Rice Researcher of the Year Award.

He determined the proper N fertilizer rate for over 50 new rice varieties, he helped to defined the use of new N fertilizers, as well as urease and nitrification inhibitors in rice, and determined the influence of environment, tillage, water management, stand density, and seeding method on rice grain yield.

His work helped to educate the farmers, extension personnel, and industry on how we should best manage fertilizers in rice so that our recommendations were sound agronomically, economically, and environmentally.

He was very active in the RTWG: serving on the Executive Committee as a Geographical Representative from Louisiana and has been Secretary/Program Chair, Chairman of the RTWG, and co-editor of the RTWG Proceedings since 2000. In 2000, he was awarded the Distinguished Rice Research and Education Award from the RTWG for his team research accomplishments in rice agronomy and soil fertility.

Distinguished Service Award

Arlen D. Klosterboer

This extension specialist of Texas A&M University was committed for over 28 years to the education and service of the Texas farmer clientele and county extension agents and possessed all of the qualities one should have to successfully carry out the duties of an extension specialist. The county extension agents in Texas felt the same way as they, on numerous occasions, selected him as the Outstanding Specialist.

He was the pulse of the Texas rice industry for the researchers at the Texas A&M Beaumont Center and he was responsible for disseminating the research database and informing the Texas rice industry of current production issues, problems, and solutions.

Not only was he an extension specialist, he was also a researcher that solved real world problems on weed control and did a remarkable job handling these important duties.

He was a founding member of the Texas Plant Protection Conference Association and routinely served on the Program Planning Committee of this organization. He was also a founding member of the National Cotton and Rice Conservation Tillage Conference, and they recognized him with their Conservation Tillage Rice Researcher of the Year Award.

In honor of his many contributions to agriculture, the United States Department of Agriculture presented him with their Superior Service Award.

He has been active in the RTWG, including serving as Panel Chair, Chairman of Local Arrangements, on the Rice Variety Acreage Committee, and on the Executive Committee as geographical representative from Texas. In 1986, he received the Distinguished Rice Research and Education Team Award from the RTWG for his contribution to the development and success of the high yielding Lemont rice variety, the first semidwarf introduced in the south.

Distinguished Service Award

Fleet N. Lee

This scientist of the University of Arkansas distinguished himself as a rice pathologist for more than 25 years in Arkansas serving the rice industry. He advised APHIS and the Arkansas State Plant Board on quarantine issues; rice millers on disease and export questions; and the Extension Service and consultants on various disease management problems.

His work in the development of rice blast resistance, sheath blight tolerance, flood depth mediation of rice blast, and rice fungicides is well known.

His research program working with USDA-ARS helped discover the blast resistance genes currently used in U.S. rice breeding programs. These genes have been widely incorporated in many popular rice cultivars since 1989.

He helped develop rice cultivars more tolerant to sheath blight disease in cooperation with the rice breeding programs. The adoption of rice cultivars moderately susceptible to sheath blight gradually reduced the impact of sheath blight and allowed Arkansas rice growers to manage much of their acreage with either no fungicides or lower rates of sheath blight fungicides than in the past.

His research results were principally of a practical nature and, thus, used extensively in Arkansas and elsewhere as the basis for rice disease management recommendations, including fungicide timing and rates for blast control; yearly reactions of conventional and new cultivars to major and minor rice diseases; management of rice blast with consistent, deep flood irrigation; and contributions to new disease resistant cultivars.

He was active in the RTWG by serving on the Rice Crop Germplasm committee, as Panel Chair, and on the Executive Committee as geographical representative from Arkansas. In 1988, he received the Distinguished Rice Research and Education Team Award from the RTWG for his contribution to the development and adoption of the Arkansas DD-50 Program.

Distinguished Service Award

Joe A. Musick

He was the Resident Director of the LSU AgCenter's Rice Research Station for 18 years. He was a committed, unselfish leader that always took great pride in the accomplishments of the scientists and staff at the Rice Research Station and supported them well. His number one priority as the Resident Director was how the Rice Research Station could help improve the rice industry. His efforts always went beyond the normal working hours, and he was a great liaison between the Rice Research Station, the Louisiana Rice Research Board, and the rice industry. He was always available to the Louisiana Rice Growers Association, providing help in answering who, what, when and where of critical issues or problems facing the growers, researchers, and industry personnel. He untiringly offered ideas and advice.

During his tenure at the Rice Research Station, he provided the leadership that improved the staff and facilities at the Station that facilitated the many accomplishments of the scientists stationed there and those that went there to conduct their research. He attended countless meetings and provided in-sight and leadership that allowed the rice industry in Louisiana to solve problems and weather tough times. The letters of support from the rice industry mentioned repeatedly the words commitment, integrity, knowledgeable, informed, and a wonderful leader for the Rice Research Station and the rice industry.

He never missed a RTWG meeting, he embraced them, he knew the importance of the meetings and scientists from differing states working together to solve rice problems. In 2002, he unselfishly offered to serve as the Chairman of Nominations Committee.

Distinguished Service Award

Joe E. Street

This scientist distinguished himself primarily as a rice weed scientist with the Mississippi State University for the first 17 years of his career and the last six years as an extension specialist for rice with the Mississippi State University.

He had a large rice weed control program that gave the growers in Mississippi valuable information on how the various herbicides best fit into weed management strategies for rice. Upon accepting the rice extension specialist responsibility, he broadened his focus to all aspects of rice production, which resulted in his increased service to growers and industry; however, he did not forsake his talents as a weed researcher. He served as the Delta Research and Extension Center's rice research coordinator and liaison to the Mississippi Rice Promotion Board. While in that capacity, he was very influential in determining research needs and assisting fellow scientists in project coordination that was aimed to provide answers for the rice clientele.

He always capitalized on opportunities to teach growers, extension agents, consultants, and industry workers in the field, through planned training courses and seminars, and popular press articles. He also accepted and fulfilled leadership roles, which included President of the Mississippi Weed Science Society and the Southern Weed Science Society.

He was very active in the RTWG: he served on the Nomination and Rice Variety Acreage Committees, Chair of Local Arrangements, on the Executive Committee as a Geographical Representative from Mississippi, and he was Secretary/Program Chair and Chairman of the RTWG.

Distinguished Service Award

John F. (Jack) Williams

He distinguished himself as a Farm Advisor of the University of California for over 30 years. His work as a Farm Advisor covered several crops, but his main work was in rice.

He was involved in many aspects of rice production technology in California. He developed fertilizer recommendations for the new semidwarf varieties, as well as conducted research in weed control and water management. He was a team leader on one of only 16 National Water Quality Demonstration projects and was instrumental in providing extension support for the reduction of pesticide residues in California waterways, widely recognized as one of the model programs in California water quality. His work in both water quality and rice straw management, leading to air and water quality improvement is recognized as a very significant achievement at the interface of agriculture and environmental issues and benefiting both the environment and the image of the rice industry.

He served on many committees and represented the California rice industry at the legislative and governmental levels and at the national and international levels. He served as UC Liaison to The California Rice Research Board and The California Cooperative Rice Research Foundation and has worked closely with the staff of the California Rice Commission.

He received many awards, including the Distinguished Service Award for Outstanding and Creative Teamwork by the UC Division of Agriculture and Natural Resources; the National Rice Industry Award; and the California Annual Rice Industry Award.

He was active in the RTWG, including serving as Panel Chair, Chairman of Nominations, and on the Executive Committee as geographical representative from California. In 1984, he received the Distinguished Rice Research and Education Team Award from the RTWG for his contribution to the development and release of the first semidwarf rice variety in the United States.

Distinguished Service Award

Salmon L. Wright III

This scientist and businessman was involved with the RTWG for more than 30 years and gained national and international recognition as a renowned authority in the area of rice enrichment and the active leader of the Wright Group. This business has been a national leader in the enrichment of rice by marketing essential vitamin and mineral premixes to the U.S. and international rice mills. The achievements of this company have contributed to improved U.S. rice exports, rice consumption, and health for millions of rice consumers throughout the world.

Wright Enrichment Inc. is a global company that has promoted rice and Crowley Louisiana throughout the world. The Crowley Chamber of Commerce recognized him as the Outstanding Business Person of the year in 1995. In 1994 and 1995, Wright Enrichment received the Valued Supplier Award from the Kellogg Company. Wright Enrichment's founding motto has been "Improvement of the nutritional quality of rice is needed more than any other food in the world." As the chairman of the Wright Group, he is responsible for the development of several innovations in formulation, application, and distribution of enriched food products, especially rice. He has directed the expansion of marketing of improved enriched rice into develop and undeveloped countries. This expansion has provided for better nutritional products in areas that are not commonly assured of superior food sources. Besides his renowned innovative skills, he is globally recognized for the meticulous adherence to the highest standards of quality and reliability in his business activities. Thus, his service, commitment, and contributions to the rice industry are truly exceptional.

He served as president of two Regional Institute of Food Technology sessions and is a lecturer for groups on the subject of food technology. He promoted tourism that involved the Blue Rose Museum, the Rice Museum, and the Crystal Rice Plantation.

His contributions have added significantly to the successes of RTWG by strengthening the relationship among research, teaching, extension, and industry groups. He contributed generously to supporting rice research and the RTWG and was a former technical advisor to the RTWG.

Distinguished Service Award

William H. "Bill" Brown

This Director has been working in Louisiana since 1976 when he became Professor and Head of the LSU Agriculture Engineering Department. He was named assistant director for grants and contracts in the Louisiana Agriculture Experiment Station in 1983 and later named associate director of that research branch of the LSU AgCenter in 1989. He attained the title of Associate Vice Chancellor for the LSU AgCenter in 1996 and the title of Vice Chancellor and Director of the LSU AgCenter in 2001 with responsibility for administering the LSU AgCenter Experiment Station with scientists conducting research at 17 campus departments and 19 research stations throughout Louisiana. He has helped Louisiana develop an extensive research program in rice and has helped make the funds available to support that research. His support for the rice research program in Louisiana has been second to none. He is recognized as a national leader in research at land grant universities but has maintained close ties with extension and helped to bring about more coordination between the LSU AgCenter's research and extension programs. "He is truly a team builder and a visionary," a fellow administrator stated. He has been the Administrative Advisor to the RTWG since 1998 as the Experiment Station Representative and those of us who have served on the Executive Committee of the RTWG during his tenure are very grateful for his participation, insight, and leadership.

MINUTES OF THE 30th RTWG MEETINGS

Opening Executive Committee Meeting

In attendance: Rick Norman (Chair), Don Groth (Secretary), Steve Linscombe (Local Arrangements Chair), Pat Bollich (Co-Publication Coordinator), C. Michael French, Bill Brown, Neil Rutger, Anna McClung, Dave Jones, Chuck Wilson, Mark Kurtz, Garry McCauley, Johnny Saichuk, Bruce Beck, Jim Thompson, Lawrence Datnoff, Cass Mutters, and Dwight Kanter.

The meeting was called to order by Chair Rick Norman at 4:15 p.m. on February 29, 2004, at the DoubleTree Hotel in New Orleans, Louisiana. Executive Committee minutes from the 2002 RTWG were accepted unanimously without reading after Pat Bollich moved and Chuck Wilson seconded.

The Financial Report of the 29th RTWG meeting was provided by Chair Rick Norman and reviewed. Rick Norman pointed out that $2173 was left over from the meeting and was put into the RTWG Contingency Fund, which brought the balance to $8148. Six thousand dollars was suggested as the standard amount to be transferred from the current host state to the next state as startup money. Concern was raised about the amount of funds in the contingency fund and how it was to be used. Rick Norman pointed out that the funds were placed into the account to cover expenses if a state fell short and could not cover expenses from the meeting. Pat Bollich raised the question about if the fund was tax exempt. No concerns were raised. Also, if a host state could not transfer $6,000 to the next state, the contingency fund could be used as startup money but be repaid. Dr. French raised the question about who should make these decisions and who had control of the fund. Rick Norman pointed out that the fund was associated with the University of Arkansas Foundation and was administered by the director of the Stuttgart Rice Research and Extension Center. Pat Bollich moved that the Executive Committee should be polled before the fund is used, Mark Kurtz seconded and the motion passed. Additional questions were raised on how the fund was to be used and when should it be repaid or not. It was suggested that a formal operating procedure for the fund be developed and addressed at the closing Executive Committee meeting on Wednesday, March 3. Rick Norman agreed to compose a draft copy of the document and present it to the committee on Wednesday. Pat Bollich motioned to accept the Financial Report, seconded by Mike French, and the motion passed.

Rick Norman reported that the RTWG manual of operation was not completed but will be ready by the next RTWG meeting in 2006. Don Groth offered to help develop the document.

Neal Rutger discussed the possibility of a permanent RTWG website to be linked to the Dale Bumper's National Research Center website. Currently, the host state maintains a website and its location is rotated every two years. A permanent website would allow people to find information about the next meeting without searching for the information. Mike French brought up that the Southern Regional Experiment Station and Extension Service Director also requested that a permanent website should be developed. The question was raised on who would maintain and update the website and who would pay for these changes. It was suggested that any costs associated with the RTWG website be submitted as an operation bill to the current host state and be include in the meeting costs. Mark Kurtz motioned for Neal Rutger to establish a permanent website associated with the Dale Bumper's website, seconded by Johnny Saichuk. The motion passed. Additional discussion ensued on who would help Dr. Rutger and what would be included on the webpage. Laurie Bernhardt, who does the Dale Bumper's site, was suggested to setup the website and maintain it. It was suggested that this topic would be addressed at the next meeting in more detail.

Chair Rick Norman announced the RTWG 2004 Award winners to be presented on Tuesday afternoon at the Awards Banquet.

Distinguished Research and Education Award: Individual – Rick Cartwright; Team - Toni Marchetti, Fleet Lee, and Karen Moldenhauer

Distinguished Service Award: Pat Bollich, Arlen Klosterboer, Fleet Lee, Joe Musick, Joe Street, S.L. Wright, and Jack Williams.

Bill Brown was nominated for the Distinguished Service Award at the meeting and was approved unanimously. Dr. Brown will be retiring in April 2004. His replacement as a RTWG advisor will be named by Chair Eric Young, the contact person for the Southern Experiment Station Directors' Association. It was hoped that a replacement could be named so their name could be included in the 30th RTWG proceedings.

Anna McClung mentioned that there was a lot of variation between size and what was included in the award nomination packets. She made the suggestion that more uniform and specific standards be developed for the guidelines published in the proceedings and mailed to the members. A name change was also suggested for the awards to differentiate between the different awards. Several changes were suggested for the nomination packet and name change. The topic was tabled until the Closing Executive Committee meeting and Anna would distribute copies of the suggested changes to each member before that meeting.

A question was raised if Distinguished Service Award winners that had retired had their meeting registration fees waived by the host state. It was suggested that this be encouraged but be left up to the host state, depending on the current financial situation of the meeting. In was pointed out that it has been common practice during past and the current meetings that these fees were waived as commonly done.

New Business

Necrology Report – Chair Rick Norman asked for any names for the Necrology Report to be announced at the Opening General Session. The only name brought up was Morris Peterson from California who passed away this year.

Mike French presented three requests from the Southern Experiment Station and Extension Directors. These included the development of a permanent website, which was discussed earlier; a request for a participant list with the proportion of functional assignment of research, extension, teaching, and industry for each participant; and regional efforts in developing extension and educational materials for agent and user training. There was also discussion on adding links to the RTWG webpage to each state's rice pages to make information on rice production more available. Mike French suggested if a general rice production publication is needed, a regional publication with authors from each state would be beneficial. Don Groth agreed to work with the Texas contingent in developing a new registration form that would include the extra information requested.

Rick Norman suggested changing the makeup of the RTWG Executive Committee to include two representatives from each state that would each serve two terms but alternate starting dates. This was suggested to increase continuity between meetings since the current committee changes every meeting. It was pointed out that the secretary, chair, immediate past chair, the three administrative advisors, and the publication coordinators all serve multi-meeting terms that give some continuity. Also, making the committee larger would make operations awkward. It was suggested that the chair send a copy of the previous minutes to new members before the RTWG meeting to read or encourage them to review them in the proceedings. Mike French suggested that an off-year Executive Business meeting might add the continuity needed. His major concern was how the member institutions feel about the additional costs that would be incurred. It was pointed out that most members pay for their travel to meetings on their own grant money. Several members thought that an off-year meeting was a good idea. Reasons given included increasing continuity, having fewer topics to cover at the RTWG meeting, and allowing the Executive Committee to help in the organization of the meeting just prior to most of the work being done. If this meeting was to be held, it should be located at a central location probably in the fall before the biennial meeting. The topic was dropped.

Don Groth informed the committee that Pat Bollich, the co-Publication Coordinator accepted a new position as administrator of a research unit in the LSU AgCenter system and will not have rice responsibilities. Pat Bollich indicated that he would continue his editing through the 2004 meeting proceedings but would probably not continue after that. Rick Norman and his Arkansas coworkers were asked if they would like to take responsibility for editing the proceedings but they declined at this time. It was recommended that the editing responsibilities not be rotated between states since continuity was very important to the quality of the publication. Pat Bollich pointed out the quality of the proceedings was dependent on a good secretary that had excellent word processing and editing skills. It was suggested that there be a permanent editor and an associate editor could be picked from the host state to work on that specific edition. No decision was made and the topic was tabled for later consideration.

Chuck Wilson led a discussion of the RTWG having a student competition similar to what other societies have. Several questions were raised, including what prizes would be presented, who would judge, how many students actually participate in RTWG, how many winners would there be, and who could participate? It was pointed out that many of the sessions are already too full and papers have to be moved to make room. Also, it takes a lot of time for someone to organize the competition. Chuck Wilson was asked to bring guidelines from other societies to present to the committee.

Rick Norman asked for a motion to adjourn the Opening Business meeting, Johnny Saichuk moved, and Pat Bollich seconded the motion. The motion passed and Chair Rick Norman closed the meeting at 6:15 pm on February 29, 2004.

Opening Business Meeting

Chair Rick Norman called the 30th RTWG meeting to order at the DoubleTree Hotel in New Orleans, Louisiana, at 8:10 a.m. on March 1, 2004. Minutes of the previous meeting were accepted unanimously without reading after Neil Rutger moved and Wayne Ebelhar seconded.

Chair Rick Norman then reviewed the main topics covered in the Executive Committee meeting as outlined above.

Rick Norman read the Necrology Report and asked for a moment of silence for Maurice Peterson from California.

Lee Tarpley read the Nomination Committee Report, which nominated the following people for the 2006 Executive Committee and Nomination Committee:

Executive Committee:
Chair: Don Groth
Secretary: Garry McCauley
Geographical Representatives:
- Arkansas – Rick Cartwright
- California – Randall Mutters
- Florida – Andrew Bennett
- Louisiana – Bill Williams
- Mississippi – Tim Walker
- Missouri – Gene Stevens
- Texas – Bob Fjellstrom

Nominations Committee:
- California – Jim Hill, Chair
- Arkansas – John Bernhardt
- Florida – Andrew Bennett
- Louisiana – Eric Webster
- Mississippi – Mark Kurtz
- Missouri – Gene Stevens
- Texas – Lee Tarpley

Rick opened the floor for additional nominations and there were none. Karen Moldenhauer moved to accept the nominations, Chuck Wilson seconded, and the motion passed.

Lee Tarpley gave the report for the Location and Time of the 2006 Meeting Committee. Texas will host the 31st meeting in Texas at an appropriate date and location to be determined in the near future. Locations being considered include Austin, Houston, and San Antonio.

Chair Rick Norman asked for a motion to adjourn the Opening Business Meeting, Mark Kurtz moved for adjournment and Jim Hill seconded the motion. The motion passed and Chair Rick Norman closed the meeting at 8:25 a.m. on March 1, 2004.

Closing Executive Committee Meeting

In attendance: Rick Norman (Chair), Don Groth (Secretary), Steve Linscombe (Local Arrangements Chair), Pat Bollich (Publication Coordinator), C. Michael French, Bill Brown, Neil Rutger, Anna McClung, Dave Jones, Chuck Wilson, Mark Kurtz, Garry McCauley, Johnny Saichuk, Bruce Beck, Jim Thompson, Dwight Kanter, Lawrence Datnoff, Cass Mutters and Andy Kendig.

Chair Rick Norman called the meeting to order at 7:05 a.m. on March 3, 2004, at the DoubleTree Hotel in New Orleans, Louisiana.

It was agreed to have an off-year Executive Committee Business meeting at either the rice breeder's meeting, through distance education, or at an appropriate central location. The RTWG Chair will set the time and place of the meeting to accommodate as many members as possible. The meeting will last two to four hours. A quorum is needed for any changes or decisions to become official.

A standard way to handle the contingency fund was accepted and it was agreed that the chair should poll the Executive Committee through Email to authorize its use. The contingency fund will be used in the following way: If a state uses money for startup they must repay it after money comes in. If a state goes into debt they can use the funds and not repay the contingency fund. As stated previously, the Executive Committee will be polled by the chair to authorize its use. Don Groth moved and Mark Kurtz seconded the motion. The motion passed.

After discussion of having a RTWG student oral and poster competition, Rick Norman appointed a temporary committee of Chuck Wilson, Neil Rutger, and Mark Kurtz to consider the possibility and report back to the Executive Committee at the off-year meeting.

Don Groth brought up the topic of the need of a permanent mail list that is updated regularly. The problem encountered included: expired email addresses, people not on the list, and it was suggested that a link be placed on the RTWG webpage that allowed members to update their contact information and add names to the list. Don Groth offered to maintain the mail list at the LSU AgCenter's Rice Research Station and changes be sent to Jodie Gautreaux at the Rice

Research Station, 1373 Caffey Road, Rayne, LA 70578 or email them to JGautreaux@agcenter.lsu.edu.

Mark Kurtz discussed the possibility of having a meeting in Missouri. Because of the limited staff working on rice and their multi-crop responsibilities, it would be very difficult. If they would have one, it would probably be held in St. Louis. If they are able to hire a new rice agronomist, it may be possible. The topic will be reopened in two years.

California also discussed where they would have their meeting in four years. Sites being considered included San Diego, Sacramento, and Reno. The committee was polled to see which site would be preferable. Each location had problems associated with it.

The date and location of the Texas meeting was discussed. Dates to avoid included the Weed Science of America's annual meeting and Mardi Gras.

Anna McClung presented her suggested changes for nominations for RTWG awards to the committee. Anna motioned and Bruce Beck seconded to accept printed proposed changes. Bruce Beck amended the motion to change recent accomplishments to significant accomplishments. Discussion revolved around the name change and what was included in the packet. The key points were a standard number of support letters included, length of the resume, and what was to be included as significant accomplishments. The committee voted five for and seven against the motion, the motion failed.

Chair Rick Norman asked for a motion to adjourn the Closing Executive Committee Meeting. Neil Rutger made the motion and Dave Jones seconded the motion. The motion passed and Chair Rick Norman closed the meeting at 8:05 a.m. on March 3, 2004.

Closing Business Meeting

Chair Rick Norman called the meeting to order at 8:30 a.m. on March 3, 2004, at the DoubleTree Hotel in New Orleans, Louisiana.

Chair Rick Norman called for committee reports.

Carl Johnson read an abbreviated edition of the Resolution Committee Report thanking various people and organizations for their effort, participation, and support. Johnny Saichuk motioned to accept the Resolution Committee Report, Garry McCauley seconded the motion, and the motion passed.

Karen Moldenhauer reported on the Rice Crop Germplasm Advisory Report topics, including the rice collection, quarantines, and other topics. Garry McCauley motioned to accept the Rice Crop Germplasm Advisory Report, James Gibbons seconded the motion, and the motion passed.

Johnny Saichuk presented the Rice Acreage Report. The reports were reviewed and found to be correct. Jim Hill motioned to accept the Rice Acreage Report, Garry McCauley seconded, and the motion passed.

Dave Jones presented the Industry Committee Report. Garry McCauley motioned to accept the Industry Report, James Gibbons seconded the motion, and the motion passed.

Don Groth presented the RTWG Proceedings Publication Report. He requested that all chairs get their abstracts, recommendations, and other information to him as soon as possible so the proceedings can be published as soon as possible. He also announced that Mike Salassi from the Agricultural Economics Department at the LSU AgCenter agreed to fill the position vacated by Pat Bollich as co-publication coordinator.

Rick Norman thanked Don Groth and Pat Bollich for editing the proceedings and getting them out sooner than they have ever been published. He also thanked the Louisiana delegation for all the hard work that went into making the 30th RTWG meeting a great one. He thanked Don Groth for being secretary and program chair and expressed his gratitude for everyone who helped him along the way.

Chair Rick Norman passed the gavel to Don Groth. Don Groth thanked Rick for his hard work and four years of effort with the RTWG. He presented Rick with a plaque. Rick thanked the Arkansas delegation and Karen Moldenhauer for their support.

Garry McCauley announced that the 31st RTWG meeting will be held during the last week of February 2006 in Texas and he hoped that the meeting would be as great as the Louisiana meeting.

Don Groth thanked the sponsors for their support. He also thanked the Local Arrangement Committee for their hard work. Don Groth asked for a motion to adjourn. Carl Johnson motioned and Karen Moldenhauer seconded the motion to adjourn the meeting. The motion passed and the meeting was closed at 9:05 a.m. on March 3, 2004.

SPECIAL COMMITTEE REPORTS

Nominations Committee

The Nominations Committee proposed the following individuals for membership on the 2006 RTWG Executive Committee and Nominations Committee:

Executive Committee:
Chair: Don Groth
Secretary: Garry McCauley
Geographical Representatives:
Arkansas – Rick Cartwright
California – Randall Mutters
Florida – Andrew Bennett
Louisiana – Bill Williams
Mississippi – Tim Walker
Missouri – Gene Stevens
Texas – Bob Fjellstrom

Nominations Committee:
California – Jim Hill, Chair
Arkansas – John Bernhardt
Florida – Andrew Bennett
Louisiana – Eric Webster
Mississippi – Mark Kurtz
Missouri – Gene Stevens
Texas – Lee Tarpley

Submitted by
Lee Tarpley

Rice Crop Germplasm Committee

The 24th meeting of the Rice Crop Germplasm Committee was held at 1:00 PM on February 29, 2004 at the 30th Rice Technical Working Group Meeting, Rosedown Room, Double Tree Hotel, New Orleans, LA. Members present were Karen Moldenhauer (Chair), James Correll, James Gibbons, Georgia Eizenga, Rick Cartwright, Jim Oard, and Robert Fjellstrom. Ex-officio members present were Harold Bockelman, Mark Bohning, Neil Rutger. Other attendees included Dwight Kanter, Federico Cuevas, Fleet Lee, Gary Cave, Chuck Rush, Molly Fogleman, Noel Yap, Dave Marshall, Kent McKenzie, Anna McClung, Lorie Bernhardt, Kirk Johnson, Donna Mitten, Morris Levy, Maria Levy, Wengui Yan, David Gealy, YiQing Guo, Gene Hookstra, Mark Walton, Yulin Jia, Howard Black, Jeff Oster, Donn Beighley, Anirudha Singh Yadav, Robert Miller, Junda Jiang, Hanlin Du, Mohammad Mostafavi, Chris Greer, Fabrocop Rodrigues, and Lawrence Datnoff.

Minutes of the 23rd meeting of the Rice Crop Germplasm Committee held on November 18, 2003 at Stuttgart, AR, were approved as amended. Georgia Eizenga made the motion and Jim Correll seconded.

1. Curator report 1:10 pm – Dr. Harold Bockelman, curator of the National Small Grains Collection in Aberdeen, ID, made a presentation on the status of the Rice Germplasm Collection. He passed out a new list of the PI assignments for rice submitted since 2002 and mentioned that the 1300 backlog accessions released from Quarantine would be increased this year at the RREC in Arkansas by Wengui Yan of the Dale Bumpers National Rice Research Center. The PI assignment list will expand greatly in 2004. Parents of a mapping population were assigned different PI numbers. The second page of the report lists the species of rice involved and the third page GRIN output data. Harold said that assigning the parents new numbers so that you would know exactly the parent for a given mapping population is a compromise as some proposals wanted PI numbers for all members of a mapping population.

2. Genetic Stocks Report 1:25 pm – Neil Rutger, Dale Bumpers National Rice Germplasm Center, Stuttgart, AR. Dr. Rutger passed out a handout. The Genetics Stocks *Oryza* program (GSOR) was established in August of 2003 at the DBNRRC. Genetic stocks storage has already been done for other crops including maize, tomatoes, barley and wheat. There are 19 entries in GSOR at present and a mapping population containing 353 lines was being grown for inclusion. Last summer, all rice mutants started being collected for inclusion not just "useful" mutants as had been looked for in the past. GSOR can be found at www.dbnrrc.ars.usda.gov/gsor/ on the Internet. Contributed seed will not be regenerated but stored and distributed as long as the original donation holds out. In other words, these stocks will not necessarily be stored in perpetuity. Lorie Bernhardt will be the information specialist in charge of GSOR records.

3. Quarantine Report, Beltsville, MD 1:33 pm – Prepared by John Hartung. Mark Bohning presented this report. Serious staffing problems continue for Rice Quarantine, which have greatly affect the rice quarantine materials. Sarbagh Salih and her technician are both gone now. No one is at the facility to handle rice at the present. The new buildings were finally completed for APHIS in Beltsville and they are moving in now. In 2003, we again had a quarantine grow out in North Carolina with David Marshall. The quarantine grow-outs in the North Carolina Field Nursery for the past three years are as follow: 1) In 2001, 51 accessions were produced; 2) in 2002, 461 accessions were produced; and 3) in 2003, the nursery was destroyed by Hurricane Isabel.

Future prospects are grim and staffing problems will not allow the production of transplants for the NC nursery in 2004. Everything is on hold at this point.

The GRIN data on all rice accessions which have been grown and harvested thus far should be up to date and accurate. Karen Moldenhauer stated that she will attend the in-depth review for the Fruit Laboratory which includes the Plant Germplasm Quarantine Office with the USDA-ARS in Beltsville to represent rice interests.

Chuck Rush (LSU), Dave Marshall (ARS, North Carolina State University), Jim Correll, Rick Cartwright and James Gibbons briefly discussed eyespot disease that has been observed at the NC nursery. Dave Marshall indicated that fungicide applications (Folicur twice) had virtually eliminated the disease prior to the hurricane.

Neil Rutger noted that 2566 accessions were still in the quarantine queue these include: 1) 422 from Bangladesh – who knows what they are? 2) 318 were from Japan and some we already have. Nourin 20 is probably the same as Norin 20 for example. 3) 860 are from Indonesia and we are still working on these. We have not thrown them out but are working to eliminate any duplication of lines. Neil Rutger said the last 500 lines or so to come through the nursery were from CIAT, Cali, Columbia

4. Foreign Exploration Grants 2:00pm - Karen Moldenhauer, Rice Research & Extension Center, Stuttgart, AR. Guidelines for foreign exploration grants have been received. For more information on these grants contact Karen Moldenhauer. Harold Bockelman noted that the International exchange protocols are becoming very complex for seed exchange, and that scientist to scientist exchanges still work the best in most foreign countries. Exchanges between germplasm collections per se are very difficult.

5. North Carolina Quarantine Transplant Nursery Report 2:02 pm – Dave Marshall presented this report. He past out a handout and made a PowerPoint presentation. Basically the 2003 nursery was wiped out by Hurricane Isabel. Tom Mew's report indicated that if you run the plants through culture media that you do not see any incidence of disease on disease free seedling grown on media. Anna McClung asked how much contamination has been found on the seedlings in the culture tubes. The group still favored running the plant through a quarantine green house if at all possible.

Dave Marshall suggested that maybe some of the states with permits generate seedlings for transplanting in the NC nursery and bypass the Beltsville problem. Kirk Johnson (Bayer) wondered about the proposal to bypass quarantine greenhouse requirements by transplanting clean seedlings into the field anywhere. Neil Rutger stated that in the late 60s or 70s, UC and the California rice industry supported an effort to establish a transplant nursery near El Centro, California.

Jim Correll made the motion to encourage Dave Marshall to pursue tissue culture at Raleigh given the circumstances at Beltsville. Georgia Eizenga seconded the motion, Motion carries by acclamation. Dave Marshall then reminded us that funding for support of the nursery has come from ARS, Peter Bretting, and that he would write to Peter requesting more funding to do this work. Anna McClung suggested that we should write a letter of support for increased funding for this nursery, and for the tissue culture if it moves to Raleigh and for the needed changes to the current permit that Dave Marshall has to allow this.

Chuck Rush stated that one of the big problems in changing the quarantine regulations is that no research has been done on seed disinfestation, etc. We need to obtain funding and do the work that would support any changes to the current regulations and not just make the changes based on assumptions. He also stated that breeders should be careful to only bring in what is potentially useful, not just everything. Breeders in the past often did not send in materials to GRIN because it was not useful or they did not have permission from the country of origin to deposit in a gene bank.

Harold Bockelman was concerned because the NC nursery has a limitation in that it cannot handle photo period sensitive or extremely long-season lines. Basmati types are all photo period sensitive and right now they have to go to Puerto Rico for seed increase. Don't rely solely on the NC nursery but continue to send remnant seed to other permit holders for special needs. Robert Fjellstrom also pointed out that we need a procedure for moving the non-performing line seed to a greenhouse somewhere. Fleet Lee suggested that we could use the UA Fayetteville facility for running these lines through quarantine, but numbers must be kept low because of limited staffing.

Kent McKenzie wondered if we could have someone go through the old backlog and test the seed for germination then throw out everything that is dead? Harold Bockelman said he suspected that you will still find most accessions still alive. They have been held under good storage conditions.

6. The CAP Project 2:45 pm – Jim Correll, University of Arkansas, Fayetteville, AR, presented the following:

USDA has requested a proposal to fund a broad-based Applied Genomics Project in rice and has indicated that $5 million will be available over the 4 year life of the project. Dr. Correll was selected as Project Manager and have requested input from all rice scientists in the U.S. to construct the proposal which is due March 15.

7. RiceTec PRA to import rice seed from Argentina (3 pm) – Federico Cuevas, RiceTec, Alvin, TX

The PRA has been completed and was submitted to APHIS in November of 2003 where it is being reviewed. Dr. Morris Levy, Purdue University will present an overview of his findings with regard to Rice Blast Pathogen Diversity in Argentina, Uruguay and South Brazil.

Dr. Levy found lineage A on tropical rices in Argentina, etc. This lineage is not currently present in the U.S. and is avirulent on Pi-ta. Other lineages are found in the U.S. Lineage H = IG-1 in California are present is one I believe was once in the southern U.S. then was sent to Uruguay (possibly other S.A. areas) and returned to the U.S. in California in the 1990s. In the meantime, it had disappeared from the U.S. over time. I do not believe the rice blast lineages present in Argentina pose any new risk to U.S. rice cultivars. There was considerable discussion about this topic among the researchers present.

Federico Cuevas told us that the tracking number for the PRA is 637 and it is listed on the APHIS website as active. Dr. Gary Cave with APHIS is here and will discuss the process. Dr. Gary Cave said that APHIS currently has two requests to amend the rice seed importation regulations. One from RiceTec and one from the government of Brazil. A scientific review must be completed by 12/31/04 then regulation aspects will be examined. Any changes would require modification of the current quarantine, replacing it with a new quarantine. Input from rice scientists, the rice industry, and the general public will be directly solicited by APHIS. APHIS will contact critical people for input, thus it will not just be a passive solicitation process as so often happens.

8. Nominating Committee Report – Rick Cartwright.

The nominating committee proposes that:

The committee accepts Thomas Tai's resignation from the CGC and that Farman Jodari (CCRF) finish the balance of Thomas Tai's 4-year term on the RCGC.

The committee accepts Barry Tillman's resignation from the CGE and that Fangming Xie (RiceTec) finish the balance of Barry Tillman term as the industry representative to the RCGC.

The committee also proposes that Dwight Kanter (Mississippi State University), Mo Way (Texas A&M University), Jim Oard (Louisiana State University), and Karen Moldenhauer (University of Arkansas) be confirmed as new members, replacing other members rotating off in 2004.

The committee also proposes Karen Moldenhauer be re-elected for another term as Chair of the RCGC.

James Gibbons made a motion to accept the Nominating Committee Report and its recommendations for membership. Seconded by Georgia Eizenga and Jim Correll. Motion Carried by Committee Vote.

9. GRAMENE report presented by Noel Yap

Gramene can be accessed at www.gramene.org on the Internet. Cornell University does the biological part of the database and Cold Spring Harbor handles the computing and software part. The database is updated every three months. Details on how to use Gramene followed using a PowerPoint presentation.

A motion to adjourn was made at 5 pm by Rick Cartwright and seconded by Georgia Eizenga. Motion carried and the meeting adjourned at 5:02 pm, February 29, 2004.

Publication Coordinator/Panel Chair Committee

Publication Coordinators Don Groth and Pat Bollich met with RTWG Chairman Rick Norman and the 2004 Panel Chairs at 2:00 PM on February 20, 2004, at the DoubleTree Hotel in New Orleans, LA. In attendance were D.E. Groth, P.K. Bollich, R.J. Norman, J. Oard, M. Smith, W.B. Williams, M. Salassi, Q.R. Chu, and S.D. Linscombe.

Discussion centered on session operating procedures, including panel recommendations, procedural issues regarding concurrent sessions, CCA credit, and publication of abstracts in the proceedings. Timely submissions, editorial review by chairs, and quality of abstracts were stressed for the proceedings. It was suggested that instructions to authors be changed so abstracts and presentations should be submitted via Email if possible. If presentations are too large to email, they should be sent on a CD before the meetings. It was stated that if an oral or poster presentation was not given the abstract would not be published in the proceedings. Discussion followed on how to use the web based system on the computer to run the sessions. Davis Dautreuil was present to answer any questions about the web-based organizational system, computer equipment, and LCD projectors. All changes in operating procedures will be incorporated into the RTWG guidelines for preparation of abstracts in the 2004 proceedings. Proceedings should be available in both hard copy and CD format within six months of the meetings.

Submitted by
Don Groth and Pat Bollich

Rice Variety Acreage Committee

The meeting was called to order at 3:10 p.m., February 29, 2004. A quorum was confirmed. In attendance were: Lawrence Datnoff, Florida; Arlen Klosterboer, Texas; Jim Stansel, Texas; Steve Linscombe, Louisiana; Kent McKenzie, California; David Jones, California; Pat Bollich, Louisiana; Chuck Wilson, Arkansas; Chris Greer, California; Jim Hill, California; and Johnny Saichuk, Louisiana.

Kent McKenzie moved and Steve Linscombe seconded the motion to approve the minutes as distributed by Chmn. Saichuk. The minutes were approved.

Each state was called on to review the year and provide an acreage report. Chuck Wilson said he expected Arkansas' acreage to be up by 150,000 to 200,000 acres over 2003. He anticipated a total acreage of 1.5 million acres. Wells had been the best variety in 2003, occupying 45% of the state's acreage and was likely to do the same in 2004. Cocodrie was planted on 20% of the acreage and should be the same also. Francis had performed either very well or very poorly. He said it was too blast susceptible, especially on light textured soils. Linscombe expressed concern over the ability or lack thereof to predict blast susceptibility. Wilson said he thought Clearfield varieties as a whole would make up 200,000 acres; of that, 40,000 planted to CLXL8 and 15,000 to XL8. Medium-grain acreage should be around 185,000 to 200,000 acres. Linscombe asked Wilson about glyphosate drift versus straighthead problems in Arkansas.

Kent McKenzie led the report from California. Additional comments were provided by Chris Greer and David Jones. They reported acres in 2003 were down because a late wet spring prevented planting in some places. The hot summer reduced yields while improving milling. For 2004, it was anticipated acreage would exceed 500,000 and the price would fall. Greer and Jones agreed the acreage could be from 525,000 to 575,000 acres. According to McKenzie, collecting acreage by variety data involved too much estimation and that more precise data could be collected by the FSA. He had distributed forms to the FSA offices but response quality varied from office to office, rendering it a dissatisfying method. He suggested we, the RTWG, support a national statement to the FSA soliciting their assistance. Johnny Saichuk reported he had contacted Mr. Willie Cooper of Louisiana with disappointing results. McKenzie discussed the differences in yield estimates by Extension and the USDA. All states agreed estimates varied in their accuracy with Arkansas, and Texas stating their figures were closer than those in California and Louisiana. No resolution to the problem was reached.

Florida reported no one was conducting rice research in Florida any more. Rice is being grown by small sugarcane farmers who rotate sugarcane with rice or vegetable crops. The acreage was expected to remain about the same in 2004.

Saichuk opened discussion regarding Louisiana. He said he expected acreage to increase by 80,000 to 100,000 acres to return to the more traditional acreage of Louisiana. Answering McKenzie's question, Saichuk stated hybrid varieties would not likely be planted to more than 1% of the state's acreage. Clearfield 161 would probably be the predominant Clearfield variety, but problems with lodging and sheath blight could be a problem. Saichuk said he thought Clearfield acreage could be as high as 100,000.

Mississippi and Missouri were not represented at the meeting.

Jim Stansel said Texas' acreage should be up 10 to 30% to total around 200,000 or more. Cocodrie was expected to occupy the largest percentage of acreage. He expected the growers to plant all of the CL161 seed they could get their hands on. He also thought Jefferson would make somewhat of a comeback. The yields in 2003 had been the worst in three years following three consecutive record years. Late planting and poor weather conditions in general were to blame. Arlen Klosterboer said the acreage planted to XL 8 would increase, especially east of Houston.

The committee members for 2006 are:

Chuck Wilson, Arkansas
Kent McKenzie, California
Curtis Rainbolt, Florida
Johnny Saichuk, Louisiana
Tim Walker, Mississippi
Bruce Beck, Missouri
Jim Stansel, Texas

Johnny Saichuk was to remain chairman unless the position becomes or is tied to publishing the proceedings.

The meeting was adjourned at 4:30 p.m.

Submitted by
Johnny Saichuk

Industry Committee

The Industry Committee again held a successful luncheon at the 30th RTWG meeting in New Orleans, Louisiana, on Monday, March 1, 2004, at the DoubleTree Hotel. The purpose of the Industry Committee luncheon is to enhance the meeting experience in several ways. First, it serves as a means of strengthening the cohesiveness of the committee itself, allowing the committee members to become better acquainted with each other. Since the luncheon is open to all attendees, it naturally encourages an interaction between industry and public sector researchers. Finally, it serves as another meeting opportunity where an invited speaker may share with the RTWG membership their thoughts and information on timely topics.

The 2004 Industry luncheon met all of these goals. The luncheon was attended by 42 guests who heard Mr. Jackie Loewer, Chairman, USA Rice Producers Group, speak about the issues and challenges of farming from a rice grower's perspective.

The Industry Committee would like to thank Dr. S.D. Linscombe, Chair, Local Arrangements Committee, for his invaluable assistance in coordinating the luncheon.

The Industry Committee looks forward to again hosting a luncheon at the 31st RTWG meeting in Texas in 2006.

Submitted by
Dave Jones

2002 ARKANSAS RICE ACREAGE BY VARIETY SURVEY

COUNTY	2001	2002	MEDIUM	LONG GRAIN							
PARISH	ACREAGE	ACREAGE	BENGAL	AHRENT	CL121	COCODRIE	CYPRESS	DREW	LAGRUE	WELLS	OTHERS[2]
ARKANSAS	116,423	113,182	1553	871	1477	36067	1558	540	13517	55369	2231
ASHLEY	15,888	16,749	0	590	0	8051	5771	565	1043	659	71
CHICOT	37,286	36,200	0	868	0	24847	3629	0	0	5777	1079
CLAY	85,579	76,991	3173	6917	1786	12507	1090	19209	175	25281	6852
CRAIGHEAD	84,975	79,462	12637	3963	1232	22318	687	273	1457	29557	7337
CRITTENDEN	37,854	42,801	1188	889	0	14501	0	0	0	25660	562
CROSS	120,133	109,238	8438	1455	368	16399	2844	954	17054	56556	5169
DESHA	44,373	47,024	3	1250	3	31558	3160	1744	255	8504	547
DREW	14,309	12,733	0	201	141	6824	653	2006	0	2649	257
FAULKNER	4,474	2,988	0	256	0	2061	0	0	0	668	3
GREENE	65,412	62,039	5522	1286	2667	9410	2041	2955	1544	30406	6207
INDEPENDENCE	12,694	8,642	0	183	0	1506	0	0	0	6954	0
JACKSON	102,589	82,983	11604	1981	1717	9533	819	5263	1156	49286	1624
JEFFERSON	64,578	58,819	906	998	664	26385	5408	1355	0	18795	4308
LAFAYETTE		3,839	0	101	0	1967	0	0	0	1771	0
LAWRENCE	93,918	89,472	12482	2155	1908	30737	6586	5038	0	26036	4530
LEE	42,931	36,529	799	1398	129	8310	0	2949	0	22943	0
LINCOLN	32,328	31,616	0	738	0	22058	3065	1045	0	3205	1506
LONOKE	79,483	73,984	4366	1522	618	17100	8313	1321	2025	38025	694
MILLER	8,556	6,218	0	0	0	0	0	0	0	6218	0
MISSISSIPPI	40,464	44,993	0	2309	0	14892	274	171	0	25462	1886
MONROE	59,177	55,319	3304	1012	470	21002	1547	942	2457	22936	1649
PHILLIPS	42,659	36,245	0	210	0	12464	4961	853	0	17715	42
POINSETT	135,975	131,273	52688	2127	1916	12387	564	2775	3003	45216	10597
PRAIRIE	72,003	68,192	6104	432	2262	29616	1999	2280	2972	21785	742
PULASKI	6,374	5,044	0	0	0	1287	0	0	0	1852	1905
RANDOLPH	30,404	24,024	6105	0	0	3817	467	0	0	12572	1062
ST. FRANCIS	55,424	53,140	3004	824	0	13624	1102	665	14	33813	95
WHITE	21,759	18,838	155	320	310	9800	138	2156	0	5580	379
WOODRUFF	65,084	62,177	5041	1462	634	15634	1515	10559	4104	19328	3901
OTHERS[3]	13,752		0	845	0	1,912	122	1,667	103	3,113	48
Unaccounted[4]		7034		--	--	--	--	--	--	--	7034
2002 TOTAL		1,506,000	139,072	37,164	18,303	438,575	58,312	67,285	50,876	623,693	65,284
2002 PERCENT		100%	9.28	2.48	1.22	29.27	3.89	4.49	3.39	41.62	4.36
2001 TOTAL	1,606,855	--	145,517	1,369	--	475,751	144,820	215,057	69,126	476,437	65,802
2001 PERCENT	100%	--	9.06%	0.09%	--	29.61%	9.01%	13.38%	4.30%	29.65%	4.10%

[1] - Harvested acreage. Source: Arkansas Argicultural Statistics and FSA; [2] - Other varieties: Alan, AB647, Alan, Clearfield 141, Clearfield 161, Della, Delmatti, Dellrose, Earl, Francis, Gulfmont, Jackson, Jefferson, Kaybonnet, Koshikari, Lafitte, Lemont, Nortai, Priscilla, and RiceTec XL-6, Rice Tec XL7, Rice Tec XL 8, Rice Tec 7015, Rosemont, Saber, and Texmont; [3] - Other counties: Clark, Cleburne, Cleveland, Conway, Crawford, Hot Spring, Little River, Logan, Perry, Pope, Sebastian, and Yell; [4] - Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA.

2002 CALIFORNIA RICE ACREAGE BY VARIETY SURVEY[1]

RICE VARIETY BY GRAIN TYPE	2001				2002			
	SEED2		TOTAL[3]		SEED2		TOTAL[3]	
	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT
SHORT GRAIN								
S-102	379	2.07	7,424	1.58	508	2.25	8,943	1.66
AKITAKOMACHI	NA	NA	8,438	1.79	NA	NA	5,618	1.04
KOSHIHIKARI	NA	NA	6,136	1.30	NA	NA	6,320	1.17
CALMOCHI-101	558	3.05	11,230	2.39	262	1.16	13,869	2.57
SUBTOTAL	**937**	**5.12**	**33,228**	**7.06**	**770**	**3.41**	**34,750**	**6.43**
MEDIUM GRAIN								
M-103	155	0.85	8,055	1.71	68	0.30	2,048	0.38
M-104	1,531	8.37	29,199	6.20	2,453	10.87	41,862	7.75
M-201	82	0.45	2,440	0.52	0	0.00	1,475	0.27
M-202	9,511	51.99	232,765	49.44	8,162	36.18	247,200	45.77
M-204	1,173	6.41	62,999	13.38	2,146	9.51	56,629	10.48
M-205	2,274	12.43	37,594	7.99	6,175	27.38	88,497	16.39
M-401	1,432	7.83	29,898	6.35	1,838	8.15	32,204	5.96
M-402	731	4.00	5,319	1.13	360	1.60	6,607	1.22
KOKUHOROSE	NA	NA	12,176	2.59	NA	NA	14,842	2.75
NFD 181	NA	NA	3,061	0.65	NA	3NA	3,527	0.65
SUBTOTAL	**16,889**	**92.32**	**423,506**	**89.96**	**21,203**	**94.00**	**494,890**	**91.63**
LONG GRAIN								
L-204	76	0.42	1,235	0.26	78	0.35	1,200	0.22
L-205	161	0.88	6,472	1.37	6	0.03	2,099	0.39
A-201	49	0.27	799	0.17	49	0.22	1,203	0.22
A-301	NA	NA	1,700	0.36	73	NA	1,469	0.27
CALMATI-201	175	0.96	1,507	0.32	33	0.14	336	0.06
SUBTOTAL	**461**	**2.52**	**11,713**	**2.49**	**238**	**1.06**	**6,306**	**1.17**
OTHER	6	0.03	2,348	0.50	346	1.53	4,153	0.77
TOTAL	**18,293**	**100.00**	**470,795**	**100.00**	**22,557**	**100.00**	**540,100**	**100.00**

[1]Estimates based on survey of rice millers and marketers and certified seed acreage conducted by the Rice Experiment Station, P.O. Box 306, Biggs, CA 95917-0306, 530-868-5481.
[2]Planted acreage of all classes of certified rice seed provided by California Crop Improvement Association.
[3]Estimates of total rice acreage based on rice millers and marketers' survey and seed acreage.
[4]Other varieties include: Short Grains S-201, Calhikari-201, and Hitomebore; Medium Grains SP 411; and specialty varieties.

2002 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Parish	2001	2002	MEDIUM GRAIN				LONG GRAIN						
	Acreage	Acreage	Bengal	Saturn	S102	Other[1]	Cocodrie	Cypress	Wells	Jefferson	Maybelle	CL121	Other[2]
Acadia	90,046	90,250	3,610	0	0	451	39,695	29,376	8,740	2,450	2,598	2,580	750
Allen	21,970	21,400	0	800	0	0	11,100	5,100	3,100	700	300	300	0
Avoyelles	13,521	12,486	0	0	0	0	9,066	3,165	0	0	0	60	195
Beauregard	2,847	2,582	0	0	0	0	1,382	442	100	0	0	658	0
Bossier	0	181	0	0	0	0	181	0	0	0	0	0	0
Caddo	0	50	0	0	0	0	50	0	0	0	0	0	0
Calcasieu	21,449	18,192	200	0	0	164	4,450	9,800	2,900	263	0	415	0
Caldwell	1,200	1,111	0	0	0	0	1,111	0	0	0	0	0	0
Cameron	11,083	14,115	0	0	0	0	5,776	6,256	510	400	0	282	891
Catahoula	9,886	7,400	0	0	0	0	2,400	5,000	0	0	0	0	0
Concordia	12,242	12,163	0	0	0	0	10,425	242	286	0	0	1,210	0
East Carroll	20,879	16,268	0	0	0	0	15,000	1,268	0	0	0	0	0
Evangeline	51,699	53,040	850	0	0	0	17,503	31,824	2,652	0	0	135	76
Franklin	984	651	0	0	0	0	327	289	35	0	0	0	0
Grant	0	8	0	0	0	0	8	0	0	0	0	0	0
Iberia	877	1,254	202	0	0	0	611	283	105	0	53	0	0
Iberville	0	98	0	0	0	0	98	0	0	0	0	0	0
Jeff Davis	83,740	85,900	2,000	0	0	0	44,200	23,600	11,000	3,000	400	1,000	700
Lafayette	6,783	6,672	275	0	0	0	3,180	2,417	300	50	100	150	200
Madison	6,115	6,897	0	0	0	0	4,767	0	80	0	0	1,800	250
Morehouse	31,535	29,696	0	0	0	0	22,274	5,939	1,187	0	0	296	0
Natchitoches	4,603	4,336	0	0	0	0	3,000	1,000	336	0	0	0	0
Ouachita	8,535	8,185	0	0	0	0	5,730	2,455	0	0	0	0	0
Pointe Coupee	2,330	1,796	0	0	0	0	1,391	255	0	0	0	45	105
Rapides	5,850	7,308	0	0	0	0	6,708	450	0	0	0	150	0
Red River	315	385	0	0	0	0	385	0	0	0	0	0	0
Richland	7,913	6,964	0	0	0	0	5,714	500	0	0	0	700	50
St. Landry	22,430	23,626	0	0	0	0	13,477	8,269	1,750	0	0	130	0
St. Martin	5,198	4,784	0	0	0	0	2,185	2,599	0	0	0	0	0
Tensas	2,349	1,990	0	0	0	0	1,590	0	200	200	0	0	0
Vermilion	87,276	86,027	1,518	0	30	0	46,071	27,175	7,615	62	724	1,920	912
West Carroll	7,337	7,319	0	0	0	0	5,490	1,629	200	0	0	0	0
2002 Total		533,134	8,655	800	30	615	285,345	169,333	41,096	7,125	4,175	11,831	4,129
2002 Percent		100.00	1.62	0.15	0.01	0.12	53.52	31.76	7.71	1.34	0.78	2.22	0.77
2001 Total	540,992		9,870	518	1,031	1,260	241,500	238,045	35,189	3,171	3,731	*	5,731
2002 Percent	100.00		1.82	0.10	0.19	0.23	44.64	44.00	6.50	0.59	0.69	*	1.06

[1] - Other Medium Grains include: Lafitte, Earl.

[2] - Other Long Grains include: CL141, CL161, Saber, Priscilla Jasmine, Francis, XL7, XL8, Della, Toro-2.

* - CL121 was not itemized in 2001.

2002 MISSISSIPPI RICE ACREAGE BY VARIETY SURVEY

County	Clearfield	Cocodrie	Cypress	Dixiebelle	Drew	Hybrid	Jackson	Jefferson	Lemont	Priscilla	Saber	Wells	Total Acreage
Bolivar	4,740	54,800		500		300		130	1,200	10,810	250	6,320	79,050
Coahoma	75	16,000	75			200		75	1,900	600		900	19,825
DeSoto			227						243			500	970
Grenada		300	300						500	800			1,900
Humphreys	300	2,120							200	700		90	3,410
Issaquena	450	1,269								565			2,284
Leflore	4,000	12,000							300	4,000		300	20,600
Panola		2,800											2,800
Quitman		8,870	145						3,344	582		1,600	14,541
Sharkey		3,061								1,063		643	4,767
Sunflower	200	25,000		1,100	200	100			3,000	8,100		300	38,000
Tallahatchie		15,880							933	2,976			19,789
Tunica		20,000	300			200			1,200	2,500		1,000	25,200
Washington		21,674		50				432	2,264	10,037		1,073	35,530
Total Acreage	9,765	183,774	1,047	1,650	200	800	0	637	15,084	42,733	250	12,726	268,666

Data collected by County Directors/Area Extension Agents and compiled by Dr. Joe Street, Rice Specialist.

2002 TEXAS RICE ACREAGE BY VARIETY SURVEY

County	2001 Acreage	2002 Acreage	Long Grains							Med. Grain	
			Cocodrie	Cypress	Jefferson	CL121	Saber	Wells	Jasmine85	Bengal	Other*
East Zone:											
Brazoria	15,279	14,969	13,431	40	1,188	166	48	0	0	0	96
Chambers	13,438	12,692	10,524	111	0	1,462	91	0	504	0	0
Galveston	768	1,166	911	58	174	0	23	0	0	0	0
Hardin	801	633	241	0	0	392	0	0	0	0	0
Jefferson	18,575	18,389	13,168	678	129	1,331	2,645	0	0	438	0
Liberty	12,705	9,073	17,764	0	226	926	127	0	0	0	30
Orange	354	414	0	166	0	0	0	0	0	248	0
East Total	**61,920**	**57,336**	**46,039**	**1,053**	**1,717**	**4,277**	**2,934**	**0**	**504**	**686**	**126**
Northwest Zone:											
Austin	2,601	1,694	1,208	0	486	0	0	0	0	0	0
Colorado	32,110	30,726	27,465	319	1,448	1,135	129	0	0	0	230
Harris	1,975	2,083	2,083	0	0	0	0	0	0	0	0
Lavaca	1,746	1,690	1,412	187	91	0	0	0	0	0	0
Waller	6,951	6,917	6,008	0	38	0	0	0	0	0	871
Wharton	50,520	49,139	35,422	1,276	5,440	2,158	3,340	253	73	0	1,177
Northwest Total	**95,903**	**92,249**	**73,598**	**1,782**	**7,503**	**3,293**	**3,469**	**253**	**73**	**0**	**2,278**
Southwest Zone:											
Calhoun	1,468	1,498	1,452	0	46	0	0	0	0	0	0
Ft. Bend	8,652	8,615	8,217	0	310	0	88	0	0	0	0
Jackson	14,953	13,214	10,325	498	913	307	969	99	0	0	103
Matagorda	24,958	27,750	21,154	1,171	2,710	68	1,706	115	0	0	826
Victoria	1,977	1,748	1,465	36	218	0	0	0	0	0	29
Southwest Total	**52,008**	**52,825**	**42,613**	**1,705**	**4,197**	**375**	**2,763**	**214**	**0**	**0**	**958**
Northeast Zone:											
Bowie	1,435	1,287	981	306	0	0	0	0	0	0	0
Hopkins	1,473	1,034	414	0	0	0	0	620	0	0	0
Red River	965	1,017	631	0	0	0	0	386	0	0	0
Northeast Total	**3,873**	**3,338**	**2,026**	**306**	**0**	**0**	**0**	**1,006**	**0**	**0**	**0**
2002 Total Acreage		205,748	164,276	4,846	13,417	7,945	9,166	1,473	577	686	3,362
2002 Percentage		100.0%	79.8%	2.4%	6.5%	3.9%	4.5%	0.7%	0.3%	0.3%	1.6%
2001 Total Acreage	213,704		165,546	23,684	10,895	2,320	560	864	718	265	8,852
2001 Percentage	100.0%		77.5%	11.1%	5.1%	1.1%	0.3%	0.4%	0.3%	0.1%	4.1%

Compiled by Dr. James Stansel and Robin Clements, Texas A&M Univ. System at Beaumont.
Survey data from dryers, sales offices, agribusiness, USDA/CFSA and County Extension Agents as appropriate.
*Other varieties include: CL 141, Gulfmont, Lemont, Dixiebelle, Maybelle, XL7&8, Texmati Class, and Risotto.

2003 ARKANSAS RICE ACREAGE BY VARIETY SURVEY

COUNTY/ PARISH	2002	2003	MEDIUM		LONG GRAIN							
	ACREAGE	ACREAGE	BENGAL	OTHERS[2]	AHRENT	CL161	COCODRIE	FRANCIS	LAGRUE	XL8	WELLS	OTHERS[2]
ARKANSAS	113,182	111,514	2,015	868	240	5,440	25,061	6,679	9,405	608	60,543	699
ASHLEY	16,749	15,513	0	0	0	468	8,161	733	1,333	0	3,404	1,414
CHICOT	36,200	32,946	0	0	0	1,138	17,575	1,105	0	0	6,861	6,267
CLAY	76,991	77,709	3,343	0	13,050	4,898	8,540	4,719	80	1,285	34,732	7,114
CRAIGHEAD	79,462	78,110	12,128	0	152	4,733	17,482	6,433	826	633	34,692	1,218
CRITTENDEN	42,801	36,818	234	0	0	673	8,625	4,580	0	251	22,227	233
CROSS	109,238	105,919	7,319	0	1,082	6,843	7,755	8,102	14,276	1,151	56,941	2,563
DESHA	47,024	42,992	376	86	828	1,145	22,110	1,080	175	1,057	15,711	432
DREW	12,733	15,906	0	0	314	651	5,721	314	0	0	6,798	2,109
FAULKNER	2,988	3,190	114	0	293	0	1,140	488	0	146	1,011	0
GREENE	62,039	61,662	8,220	234	0	2,099	15,782	2,315	3,442	3,027	26,619	54
INDEPENDENCE	8,642	8,634	0	0	0	0	0	0	0	0	8,634	0
JACKSON	82,983	82,292	16,023	141	1,595	2,280	9,573	4,727	415	1,981	44,448	1,359
JEFFERSON	58,819	58,872	437	0	750	1,942	10,879	5,310	0	0	32,175	6,816
LAFAYETTE	3,839	3,169	0	0	0	113	1,674	82	0	0	1,274	25
LAWRENCE	89,472	94,864	21,868	0	3,300	11,109	22,153	3,371	598	615	26,787	5,400
LEE	36,529	23,415	560	0	1,278	1,011	573	1,341	0	0	18,661	0
LINCOLN	31,616	32,355	507	0	0	1,204	20,082	857	0	0	7,369	2,344
LONOKE	73,984	77,046	9,315	0	393	3,250	15,352	3,851	756	54	41,271	2,948
MILLER	6,218	5,819	0	0	0	0	4,442	0	0	0	1,377	0
MISSISSIPPI	44,993	39,287	302	0	0	1,089	4,949	8,255	0	1,042	23,655	0
MONROE	55,319	51,398	2,722	0	1,866	1,512	17,370	3,310	78	25	23,915	641
PHILLIPS	36,245	25,574	0	0	1,723	0	11,044	2,879	0	306	9,621	0
POINSETT	131,273	126,683	47,601	70	686	7,248	6,533	10,671	1,027	1,310	50,175	2,097
PRAIRIE	68,192	57,031	6,942	321	229	1,256	18,277	4,596	1,392	888	22,393	849
PULASKI	5,044	4,792	0	0	0	0	0	0	0	0	4,792	0
RANDOLPH	24,024	28,848	7,352	0	0	2,875	5,733	685	0	80	12,236	0
ST. FRANCIS	53,140	47,353	5,564	0	125	34	9,832	1,475	1,767	17	28,221	404
WHITE	18,838	16,060	565	0	1,547	384	6,230	154	0	0	6,440	749
WOODRUFF	62,177	62,323	8,659	0	3,637	4,513	13,574	3,239	2,793	849	22,762	2,432
OTHERS[3]	7,034	6,861	0	0	0	727	1,029	210	0	0	2,406	2,489
Unaccounted[4]		20,048	--	--	--	--	--	--	--	--	--	--
2003 TOTAL		1,455,000	162,163	1,721	33,087	68,636	317,251	91,561	38,363	15,325	658,150	50,654
2003 PERCENT		100.00%	11.15%	0.12%	2.27%	4.72%	21.80%	6.29%	2.64%	1.05%	45.23%	3.48%
2002 TOTAL	1,506,000		139,072	22,315	37,164	5,087	438,575	4,101	50,876	44	623,693	65,284
2002 PERCENT	100%		9.28	1.49%	2.48%	0.34%	29.27%	0.27%	3.39%	0.00%	41.62%	4.36%

[1] - Harvested acreage. Source: Arkansas Argicultural Statistics and FSA. [2] - Other varieties: Alan, AB647, Alan, Clearfield 121, Clearfield 141, Cypress, Della, Delmatti, Delmont, Dellrose, Drew, Earl, Jasmine, Jefferson, Kaybonnet, Koshikari, Lemont, Nortai, Priscilla, and RiceTec XL-6, Rice Tec XL7, Rice Tec 7015, and Saber. [3] - Other counties: Clark, Conway, Crawford, Hot Spring, Little River, Perry, Pope, Stone, and Yell. [4] - Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA.

2003 CALIFORNIA RICE ACREAGE BY VARIETY SURVEY[1]

RICE VARIETY BY GRAIN TYPE	2002				2003			
	SEED2		TOTAL[3]		SEED2		TOTAL[3]	
	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT	ACRES	PERCENT
SHORT GRAIN								
S-102	508	2.25	8,943	1.66	342	1.78	9,071	1.85
AKITAKOMACHI	NA	NA	5,618	1.04	NA	NA	7,497	1.53
KOSHIHIKARI	NA	NA	6,320	1.17	NA	NA	4,659	0.95
CALMOCHI-101	262	1.16	13,869	2.57	469	2.44	15,843	3.23
OTHER	NA	NA	NA	NA	21	0.11	3,065	0.63
SUBTOTAL	**770**	**3.41**	**34,750**	**6.43**	**833**	**4.33**	**40,135**	**8.19**
MEDIUM GRAIN								
M-103	68	0.30	2,045	0.38	87	0.45	7,756	1.58
M-104	2,453	10.87	41,862	7.75	2,322	12.09	62,865	12.83
M-201	0	0.00	1,475	0.27	0.00	0.00	4,000	0.82
M-202	8,162	36.18	247,200	45.77	7,180	37.37	221,883	45.28
M-204	2,146	9.51	56,629	10.48	1,520	7.91	33,261	6.79
M-205	6,175	27.38	88,497	16.39	4,218	21.96	69,635	14.21
M-206	8	0.00	8	0.00	591	3.07	591	0.12
M-401	1,838	8.15	32,210	5.96	1,449	7.54	18,607	3.80
M-402	360	1.60	6,607	1.22	164	0.86	9,466	1.93
OTHER	NA	NA	18,367	3.40	NA	NA	12,175	2.48
SUBTOTAL	**21,210**	**94.00**	**494,900**	**91.63**	**17,530**	**91.25**	**440,238**	**89.84**
LONG GRAIN								
L-204	78	0.35	1,200	0.22	139	0.72	1,929	0.39
L-205	6	0.03	2,099	0.39	28	0.15	1,893	0.39
A-201	49	0.22	1,203	0.22	43	0.22	1,455	0.30
A-301	73	0.33	1,469	0.27	92	0.48	790	0.16
CALMATI-201	33	0.15	336	0.06	21	0.11	874	0.18
OTHER	NA	NA	NA	NA	NA	NA	500	0.10
SUBTOTAL	**239**	**1.08**	**6,307**	**1.17**	**323**	**1.68**	**7,441**	**1.52**
OTHER	**338**	**1.50**	**4,143**	**0.77**	**525**	**2.73**	**2,235**	**0.46%**
TOTAL	**22,557**	**100.00**	**540,100**	**100.00**	**19,210**	**100.00**	**490,049**	**100.00**

[1]Estimates based on survey of rice millers and marketers and certified seed acreage conducted by the Rice Experiment Station, P.O. Box 306, Biggs, CA 95917-0306, 530-868-5481.
[2]Planted acreage of all classes of certified rice seed provided by California Crop Improvement Association.
[3]Estimates of total rice acreage based on rice millers and marketers survey and seed acreage.
[4]Other varieties include; Short Grains S-201, Calhikari-201; and proprietary and specialty varieties.

2003 LOUISIANA RICE ACREAGE BY VARIETY SURVEY

Parish	2002	2003	MEDIUM GRAIN				LONG GRAIN						
	Acreage	Acreage	Bengal	Saturn	Lafitte	Other[1]	Cocodrie	Cypress	Wells	Jefferson	Maybelle	CL 161	Other[2]
Acadia	90,250	76,217	7,500	0	0	150	36,467	21,500	1,800	1,200	0	5,500	2,100
Allen	21,400	17,190	560	300	0	0	9,550	4,895	400	725	0	0	760
Avoyelles	12,486	11,384	0	0	0	0	4,093	4,789	0	0	0	965	1,537
Beauregard	2,582	1,901	30	0	0	0	1,311	0	0	0	0	356	204
Bossier	181	0	0	0	0	0	0	0	0	0	0	0	0
Caddo	50	0	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	18,192	12,970	150	0	240	0	6,753	4,502	125	0	0	1,200	0
Caldwell	1,111	1,178	0	0	0	0	1,178	0	0	0	0	0	0
Cameron	14,115	12,069	0	0	0	0	7,245	3,174	0	268	0	824	558
Catahoula	7,400	2,500	0	0	0	0	1,750	750	0	0	0	0	0
Concordia	12,163	10,234	0	0	0	0	7,160	350	200	0	0	1,644	880
East Carroll	16,268	15,910	716	0	0	0	10,723	859	1,655	0	0	446	1,511
Evangeline	53,040	43,689	3,495	0	0	0	21,873	14,966	1,151	0	0	2,184	20
Franklin	651	921	0	0	0	0	321	600	0	0	0	0	0
Grant	8	0	0	0	0	0	0	0	0	0	0	0	0
Iberia	1,254	715	122	0	0	0	226	113	0	0	160	94	0
Iberville	98	214	0	0	0	0	214	0	0	0	0	0	0
Jeff Davis	85,900	75,455	1,166	0	0	0	38,147	24,591	2,100	2,325	0	5,000	2,126
Lafayette	6,672	5,319	400	0	0	0	2,419	1,500	200	200	100	500	0
Madison	6,897	4,711	0	0	0	0	3,711	0	0	0	0	1,000	0
Morehouse	29,696	28,795	0	0	0	0	23,795	1,500	0	0	0	3,500	0
Natchitoches	4,336	4,295	0	0	0	0	4,000	0	195	0	0	0	100
Ouachita	8,185	8,754	686	0	0	0	7,908	0	0	0	0	0	160
Pointe Coupee	1,796	2,200	0	0	0	0	1,710	400	0	0	0	90	0
Rapides	7,308	6,325	0	0	0	0	5,810	0	0	0	0	515	0
Red River	385	350	0	0	0	0	350	0	0	0	0	0	0
Richland	6,964	6,330	0	0	0	0	4,530	500	0	0	0	1,200	100
St. Landry	23,626	18,370	0	0	0	0	11,022	5,144	0	0	0	1,837	367
St. Martin	4,784	2,000	0	0	0	0	1,448	473	0	0	0	79	0
Tensas	1,990	2,646	0	0	0	0	2,000	0	600	0	0	0	46
Vermilion	86,027	67,073	2,945	0	0	25	36,992	20,808	1,902	150	487	3,290	474
West Carroll	7,319	5,785	0	0	0	0	5,200	585	0	0	0	0	0
2003 Total		445,500	17,770	300	240	175	257,906	111,999	10,328	4,868	747	30,224	10,943
2003 Percent		100.00	3.99	0.07	0.05	0.04	57.89	25.14	2.32	1.09	0.17	6.78	2.46
2002 Total	533,134		8,729	800	30	815	286,754	169,333	41,096	7,125	4,175	0	15,960
2002 Percent	100.00		1.64	0.15	0.01	0.15	53.79	31.76	7.71	1.34	0.78	0.00	2.99

[1] - Other Medium Grains include: Earl, Pirogue (short grain).

[2] - Other Long Grains include: Francis, CL121, CL141, XL8, Saber, CLXL8, Jasmine, Toro-2, Chenier, XP710, Della, Jodon, Priscilla.

2003 MISSISSIPPI RICE ACREAGE BY VARIETY SURVEY

County	Clearfield	Cocodrie	Cypress	Dixiebelle	Drew	Hybrid	Jackson	Jefferson	Lemont	Priscilla	Francis	Wells	Total Acreage
Bolivar	13,410	52,150		300		450		350		4,470	1,500	1,850	74,480
Coahoma	249	11,201				373				622			12,445
DeSoto			2,700								500		3,200
Grenada		300							200	500			1,000
Humphreys	525	2,800								300	150		3,775
Issaquena	1,875	1,160											3,035
Leflore	3,400	9,800								2,550	600	650	17,000
Panola	500	2,600								200			3,300
Quitman	2,600	7,000								100		300	10,000
Sharkey		3,273								278	50	520	4,121
Sunflower	2,800	20,143				400			2,000	7,000	500	400	33,243
Tallahatchie	858	15,449								858			17,165
Tunica	1,600	18,500				400		800		700	300	1,200	23,500
Washington	932	20,074								13,550		1,505	36,061
Total Acreage	28,749	164,450	2,700	300	0	1,623	0	1,150	2,200	31,128	3,600	6,425	242,325

Data collected by County Directors/Area Extension Agents and compiled by Dr. Joe Street, Rice Specialist.

MISSOURI RICE ACRES PLANTED – 2001-2003

County	2001	2002	2003	% change ('02 to'03)
Bollinger	1,305.2	459.6	894.0	+94.5 %
Butler	69887.4	63,297.0	63,155.1	-0.2 %
Cape Girardeau	0	0	191.9	+191.9 a.
Dunklin	13,092.1	15,028.0	13,732.0	-8.6 %
Mississippi	425.0	100.0	320.0	+320 %
New Madrid	29,466.3	26,400	19,578.3	-25.2 %
Pemiscot	16,009.4	19,149.8	17,970.8	-6.2 %
Ripley	5,847.9	4,976.3	4,896.2	-1.6 %
Scott	1,433.0	1,101.0	1,409.0	+28.0 %
Stoddard	69,316.0	61,590.7	51,633.0	-6.4 %
Wayne	35.8	0	0	0
Total	**206,818.1**	**192,102.4**	**155,809.5**	**-18.9 %**

Source:

USDA-FSA offices in the respective counties.

Compiled by:

Bruce Beck. Agronomy Specialist
University Outreach and Extension
222 North Broadway
Poplar Bluff, MO 63901

2003 TEXAS RICE ACREAGE BY VARIETY SURVEY

County	2002 Acreage	2003 Acreage	Long Grain											Med. Grain	
			Cocodrie	Cypress	CL161	Jefferson	Francis	XL8	Wells	Saber	Dixiebelle	XL7	Risotto	Bengal	Other*
East Zone:															
Brazoria	14,969	10,646	8,264	259	518	518	259								828
Chambers	12,692	10,937	7,734		2,620		426	157							
Galveston	1,166	781	781												
Hardin	633	738	480		258										
Jefferson	18,389	15,187	7,593		6,834	152				152				304	152
Liberty	9,073	7,788	5,093		1,970		79	158						99	389
Orange	414	0													
East Total	**57,336**	**46,077**	**29,945**	**259**	**12,200**	**670**	**764**	**315**		**152**				**403**	**1,369**
Northwest Zone:															
Austin	1,694	1,684	711	356		617									
Colorado	30,726	28,572	23,210	3,101	1,899		144	218							
Harris	2,083	1,664	1,016					42		606					
Lavaca	1,690	1,582	140	1,256		186									
Waller	6,917	7,300	6,280		196	206		382				44			192
Wharton	49,139	46,454	34,632	5,862	2,448	2,191	251	192	109	109	78	204			378
Northwest Total	**92,249**	**87,256**	**65,989**	**10,575**	**4,543**	**3,200**	**395**	**834**	**109**	**715**	**78**	**248**			**570**
Southwest Zone:															
Calhoun	1,498	1,897	1,634	263											
Fort Bend	8,615	6,525	5,617			131									777
Jackson	13,214	13,510	6,327	6,057	733	309	46			38					
Matagorda	27,750	18,884	15,631	331		2,276	61				458		102		25
Victoria	1,748	1,247	1,247												
Southwest Total	**52,825**	**42,063**	**30,456**	**6,651**	**733**	**2,716**	**107**			**38**	**458**		**102**		**802**
Northeast Zone:															
Bowie	1,287	1,332	81	405			36		629	18				163	
Hopkins	1,034	713	713												
Red River	1,017	587	387						200						
Northeast Total	**3,338**	**2,632**	**1,181**	**405**			**36**		**829**	**18**				**163**	
2003 Total Acreage		178,028	127,571	17,890	17,476	6,586	1,302	1,149	938	923	536	248	102	566	2,741
2003 Percentage		100.0%	71.7%	10.0%	9.8%	3.7%	0.7%	0.6%	0.5%	0.5%	0.3%	0.1%	0.1%	0.3%	1.5%
2002 Total Acreage	205,748		164,257	4,851		13,424		121	1,475	9,164	1,096	856		686	9,818
2002 Percentage	100.0%		79.8%	2.4%		6.5%		0.1%	0.7%	4.5%	0.5%	0.4%		0.3%	4.8%

Compiled by Dr. James Stansel and Robin Clements, Texas A&M Univ. System at Beaumont. Survey data from dryers, sales offices, agribusiness, USDA/CFSA and County Extension Agents as appropriate. *Other varieties include: Delmatti, XP710, Millgro, CL121, Sierra, Texmati Type, Cheniere, XP110, CLXL8.

RECOMMENDATIONS OF THE PANELS

BREEDING AND GENETICS

Q.R. CHU, Chair; S. PINSON, Chair-Elect (2006); Q. CHU, F. JODARI, C. RUSH, D. BEIGHLEY, J. GIBBONS, X. SHA, Moderators; A. MCCLUNG, K. JOHNSON, R. PORTER, G. ALUKO, K. TRAORE, R. SHANK, J. KEPIRO, V. ANDAYA, H. BOCKELMAN, M. MOSTAFAVI, A. YADAN, Q. SHAO, X. CHENG, W. YAN, F. XIE, E. SARREAL, O. SAMONTE, S. MOON, G. HOOKSFRA, C. ANDAYA, S. ZHANG, J. CORRELL, M. SPANIEL, R. TABIEN, J. SMITH, J. SHOFFNER, K. TAYLOR, C. DICKENS, B. JORDAN, A. RIVERA, J. DELESTRE, D. RICHARDS, T. BEATY, Q. HO, C. LAY, B. WOODRUFF, H. UTOMO, V. JOHNSON, P. SINGH, Y. WAMISHE, R. REFELD, J. NASH, D. KANTER, K. MOLDENHAUER, M. SHAH, C. MARTINEZ, N. ZHANG, K. FOSTER, E. VRANCKEN, M. ARIZA-NIETO, Participants.

Cooperation of rice breeders and geneticists with pathologists, physiologists, cereal chemists, soil scientists, agronomists, entomologists, and weed scientists is essential in developing superior cultivars that will afford maximum and stable production of rice desired by consumers. Much of this progress is dependent on coordinated research to develop improved methodologies. The close working relationship maintained with all segments of the rice industry should be strengthened wherever possible.

Present research should be continued or new research initiated in the following areas:

Genetics
Additional information is needed on the mode of inheritance of economically important characters. Phenotypic and genetic associations among such characters should be determined. Basic research is needed to determine the factors influencing pollination and fertilization over a wide range of plant environments. Efforts should be made to incorporate the cytoplasmic and nuclear genetic elements necessary for hybrid rice production into germplasm that is well adapted to the respective rice growing areas. Also, information on the feasibility of economic production of hybrid seed and amount of heterosis obtainable under grower cultural practices is needed. Genetic control of efficiency of solar energy conversion, including photosynthetic efficiency, respiration losses, translocation rates, source-sink relationships, plant morphology, chlorophyll quality and quantity, etc., must be explored to determine if such factors can benefit the development of superior yielding varieties. Particularly in some areas along the Gulf Coast, improving ratoon crop yield potential is very important to the profitability of producers. Developing an understanding of the genetic, physiological, morphological, and environmental factors that influence ratoon crop yield is important for varietal improvement. Genetic stocks that have current or as-yet-unanticipated value should be preserved by entry into the newly-established Genetic Stocks-Oryza (GSOR) collection. Materials contributed will be accessible through GRIN and will be available to all interested researchers.

Molecular Genetics and Genetic Engineering
Molecular genetic studies of rice have accelerated rapidly due to the favorable qualities of this species, including its small genome size and ease of transformation. Molecular markers such as RFLPs, RAPDs, AFLPs, and microsatellites have been used to map loci controlling economically important traits. This knowledge should be extended to public and private breeders for application in marker assisted selection schemes. PUBLIC USER-FRIENDLY DATABASES SHOULD BE CREATED, MAINTAINED, AND UPDATED FOR THE ON-GOING ADVANCE OF THIS SCIENCE. The technology should be applied to mapping the traits listed above that have not been studied. Particular attention needs to be focused on developing markers such as microsatellites that can be used in crosses between japonica rices. Genetic engineering is considered an emerging tool that will complement traditional methods for germplasm and varietal development. Genes for herbicide, insect, and disease resistance are being isolated and transferred to elite lines for field evaluation. Rice breeders should cooperate with molecular biologists for proper evaluation and selection of transgenic lines that would benefit the rice producers. When available, genes for increased yield and grain quality should be transferred into elite lines.

Response to Environment
Superior-yielding, widely adapted varieties should be developed that have increased tolerance to low soil, water, and air temperatures; greater tolerance to prolonged extremes in day/night temperatures during flowering and grain filling stages that reduce grain and milling yields and increase spikelet sterility; greater tolerance to saline or alkaline conditions; plant types with the capability of utilizing maximum available light energy and of possessing reduced water requirements. However, because of the geographical and climatic diversity among rice-producing areas in the U.S., a need still exists to develop varieties for specific areas. New varieties and advanced experimental lines should be tested for reaction or response to registered/

experimental pesticides in order to determine whether they are tolerant or susceptible to chemicals already in wide usage or which may be widely used in weed, disease, or insect control.

Resistance to Diseases and Insects

Intensive studies are required to develop varieties resistant to economically important diseases and insects. Breeding for increased resistance to all known races of rice blast fungus *(Pyricularia grisea)*, the rice sheath blight fungus *(Rhizoctonia solani)*, aggregate sheath spot fungus *(Rhizoctonia oryzae sativae)*, and the stem rot fungus *(Sclerotium oryzae)* should be emphasized with the objective of obtaining highly resistant varieties within all maturity groups and grain types. Efforts should be made to develop varieties with greater field resistance to these and other diseases. Breeding for resistance to brown spot *(Bipolaris oryzae)*, kernel smut *(Neovossia horrida)*, false smut *(Ustilaginoidea virens)*, the water mold complex *(Achlya and Pythium* spp.*)*, sheath rot *(Sarocladium oryzae)*, narrow brown leaf spot *(Cercospora janseana)*, panicle blight (*Buckholderia glumae)*, leaf scald, leaf smut, "pecky rice," and the physiologic disease straighthead should be continued. A continuing emphasis on sources of resistance to these diseases in intensified cultural systems is needed. Breeding for insect resistance to rice water weevil *(Lissorhoptrus oryzophilus* (Kuschel)*)*, rice stink bug *(Oebalus pugnax* (Fabricius)*)*, and stored grain insects is also encouraged.

***Oryza* Species**

Other species of *Oryza* may contain the needed resistance or tolerance genes to important diseases, insects, and environmental stresses AND/OR GRAIN CHEMICAL QUALITIES that have not been recovered in *O. sativa*. Evaluation of these species and the transfer of desirable factors into adapted rice lines should be pursued. As germplasm lines are recovered from interspecific crosses, cooperative evaluation for disease resistance, insect resistance, and other features of interest would be desirable. Data from these evaluations should be entered in GRIN/GRAMENE.

Fertilizer Response

Factors that determine fertilizer response and lodging resistance and affect yield components are closely associated in determining total production and quality of grain. These factors must be studied collectively in order to understand the effects of quality, quantity, and timing of fertilizer applications on plant growth and yield components. Efforts should be increased to develop varieties that give maximum yield per unit of nitrogen fertilization.

Processing, Cooking, and Nutritional Characteristics

Basic studies are needed to learn more about the role of each constituent of the rice kernel in processing, cooking behavior, and nutritional value. As these properties are more clearly delineated, new techniques, including bioassays, should be developed to evaluate breeding lines for these factors. These studies should be coordinated with attempts to genetically improve grain quality factors, including translucency, head rice yields, protein content, and cooking properties. There is increased interest in developing rice cultivars to target specialty markets, such as soft cooking rice, aromatics, waxy types, Basmati types, and Japanese premium quality rices. Research efforts need to be directed toward determining quality traits associated with various specialty rices, analytical methods for evaluation, genetic variability, influence of environmental variables on character expression, and factors associated with consumer acceptance.

Cultivar Performance and Seed Source of Cultivars and Superior Breeding Materials

Rice breeders are responsible for obtaining and making available information on performance of rice cultivars and elite germplasm stocks. They also are responsible for maintaining breeder seed of recommended cultivars developed by public agencies. In addition, they must ascertain that stocks of superior breeding material are developed and maintained. Wide germplasm bases are needed and must be maintained. All breeders must make continuing efforts to preserve and broaden the world collection of rice. In order to enhance the rapid use of rice plant introductions and the exchange of pertinent information, we must work with those responsible for plant introduction, description, and dissemination of rice accessions and pertinent information. Increased efforts also are needed to evaluate and maintain all entries in the active, working collection and to enter all descriptive data into the automatic data storage and retrieval system developed for the USDA Rice World Collection.

Germplasm Evaluation and Enhancement

Efforts should be made to develop relatively adapted, broad-based gene pools having a diversity of phenotypic and genotypic traits. Characteristics include components required for increasing yields of future cultivars and/or hybrids, such as straw strength, seed size, and number of florets per panicle. Other useful characteristics as may be identified during evaluation efforts may be incorporated into existing or new pools as appropriate. Genetic male steriles and/or gametacides may facilitate these efforts that should not detract from continuing to develop a gene pool of high grain yield irrespective of quality or other undesirable characters. Development of indica germplasm with high yield and grain quality standards similar to U.S. cultivars should be pursued. The core subset strategy should be an effective way to evaluate germplasm collections. A core subset of about 10% of the U.S. rice collection has been established. Comprehensive evaluations of the core subset for phenotypic descriptors and DNA fingerprinting should be pursued by cooperative federal, state, and industry efforts.

ECONOMICS AND MARKETING

M. SALASSI, Chair; D. ANDERSON, Chair-Elect (2006); D. MITTEN, R. SHILLITO, B. GRIFFIN, R. KADAU, N. GUTIERREZ, E. WAILES, K. YOUNG, J. LIVEZEY, L. FOREMAN, J. OUTLAW, H. CAFFEY, D. DICKEY, L. FALCONER, S. KNARR, B. SCHULTZ, B. WATKINS, R. WIMBERLEY, W. BROWN, N. CHILDS, H. CORMIER, S. WRIGHT, L. POPE, B. OWEN, K. HAWKINS, A. AARONSON, S. NO, participants.

Supply/Production Research
Investigate water use practices in various rice producing regions and estimate the costs to producers of compliance with proposed EPA water use and quality regulations.

Identify factors accounting for differences in cost of production by state and region.

Provide economic analysis of conventional and experimental rice production systems by producing region. The main objective is to improve farm management decisions.

Estimate the economic impact of rice field topography and harvest technology. Major impacts will be reduced costs, enhanced planting, water management, and harvesting efficiency.

Evaluate and measure economic impacts of environmental and recreational costs and benefits associated with rice production.

Evaluate the impact of adoption genetically improved rice varieties on producer welfare, prices, and cost of production.

Analyze the economic impact of identity preservation and variety contracting on the U.S. rice market.

Make economic comparisons of alternative rice varieties and associated cultural practices

Make economic comparisons of alternative land tenure arrangements and respective returns to landowners, tenants, and waterlords.

Make economic evaluation of alternative enterprises as a component of rice farming systems.

Policy, Demand, and Marketing Research
Identify factors that are affecting rice consumption in the U.S. and study marketing schemes that may impact per capita consumption.

Estimate the impact of rice imports on U.S. consumption and production.

Evaluate potential impacts of the current round of the WTO on global rice trade and the competitiveness of the U.S. rice industry.

Develop a full export-import trade matrix for international rice by grain type and quality.

Investigate various marketing alternatives available to rice producers.

Evaluate the performance of the rough rice futures market.

Examine changes in the structure of the U.S. rice industry and determine the implications for producers and consumers.

Evaluate the potential market for rice by-products and new value-added products.

Evaluate how changing markets impact the structure of the rice industry from the farm level to retail.

Other Information
The Economics and Marketing Panel recognizes two separate awards in the Panel meetings, the Outstanding Graduate Student rice research paper or thesis and the Outstanding Rice Economist/Marketing Research/ Extension Service Award. The awards committee is chaired by the past co-chairs of the Economics and Marketing panel. Submissions for these awards in 2006 should be forwarded by December 20, 2005 to Mike Salassi at Louisiana State University or Nathan Childs at the Economic Research Service, USDA.

PLANT PROTECTION

M. STOUT, Chair; M. WAY, Chair-Elect (2006); J. BERNHARDT, J. OLSON, S. LAWLER, R. DELONG, G. SCIUMBATO, D. GROTH, A. HOPKINS, K. VODRAZKA, D. BLACK, J. OSTER, T. RASHID, D. JOHNSON, S. LEONG, L. ANDERSON, R. WEBSTER, J. ROBBINS, M. RUSH, Y. JIA, J. OARD, M. WAY, Q. SHAO, R. LEWIS, A. RICHARDS, G. CHENG, L. ZOU, M. PERICH, D. LONG, C. DICKENS, M. ISBELL, J. JONES, C. PARSONS, W. MINSON, T. GANTENBEIN, F. FROST, J. SHOFFNER, J. ROBINSON, J. KRAUSZ, C. HOLLIER, M. FREY, L. SMITH, D. GUETHLE, J. BLOOMBERG, V. BOYD, J. SAICHUK, L. POPE, J. GRANTHAM, J. HOLZHAUER, T. FLOWERS, K. DRIGGS, T. BAIRD, S. THEUNISSEN, M. WA, L. MCANALLY, J. FONTENOT, L. HOLLOWAY, C. HOLLIER, R. SHANK, J. NEAL, D. SCHALTEIS, M. SINGH, M. ROOD, A. SHAHJAHAN, G. EIZGENGA, R. MILLER, M. BROWNING, L. SCHAFER, participants.

Diseases

The primary applications of basic and applied research on rice diseases are directed toward obtaining a better understanding of rice diseases and the ultimate control of these diseases. All avenues of research that have control as the final objective should be utilized. An integrated pest management approach to research for disease control includes studies related to cultural practices, resistant varieties, chemical control, and biological control of pathogens and objectionable plant species, and research related to the occurrence should be studied by pathologists in cooperation with agronomists and soil scientists. The ultimate objective of disease research is an integrated disease control program that would limit disease losses to an economically acceptable level.

The major diseases causing damage to the United States rice crop are sheath blight, caused by *Thanatephorus cucumeris* (Frank) Donk.; stem rot caused by *Magnaporthe salvinii* (Catt.) Krause & Webster; blast caused by *Magnaporthe grisea* (Hebert) Barr; kernel smut caused by *Neovossia (Tilletia) horrida* (Tak.) Padwick & Kahn; narrow brown leaf spot caused by *Sphaerulina oryzina* Hara; aggregate sheath spot caused by *Rhizoctonia oryzae-sativae* (Sawada) Mordue; brown spot caused by *Cochliobolus miyabeanus* (Ito & Kur.) Drech; and bacterial panicle blight caused by *Burkholderia glumae*. Seeding diseases caused by species of *Achlya* and *Pythium* are also important in water-seeded rice. Important seedling diseases of dry-seeded rice are caused by *Fusarium* spp., *Curvularia* spp. *Bipolaris* spp., *Rhizoctonia* spp., and *Gerlachia* spp.

Minor diseases or diseases of limited distribution include crown rot, causal agent unknown; leaf scald caused by *Gerlachia oryzae* (Hashioka & Yokogi) W. Gams & D. Hawksw.; sheath rot caused by *Sarocladium oryzae* (Sawada) W. Gams & D. Hawksw.; stackburn disease caused by *Alternaria padwickii* (Ganguly) Ellis; sheath spot caused by *Rhizoctonia oryzae* Ryker & Gooch; crown sheath rot caused by *Gaeumannomyces graminis* (Sacc.) von Arx & Oliver var *graminis*; black kernel caused by *Curvularia* spp.; false smut caused by *Ustilaginoidea virens* (Cke.) Tak.; leaf smut caused by *Entyloma oryzae* H. & D. Syndow; sheath blotch caused by *Pyrenochaeta oryzae* Shirai ex Miyake; bacterial leaf blight caused by a very weak strain of *Xanthomonas oryzae* Ishiyama pv. *oryzae* Swings; bakanae caused by *Fusarium moniliforme,* and several miscellaneous leaf, glume, and grain spotting diseases.

A disorder known as panicle or spikelet "blight" has become increasingly important in the last few years. The cause has been identified as a bacterial pathogen *Burkholderia glumae.*

An undefined pathogen complex acting alone or in conjunction with insect damage (feeding) is causing damage (peck) to rice kernels.

The physiological disorders straighthead and bronzing continue to occur throughout the southern rice area and are locally severe.

Areas in which research should be continued or initiated concerning these new diseases include the following:

1. The cooperative testing and breeding program with the rice breeders should be continued for the development of new disease-resistant rice varieties. Newly released varieties should be fully evaluated for reaction to all disease and insect pests. In addition, screening programs should endeavor to locate new germplasm with high degrees of resistance to sheath blight, blast, stem rot, narrow brown spot, and kernel smut diseases. Cultivar susceptibility to the minor diseases should be monitored. Cooperative regional or area testing is encouraged.

2. With an increasing incidence and severity of disease, particularly rice sheath blight, in conjunction with an increasing per acre crop value and in the absence of other control measures, the

need for effective chemical control measures is becoming acute. Increased emphasis should be placed on developing effective fungicides for controlling sheath blight, blast, stem rot, and kernel smut diseases. Methods of predicting disease occurrence and severity must be developed to support spray recommendations.

3. New fungicides should be evaluated under both drill- and water-seeded conditions for control of seedling diseases. Promising materials should be included in uniform seed treatment tests in the southern rice area. Investigations concerning improved seedling vigor and cold tolerance and the effects of these factors on stand establishment should be conducted.

4. Experiments to develop more accurate information concerning losses due to diseases of all types should be conducted. Experimental plots should be designed, when feasible, to enable collection of more precise data on the losses incurred in relation to disease severity.

5. Selections from the rice breeders in the southern rice area should be tested for straighthead. Although straighthead-resistant or tolerant varieties are in current use, a continuing program is needed to classify potential new varieties. The method for artificial induction of straighthead, such as treatment with MSMA should be improved upon.

6. A continuing program is needed to monitor new diseases and to study the etiology and epidemiology of the diseases already occurring in the United States. The fungi causing major diseases should be monitored for the development of new pathogenic races. The effects of changes in cultural practices on diseases must be observed constantly. Factors favoring epidemic conditions should be identified and steps made toward quantifying incidence and severity of diseases and associated effects on yield and quality in commercial acreage.

7. There is a need for a thorough investigation into the biological interactions of pathogen and non-pathogenic organisms with existing or new control measures for pests in rice. Investigations into the utilization of pathogens as bioherbicides should be continued, as should investigations into the interaction of pesticides with pathogenic and non-pathogenic organisms in rice. Research into the reduction of disease intensity and severity through biological control systems should be expanded.

8. Research into the modification of cultural practices for the purpose of disease control or the reduction in disease severity should be continued. Research into the use of mineral and nutrimental amendments to reduce disease severity should be continued and increased.

9. Rapid and orderly dissemination of exotic rice germplasm from the germplasm collection is a priority. Efficiency in use of space at the Beltsville, Maryland, facility should be improved, and funding should be sought for review/revision of present quarantine procedures based on current knowledge of diseases worldwide. However, we recommend that existing federally specified quarantine procedures be adhered to when new strains are imported.

10. The potential for applications of recent advances in biotechnology, such as somaculture, gameto-culture, and recombinant DNA, in the development of rice germplasm with improved disease and insect resistance and stress tolerances should be explored further.

Insects and Other Animal Pests

We have attempted to point out research areas that are concerned with immediate and long-term problems. No attempts have been made to place recommendations in order of importance.

Investigations should include the use of biological agents, cultural practices, resistant varieties, and other methods that might be integrated with chemical control to provide the most effective economical and safe way to manage insect and related pests attacking rice.

The major insect pests that damage the seed or rice plants between planting and harvesting are the rice water weevil, *Lissorhoptrus oryzophilus* Kuschel; rice stink bug, *Oebalus pugnax* (Fabricius); grape colaspis, *Colaspis brunnea* (Fabricius); stem borers, *Diatrea saccharalis* (F.), *Eoreuma loftini* (Dyar), and *Chilo plejadellus* Zincken; rice leaf miner, *Hydrellia griseola* (Fallen); armyworm, *Pseudaletia unipuncta* (Haworth); fall armyworm, *Spodoptera frugiperda* (J.E. Smith); chinch bug, *Blissus leucopterus leucopterus* (Say); various species of leaf- and planthoppers; numerous grasshopper species (Locustidae and Tettigoniidae); midge larvae (Chironomidae); greenbug, Schizaphis graminum (Rondani); bird cherry-oat aphid, Rhopalosiphum padi (L.); and an exotic stink bug, *Oebalus ypsilon-griseus* (DeGeer), found in Florida. Pests other than insects can damage rice directly or indirectly. *Triops longicaudatus* (LeConte), the tadpole shrimp, causes seedling drift by dislodging loosely rooted seedlings while feeding on the leaves and roots. Crayfish, *Procambarus clarki* (Girard), damage irrigation systems by burrowing and also reduce stand establishment by feeding on germinating seeds and small seedlings. Birds trample and feed on seeds and sprouting and ripening rice. Rodents, through their burrowing activity, damage levees and directly feed on rice plants.

Specific recommendations include the following:

1. Continue studies on the biology and ecology of rice insects, especially in relation to the influence of cropping and management practices such as water management, fertilization, and varietal changes on rice pests and their natural enemies.

2. Conduct studies on interactions between insects and other stresses (both biotic and abiotic) on plant growth and development.

3. Continue research on chemical control compounds and determine their a) efficacy, b) effect on non-target organisms, c) compatibility with other agricultural chemicals, d) relationship between dosages and mortality, and e) proper timing, application, and formulation.

4. Monitor the potential of pests to become resistant to chemicals used in pest control programs.

5. Determine the role of natural enemies and pathogens, individually and collectively, in reducing rice pest populations.

6. Continue interdisciplinary cooperation with rice breeders and plant pathologists to evaluate and identify rice lines for resistance to insects and/or disease problems.

7. Encourage and assist in the development of genetically engineered rice plants for pest control.

8. Determine economic levels and improve and standardize methods of sampling for possible use in systems-approach, pest management programs.

9. Monitor rice for possible introduction of exotic pests.

10. Identify and assess bird and rodent damage and develop management programs that are cost effective and environmentally safe.

PROCESSING, STORAGE, AND QUALITY

E. CHAMPAGNE, Chair; C. EARP, Chair-elect (2006); F. SHIH; A. NOBLE; K. BETT-GARBER; H. HE; S. KNARR; Y. LAN; S. SAIF; Z. PAN; R. BRYANT; C. JAMES; H. GURAYA

Our group is concerned with the processing, storage, and quality of rice. We believe research is needed in the following areas:

Website: Varietal Database
Breeding stations in the mid-south and gulf coast (CA has already completed this effort) would post data for released varieties, including parentage, amylose content, milling yield, grain weight, alkali number, sensory and functional data, etc.

Rice Harvesting, Drying, Storage, and Handling
Correlate environmental factors (temperature, humidity) at harvest to physical, chemical, and functional properties of the rice kernel.

Develop new and/or improved rice drying, storage, and handling systems to impart desirable functional properties, improve efficiency, and reduce energy use.

Incorporate economic factors into postharvest models and guidelines for harvesting, drying, and storage recommendations.

Develop sensors to rapidly and objectively monitor rice properties.

Evaluate alternatives to chemical fumigants for grain and facility treatment.

Develop biological and other non-chemical pest control measures using parasites, predators, and microorganisms.

Milling Characteristics
Determine the physicochemical properties of rice varieties and milling conditions that contribute to optimizing milling performance based on degree of milling.

Determine the nature of defective or fissured grains that survive processing and their effect on end use processing.

Develop sensors to rapidly determine and objectively predict milling quality (constrained by degree of milling) for U.S. and international varieties.

Incorporate laboratory research into industry practice. Validate methods and identify performance levels.

Processing Quality and Cooking Characteristics
Develop instrumental methods for screening lots and evaluation of prospective new varieties for processing quality.

Determine basic relationships between composition, molecular structure, physical state, and end-use performance (flavor, texture, processing properties, storage stability, etc.).

Determine impact of genetic, environmental, and processing factors on sensory properties, functionality, kernel size and property uniformity, and storage stability.

Improve inspection methods for measuring chemical constituents and quality factors.

Develop identity preservation and detection techniques for genetically modified and transgenic rice.

Utilization of Rice Components
Develop effective, cost-efficient methods for fractionating rice components (e.g., starch, protein, oil, and fiber).

Identify applications for components in native and modified forms.

Characterize bioactive components in varieties in regards to physicochemical and functional properties. Measure the amounts of these bioactive components in various varieties.

Develop non-food uses for rice, rice hulls and ash, straw, bran, and protein.

Nutrition and Food Safety
Promote the health benefits of rice and develop rice products and constituents that promote human and animal health.

Evaluate the bioavailability of rice components, specifically nutraceuticals, and investigate the levels required to generate responses in humans and animals.

Investigate the effects of processing and storage conditions on microbial loads in rice for improved food safety.

RICE CULTURE

J. OARD, Chair; L. TARPLEY, Chair-Elect (2006); D.B. JONES, N. SLATON, C.E. WILSON, JR., P.K. BOLLICH, J.K. SAICHUK, M. JUND, F.T. TURNER, T.W. WALKER, M.W. EBELHAR, J. HILL, D. HAGLER, and R.J. NORMAN, Participants.

The panel on rice culture reaffirms the value of the meeting in (1) reviewing the research already completed, (2) facilitating the exchange of information, (3) developing cooperative research on problems of mutual interest, and (4) in directing the attention of proper authorities to further work that should be undertaken. Under various research categories represented by this panel, the following continuing research needs are specified:

Cultural Practices
Evaluate rotation systems that involve rice.

Determine the effects of water management, fertilization, and water-use efficiency on grain yield and quality.

Identify factors that cause poor stand establishment, and develop practices that will ameliorate these conditions.

Develop conservation tillage practices for efficient production of rice under water-seeded and dry-seeded systems, including “stale” seedbed management.

Expand research on crop residue management, including soil incorporation, collection, and economic uses.

Study management systems that enhance ratoon production.

Evaluate aquaculture rotation systems that involve rice, such as, but not limited to, crawfish/rice rotations.

Explore crop establishment, including planting methods and geometry, plant density, and other factors necessary to characterize BMP’s for various cultivars of interest.

Evaluate the use of harvest aid chemicals in rice production.

Fertilizers and Soils
Develop a greater understanding of the chemical, physical, and physiochemical changes that occur in flooded soils and their influence on the growth of rice, nutrient transformations, and continued productivity of the soil.

Study nutrient transformations, biological nitrogen fixation, and fertilizer management systems in wetland soils, especially as related to soil pH.

Develop soil and plant analysis techniques for evaluation of the nutrient supply capacity of soils and the nutritional status of rice to enhance the formulation of fertilizer recommendations.

Cooperate with plant breeders, physiologists, and soil researchers to develop techniques for efficient utilization of nutrients.

In cooperation with other disciplines, study the interactions among cultivars, soil fertility, diseases, weeds, insects, climate, and water management.

Develop integrated systems to more efficiently utilize fertilizer while reducing pesticide use.

Gain a better understanding of silica deficient soils, silica sources, and their effect on rice yield.

Determine the potential use of non-traditional fertilizer sources and additives in rice production

Physiology
Determine the effects of varying climatic environments on growth, development, and yield of both main and ratoon crops of rice.

Determine the physiological factors related to grain yield and quality and plant growth and development of the main and ratoon crops of rice.

Determine the physiological processes, including root functions, involved in nutrient uptake and utilization in an anoxic environment.

Water
Accurately determine the complete water balance on rice as a function of soil textural groups, regions, time within the irrigation season, rice growth stage, and meteorological parameters.

Determine the impact of sub-optimal water availability at various physiological stages on dry matter accumulation, maturation, grain yield, and grain quality.

Determine optimum water management guidelines for flush-flood, pin-point flood, and continuous-flood irrigation.

Evaluate the effect of water conservation practices such as underground pipe and/or flexible polyethylene pipe, land forming, multiple inlets, reduced levee intervals, and lateral maintenance on water use.

Continue to evaluate water quality in terms of salinity and alkalinity and its effect on rice productivity.

Evaluate water use as related to water loss and evapotranspiration.

Environmental Quality
Determine the effect of various management systems on changes in the quality of water used in rice production. Monitoring should include all water quality parameters such as nutrient inputs, suspended and/or dissolved solids, organic matter, etc.

Determine the fate of agricultural inputs in the soil, water, and plant continuum as related to varying rice cropping systems. This information should be applied to minimize losses from the field and reduce any attendant environmental degradation associated with such losses and in the development of Nutrient Management Plans.

Assess the relationship between greenhouse gasses, global climatic change, and rice production and evaluate the magnitude of potential environmental effects of gaseous losses from rice fields.

Assess the relationships of global climactic change and rice production.

Engineering Systems
Study energy inputs in rice production and harvesting.

Expand investigations to improve equipment for proper and efficacious applications of seed and fertilizers.

Analyze and improve harvesting practices to assure maximum recovery of top quality grain through timeliness of harvest and harvester adjustments by cultivar and climatic zone.

Determine ways to use the Global Positioning System and Geographic Information System to aid rice research and reduce rice production cost.

Rice Systems Modeling
Encourage development of rice models and expert systems that enhance our knowledge of rice development, aid in diagnosing problem situations, and provide decision support for growers.

Determine the effects of cultural and chemical practices used in rice-based cropping systems on species demography and dynamics.

RICE WEED CONTROL AND GROWTH REGULATION

B.J. WILLIAMS, Chair; J.M. CHANDLER, Chair-Elect (2006); N.R. BURGOS, G. MCCAULEY, D.R. GEALY, A.J. FISCHER, R.E. TALBERT, R. SCOTT, J.W. BRANSON, K.L. SMITH, R.C. NAMENEK, K.J. PELLERIN, C.T. LEON, B.V. OTTIS, J.H. O'BRARR, H.M. HACKWORTH, M.L. LOVELACE, E.F. SCHERDER, J.B. GUICE, M.S. MALIK, W. ZHANG, M.E. KURTZ, E.N. STIERS, S.N. RAJGURU, T.L. DILLON, L. TARPLEY, E. WEBSTER, R. DUNAND, B. OTTIS, and J. O'BARR, Participants.

The overall objective of the Rice Weed Control and Growth Regulation Panel's recommendations is to achieve maximum integration of nonchemical and chemical methods with basic biological processes to improve weed control and growth regulation in rice. The categories listed below are separated for the purpose of describing the research areas more specifically.

Chemical Weed Control
Control of herbicide-resistant weeds.

Mechanisms of resistance.

Evaluate new chemicals for the control of weeds in rice.

Facilitate label clearance for herbicides and continued registration for phenoxy herbicides.

Evaluate varietal tolerance to herbicides in cooperation with plant breeders.

Study new and existing herbicides for their fit in low and non-tillage rice-based cropping systems for the conservation of resources.

Cooperate with environmental toxicologists and others to study the fate of herbicides in the rice environment and their potential to affect non-target organisms.

Cooperate with agricultural engineers and others to study improved application systems.

Study basic processes on the effect of herbicides on growth and physiology of rice and weeds.

Cooperate in the development of genetically engineered herbicide tolerance in rice.

Establish rotational methods with new chemistries for red rice control to prevent possible outcrossing.

Weed Biology
Determine and verify competitive indices for rice weeds to predict yield and quality losses and cost/benefit ratios for weed control practices. Verify yield and quality loss models.

Intensify studies on weed biology and physiology, including red rice.

Survey rice-producing areas to estimate weed infestations and losses due to weeds.

Determine the effects of cultural and chemical practices used in rice-based cropping systems on species demography and dynamics.

Non-Chemical Weed Control
Evaluate the influence of cultural practices, including crop density, fertility and irrigation management, tillage practices, and others (xyz) on weed control and production efficiency.

Evaluate the influence of cultural practices on red rice control.

Study methods for the biological control of important rice weeds, including the potential for allelopathic control.

Growth Regulation
Evaluate the use of growth regulators for areas such as yield enhancement, shortening plant height, increasing seedling vigor, and red rice seedhead suppression in rice.

Study basic biological and physiological processes regulated by applied chemicals.

Facilitate label clearance for growth regulators.

Cooperate with environmental toxicologists and others to study the fate of growth regulators in the rice environment and their potential to affect non-target organisms.

Abstracts of Symposium Presentations: Risk of Introduced Pests
Panel Chair: D.E. Groth

The Challenge of Introduced Invertebrate Pests of Rice in the United States

Way, M.O.

The introduction of noxious invertebrates into the rice agroecosystem of the United States and other countries has been and will continue to be of concern. In fact, with increasing globalization of commerce, faster, and easier modes of continental and intercontinental travel, and a recent trend towards the relaxation of national trade barriers, all of U.S. agriculture can expect more problems involving the introduction, establishment, and spread of exotic pests.

For a species to invade a new area, certain abiotic and biotic conditions greatly influence the success of introduction. First is the similarity of the native and foreign environments. Obviously, an introduced species' chance of success will be greater if the native and foreign environments are similar. Climate, topography, temporal, and spatial availability of suitable hosts, edaphic factors, and presence/absence of natural enemies are crucial environmental factors that greatly influence survival. However, some species, such as the rice water weevil (RWW), *Lissorhoptrus oryzophilus*, which is indigenous to the southeastern United States, enter a state of diapause when environmental conditions are unfavorable. Another example is the tadpole shrimp, *Triops longicaudatus*, which lays eggs in natural vernal pools or manmade rice paddies in California. These eggs can survive extended periods of desiccation and are "genetically programmed" to hatch over several years when moisture and other environmental conditions are favorable. These kinds of species are able to cope with temporary, hostile environments. Second is the biotic potential of the introduced species. For instance, certain insects, such as aphids, reproduce parthenogenetically (without benefit of male). The RWW also can reproduce parthenogenetically. This biological trait is characteristic of a successful colonizing species. In addition, some insects, categorized as "r-strategists," produce many offspring in a short period of time (produce multiple generations annually). An example of an "r-strategist" is the brown planthopper (BPH), *Nilaparvata lugens*. This insect is unable to overwinter north of the Tropic of Cancer, so it builds up in the Tropics of Asia then moves into northern China, northern India, Korea, and Japan where populations increase exponentially over multiple generations to produce extensive "hopperburn" damage to rice. The insect also transmits viruses that cause grassy stunt and ragged stunt diseases. Thus, the BPH takes advantage of a temporary, favorable environment through migration and an "r-strategy" of reproduction. Another planthopper, the rice delphacid, *Tagosodes oryzicolus*, is found in Central and South America and the Caribbean. Like the BPH, *T. oryzicolus* can build up high populations to cause "hopperburn" and can transmit a virus that causes the rice hoja blanca disease. In the late 1950s, *T. orizicolus* and hoja blanca were found in Florida and Louisiana. The insect also was detected in Mississippi. It is not clear if this insect was introduced into the United States. If so, *T. oryzicolus* probably entered the United States via flight assisted by wind. Considerable research was conducted in the late 1950s and early 1960s by USDA, experiment stations, and cooperating international agencies. Research included biological studies of the vector, vector/virus relationships, host plant resistance, and chemical control. Experiments were conducted in the United States, Latin America, and the Caribbean. Since that time, little or no research has been conducted in the United States on *T. oryzicolus* and/or hoja blanca. Perhaps the insect did not survive, has not been re-introduced, occurs in the South in very low numbers, or does not survive well on currently grown rice varieties. Third is the host range of the introduced species. Some invertebrates are monophagous and others are polyphagous. Those species that are polyphagous have a better chance of survival in a new environment. An example of a monophagous species is the boll weevil, *Anthonomus grandis*. A major reason why the boll weevil eradication program has been successful is that this species has only one host; eradication efforts can be focused on a single commodity, cotton. The Mexican rice borer (MRB), *Eoreuma loftini*, was introduced from Mexico into the Lower Rio Grande Valley of Texas in 1980. This stalk borer now occupies all Texas rice-producing counties except those east of Harris where Houston is located. Unlike the boll weevil, this insect has an extensive host range and attacks many Poaceae species, such as rice, sugarcane, sorghum, and corn. Clearly, this wide host range has enabled the MRB to spread in Texas and threaten the Louisiana sugarcane and rice industries. Fourth is the mobility of the pest. The RWW is a highly mobile insect that spreads by flight, as well as by human assistance. This insect was introduced into California in the 1950s from the southeastern United States via interstate commerce. Next, the RWW was detected in Japan in 1976; introduction was probably from a hay shipment from California. From Japan, it spread to the Korean peninsula and northern China where it was first reported in 1988. Introduction was probably by flight with assistance from wind currents. In 1990, the insect was detected close to an airport in Taiwan. It probably entered Taiwan in a turfgrass shipment by air from Japan. In 1993, the RWW was detected in southeastern China. Then, in 2002, it spread to Anhui and Hunan provinces, also in southeastern China. Again, flight and wind currents probably brought the RWW to China. An example of an introduced species with limited natural mobility is the channeled apple snail, *Pomacea canaliculata*. This mollusk is native to South America and was introduced into Asia as food for humans. This snail has become a serious pest of rice in Asia. Now, it is found in the Texas Rice Belt near Houston and Florida where introduction occurred via the pet trade.

The introduction of exotic rice pests has and will continue to be a problem. An early warning system is essential to alert the rice industry of potential problems and to develop pro-active IPM programs to deal with these pests. USDA, state extension services and experiment stations, consultants, and farmers currently serve this role. Interstate and intercontinental cooperation among regulatory and educational agencies must be encouraged. The advent of rapid, global electronic communication has been instrumental in fostering cooperation and sharing information among these agencies. Resources targeted to solving introduced pest problems are essential. Commodity groups, private industry, and governmental agencies can provide financial support. For instance, the rice and sugarcane commodity groups in Texas and Louisiana, respectively; selected agrichemical companies; and the USDA CSREES (Crops at Risk and Critical Issues grants) have provided financial aid in support of research and extension activities to manage the MRB. In other words, cooperation — sharing of information, research, and resources — is the keystone to managing introduced pests.

Risk of Introduced Rice Pathogens

Cartwright, R.D.

Rice pathogens include fungi, viruses, bacteria, and nematodes. Worldwide, there at least 20 virus diseases of rice, 35 or more fungal diseases, 10 bacterial diseases, and 6 nematodes routinely reported. In the United States, there are no virus diseases, 20 or more fungal diseases, 3 bacterial diseases, and 2 nematodes. Several pathogens reported to be in the United States are probably errors. Costs associated with the introduction of a new pathogen include potential loss of currently useful rice germplasm, direct yield and quality losses, increased control costs, increased research and education costs, increased regulation costs, and loss of trade.

With the exception of viruses, many rice pathogens can be easily moved on planting seed, and this is believed to have been the biggest source of rice pathogen introductions historically. Seed can be introduced legally but is subject to strict quarantine procedures that usually include a greenhouse "grow-out" for highest security. Seed has also been introduced illegally, and this is a difficult process to detect and regulate. Other routes of introduction may include rough rice grain for milling and resulting hulls, rice plant parts and straw used in products, alternative host plant introduction through the horticultural trade, movement of soil, movement of people and machines, bioterrorism, and weather phenomena.

There are differing levels of concern within the rice industry of the United States. Some parties appear to have little concern due to overriding interest in free trade or lack of knowledge, others have some concern but believe that the benefit of rice movement is at least as important as its risk and these persons focus on the threat from only major pathogens, and finally, persons with the greatest concern. The latter usually follows the philosophy that if we don't have it, we don't want it. Generally, these persons believe that most pathogens can be of significant risk because we cannot predict their reaction to our environment and that quarantines are useful because U.S. rice production remains isolated and small in size. Examples of minor diseases that have recently become important problems in the United States include *Burkholderia glumae* in southern states, *Ustilaginoidea virens* in Arkansas, and *Gibberella fujikuroi* in California. Because the southern United States relies on major resistant genes to the blast pathogen, the introduction of exotic strains of this well-established major pathogen would be of concern as well.

The disruption of trade can be a major problem related to rice pathogens. Importing countries often have concerns about pathogens in rough rice shipments. Sometimes, these are legitimate concerns and sometimes they are emphasized for political or economic reasons. In Arkansas, *Neovossia horrida* and *Aphelenchoides besseyi* have been consistent problems for rough rice exports. In recent years, *Ustilaginoidea virens* has disrupted a number of exports.

Rice pathogens that are currently of concern among experts include exotic strains of *Magnaporthe grisea*, *Xanthomonas oryzae* pv *oryzae* (true bacterial leaf blight), *Xanthomonas oryzae* pv *oryzicola*, any virus, *Balansia oryzae-sativae*, *Ditylenchus angustus,* and *Gibberella fujikuroi* (into southern United States).

As a result of various factors, a regional rice pathogen survey will be conducted by APHIS and state regulatory agencies in cooperation with University personnel in parts of the southern U.S. rice production area beginning in 2004. The objectives are to identify pathogens present in commercial rice production and update current endemic lists. A supplemental objective is to produce a modern field guide for the identification of rice problems in the field.

In conclusion, the most concern about the introduction of rice pathogens revolves about the importation of planting seed. Many experts believe that routine movement of seed leads to the inevitable introduction and establishment of pathogens. And, regulation efforts only slow this process, not stop it. However, seed imports in other crops have not led to their destruction, and many U.S. rice industry personnel believe that increased seed movement between countries is inevitable as well.

Current needs in this area of concern include improved domestic disease monitoring, improved pathogen detection methods, updated endemic pathogen lists, better educational materials, and modern, well conceived regulations.

Invasive Aquatic Plants: Current and Potential Threats

Sanders, D.E.

Invasive aquatic plants have plagued rice producers since rice was first grown in a flooded field. The movement and distribution of these plant pests were limited for millennia by inability of these organisms to traverse long distances in a viable condition. The advent of the sailing ship and later the airplane has rapidly hastened the ability of these pests to move large distances from months to hours. The underlying factors that cause one plant to be invasive and another not is that the invasive plant is 1) most often moved from its native origin where it developed over time in balance with its environment and 2) must be aggressive in establishment and reproduction. Naturally occurring checks and balances usually prevent any one species from becoming completely dominant. When removed from these checks and balances and freed of its predators and pests, the plant becomes invasive and threatens to dominate its new environment. While many plants may be translocated into a new environment, unless they can thrive they often simply die out. Those plants that are competitive and are moved to a new environment become invasive. Unfortunately, this is often a rice field or water source for the rice field.

Probably, the original invasive aquatic weed in U.S. rice was red rice, apparently brought into the new world along with some of the first domesticated rice seed. Its ability to produce seed that have a natural dormancy with the ability to produce large numbers of seed generation after generation gives it a natural advantage over domesticated rice. The classic example of an invasive aquatic plant and its effect on rice is the water hyacinth (*Eichhornia crassipes*). The water hyacinth was first introduced from its native Brazil during the World's Industrial and Cotton Centennial Exposition of 1884 in New Orleans, Louisiana. Individual plants were given away as gifts at the Exposition, and admirers of the plants' showy violet flowers soon spread the plant throughout the south. Currently, nearly 100,000 acres of water hyacinth are treated annually in Louisiana, including many miles of irrigation and drainage canals in the rice growing region. This adds countless dollars to the cost of moving water and, thus, the cost of growing rice.

The U.S. Geological Survey (USGS) has recorded 58 nonindigenous aquatic plants in the six U.S. rice producing states. Many of these plants have been in place for decades and are commonplace while others were first identified very recently. Of the species listed by the USGS, the following are invasive and present a current or potential threat to rice production: alligatorweed, Brazilian waterweed, duck-lettuce, Eurasian water-milfoil, giant salvinia, hydrilla, red rice, torpedograss, common salvinia, water hyacinth, water spinach, water sprite, false pickerelweed, purple loosestrife, ricefield naiad, Indian hygrophila, and perennial barnyardgrass. Obviously, these invaders are not all equal in their ability to become invasive and pose differing economic threats in the relationship to rice production. Alligatorweed and water hyacinth have been problematic for over a hundred years and control programs are meshed into standard rice weed control programs. Duck-lettuce (*Ottelia alismoides*) is considered by many to be very invasive and has been found in most of the rice growing states but has never caused a severe problem to date. Giant salvinia (*Salvinia molesta*) was first identified in Louisiana and Texas less than 5 years ago and has already become a significant problem in both states, blocking canals and threatening reservoirs. Giant salvinia poses a threat to all of the rice growing states, as well as other rice growing areas around the world. Under optimum growing conditions, this plant can double in volume every 4 to 5 days.

Herbicidal control of these invasive threats is available. Some, like alligatorweed, are successfully controlled for a few dollars per acre. However, in the case of some like hydrilla, the herbicide and application costs may approach $400 to $500/A. Biocontrol programs for many of the pests have been ongoing for decades. Some have been partially successful while others have produced little. Ultimately, the basis for any management program rests on three basic concepts: 1) Prevention of introduction, 2) intense chemical control upon introduction, and 3) development of biocontrol strategies for long-term control.

CPHST, PERAL, International Trade and Invasive Plant Pests

Cave, G.L.

The Center for Plant Health Science and Technology (CPHST) is a division within the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA, APHIS, PPQ). The primary mission of CPHST is to provide leadership in science-based issues relevant to phytosanitary decision-making and safeguarding of agriculture and natural ecosystems for USDA, APHIS, PPQ. This is accomplished by 270 scientists, analysts, and staff at 10 laboratories and eight units in the United States and Guatemala. Within CPHST, the Plant Epidemiology and Risk Analysis Laboratory (PERAL) has the mandate to assess risks posed by exotic pests to food, fiber, and the environment; identify pathways used by exotic plant pests and weeds; and to identify mitigation measures that reduce the impact of significant exotic pests. Currently, PERAL is addressing a number of regulatory issues relevant to the U.S. rice industry. These include: bakanae, *Gibberella fujikuroi*, a bioterrorism select agent, *Xanthomonas oryzae* pv. o*ryzicola*, the channeled apple snail, *Pomacea canaliculata*, and import risk analyses for propagative rice seed.

Abstracts of Papers on Breeding and Genetics
Panel Chair: Q.R. Chu

Development of Early Maturing, Intermediate Amylose, Indica Germplasm

Rutger, J.N. and Bryant, R.J.

Indica/indica crossing was initiated as a means of base broadening in U.S. rice, where very narrow genetic bases, essentially all in japonicas, have evolved because of need for adaptation to temperate climates and to specific grain quality requirements. The indica cultivar Zhe 733 from China, which has higher amylose than desired for US markets, was used as a donor of very early maturity. It was crossed as a female with the indica cultivar IR64 and six indica experimental lines graciously provided by G.S. Khush of IRRI. The IRRI materials have intermediate amylose contents similar to US long grain cultivars but generally are later maturing than desired in the United States. Grain dimensions of the IRRI materials are similar to U.S. long-grain cultivars, while Zhe 733 has shorter and heavier grains.

Crosses were made in the greenhouse during the winter of 1997/98, then materials were expeditiously advanced in the field in Stuttgart, Arkansas, and the winter nursery in Lajas, Puerto Rico. Selection for early maturity was conducted in the 1999 F_2 and 2000 F_5 generations in Stuttgart. Selection for intermediate amylose content was conducted in the 2000 F_5 and 2001 F_7 generations grown in Stuttgart.

Yield tests were conducted in 2001 and 2002 on 59 recombinants with nitrogen fertilizer applied preflood at the rate of 112 kg/ha. In 2002, the weak straw of the indicas became apparent, when severe lodging following 10 cm of rainfall in 1 week shortly after heading resulted in inconclusive yield data. For 2003, the number of lines was reduced to nine that had performed well in 2001, and the nitrogen rate reduced to 55 kg/ha. The male parent of one line was IR64, the male parent of five lines came from selections from the IRRI cross IR65629, and one line each came from male parents IR65450, IR53936, and IR60864.

These nine indica germplasms are similar to or earlier than the Arkansas tropical japonica check cultivar Francis and have similar intermediate amylose contents. Weak straw is a problem at higher nitrogen levels. These lines are being considered for release as improved indica germplasms.

Susceptibility of Nine Indica Germplasm Lines to Three Rice Insect Pests

Bernhardt, J. and Rutger, J.N.

The nine indica germplasm lines evaluated for insect susceptibility were selections from crosses between ‘Zhe 733’ from China and the indica cultivar ‘IR64’ and six indica experimental lines from IRRI (G.S. Khush). The crosses were made in 1998 and followed by four years of field selections for early maturity and laboratory tests for intermediate amylose content of selections. Soil core samples from the 2001 field tests were evaluated for rice water weevil larvae, *Lissorhoptrus oryzophilus* Kuschel, in some of the 68 F_7 selections, the tropical japonica checks (‘Drew’ and ‘LaGrue’), and two of the indica parents (Zhe 733 and IR64). Drew and LaGrue had 65 and 27 larvae per core sample, respectively, and yielded 5804 and 5020 kg/ha, respectively. The indica lines had infestations ranging from 62 to 98 larvae per core sample and had yields ranging from 6546 to 9477 kg/ha. The apparent tolerance of some of the indica lines to rice water weevil injury was interesting and further tests were planned in 2003.

A split-plot design with four replications was chosen with and without insecticide as main plots and with indica lines and japonica checks as subplots. A surface application of Icon 6.2FS at 0.056 kg ai/ha was incorporated within 15 min. after application with a tractor-mounted rotary tiller. Icon was used to control rice water weevil larvae and suppress damage by rice stalk borer, *Chilo plejadellus* Zincken. Rice was drill-seeded at 100 kg/ha on 9 June and emerged to a stand on 14 June. Plots were nine rows with 17.8-cm (7-inch) spacing by 2.4 m (8 ft.). Indica lines received 56 kg/ha (50 lb/A) of urea preflood and a similar amount at midseason. The checks were 'LaGrue,' 'Cocodrie,' and 'Wells' and were fertilized at 118 kg/ha of urea preflood and 50.4 kg/ha at midseason. The plots were flooded on 9 July to take advantage of high population densities of rice water weevil, rice stalk borer, and rice stink bug, *Oebalus pugnax* (F.). Two standard core samples/plot were taken on 31 July and 7 August and evaluated for rice water weevil immatures. The density of whiteheads/plot was taken on 10 September as an indicator of susceptibility to rice stalk borer. Plots were binder-cut and hand-threshed on 13 October. Two rough rice subsamples of 200 g each were taken from each plot and evaluated for discolored kernels as an indicator for susceptibility to rice stink bug and pathogens.

Six of the indica lines and Cocodrie averaged more than 30 rice water weevil larvae per core and three of the indica lines plus Wells and LaGrue averaged between 22 and 27 larvae per core. Comparisons of rough rice yields between the treated and untreated plots indicated that only two indica lines, designated as 8008-3 and Zhe733/IR64, positively benefited from the insecticide protection with 316.7 and 87.8 kg/ha increases, respectively. Insecticide-treated Cocodrie, LaGrue, and Wells had increases over the untreated plots that averaged 870.3, 488.3, and 190 kg/ha, respectively.

Only three indica lines, Zhe733/IR64, 8008-3, and 8008-5, were found to be slightly susceptible to rice stalk borer with average of 10.3, 9.0, and 8.5 whiteheads/plot, respectively. The other indica lines ranged from a high of 2.3 to lows of 0.5 and 0.3 whiteheads/plot in lines 8008-4 and 8017, respectively. Cocodrie, LaGrue, and Wells averaged 65.0, 11.8, and 2.3 whiteheads/plot, respectively. Icon reduced whiteheads by 74% in the indica lines and 71% in the japonica cultivars.

Evaluation of brown rice samples for discolored kernels indicated that none of the indica lines were as susceptible to kernel smut as Cocodrie and LaGrue. All indica lines and check cultivars had small amounts of false smut. Four indica lines had rice stink bug damage that exceeded 2% by weight (very susceptible) and five had amounts that ranged from 1.2 in 8008-4 to 1.9% in 8008-5 (susceptible to moderately susceptible). The japonica checks had damage of 1.1% in Cocodrie and 0.6% in Wells and LaGrue. Lodging of the indica lines and the long-season maturity of the japonica checks may have influenced evaluation for rice stink bug susceptibility.

Individual Grain Moisture of California Rice Cultivars-2003

McKenzie, K.S., Jodari, F., Johnson, C.W., Campbell. B.T., and Noble, A.E.

Grain moisture at harvest is a major factor affecting whole kernel and total milling yield of rice. Moisture determinations are generally made on bulk samples of grain and an average value is generated for each sample. Researchers have long recognized and demonstrated that the moisture content of individual rice grains in a harvested sample of rice show a wide range of moisture contents. This variability in individual grain moisture content is of interest because of the potential influence it may have on the milling quality, characterizing the effect of environment and varietal differences, and the possibility that this information may contribute to improvements in rice milling quality.

Individual kernel moistures were determined with a Shizuoka Seiki CTR-800E single kernel moisture tester at the Rice Experiment Station (RES) in 2003. Evaluations were done on hand harvested milling test samples collected over a range of harvest moistures from the RES breeding program nursery and foundation seed fields. The samples included long-, medium-, and short-grain cultivars and experimental lines. One hundred grains of paddy rice were analyzed per sample and output included a frequency distribution, mean, range, and standard deviation on sequential harvest samples during ripening. Moisture content on residual rice from the sample was also measured on a Dickey John GAC 2100. The rice sample was then air dried and laboratory whole kernel and total milled rice yield determined.

The 2003 season was the first opportunity to examine single grain moistures with the CTR-800E at the RES and results represent only a single year and location in a crop year that was atypical due to late planting and high average temperatures during the growing season. Individual grain moisture values on harvested samples revealed some very high variation. Grain moistures ranging from 15 to 40% were observed in many samples. Grain moisture distribution patterns and changes during ripening were apparent and results were examined in regard to sample milling performance.

Traitmill: A Functional Genomics Approach to Improving Yield and Yield Stability in Rice

Vrancken, E., Dillen, D., Lejeune, P., Leyns, F., De Wolf, J., Van Quickenborne, M.,
Frankard, V., Sanz, A., Reuzeau, C., Hatzfeld, Y., Van Caeneghem, W., Hervé, P., De Wilde, C.,
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Gene leads from genomics, even when supported by function prediction bioinformatics, do not necessarily result in a phenotypic difference when expressed in plants. With the aim of closing the application gap between classical genomics and the development of improved or novel crop traits, CropDesign has developed a functional genomics program, named the TraitMill. TraitMill employs rice as a model crop and comprises i) a high-throughput cloning system that allows modulation of expression levels of selected genes and gene combinations throughout the whole plant or in selected tissues; ii) an efficient transformation system generating thousands of transgenic plants per year; iii) automated evaluation procedures to assess vegetative plant growth and organ development as well as seed properties. TraitMill provides data on the effect of between 500 and 1000 gene constructs yearly.

In this presentation, the plant evaluation part will be discussed in more detail. Seeds harvested on primary transgenic plants are the subject of evaluation. In a highly controlled greenhouse with a capacity of approximately 100,000 rice plants per year, the growth and development of plants are assessed by means of digital imaging and image processing. Plants are imaged at regular intervals throughout the cycle and parameters that are relevant to yield are extracted from the images. Plants are individually labelled and tracked. All growth measurements are automatically linked to the plant identity and fed into a database system. Growth curves are constructed and the effect of gene manipulations is assessed with the aid of statistical tools. To avoid biases introduced by parental effects, the basis for comparing the effect of gene constructs is a comparison of the performance of positive versus negative segregants for the gene (within-line comparison). Seeds are harvested on individual plants. After processing, weighing, and imaging, seed yield in terms of weight and numbers, as well as seed dimensions, are established and, when combined with vegetative growth measurements, harvest indexes can be calculated. Selected cases demonstrating the potential of the approach will be presented.

Overview of American Wildrice Breeding and Genetics

Porter, R.A., Phillips, R.L., Kahler, A.L., Kennard, W.C., and Grombacher, A.W.

American wildrice (*Zizania palustris*) has been harvested in the wild by American Indians for centuries, but it was not cultivated in paddies until 1950. Breeding efforts began in Minnesota in the early 1970s. The cultivated crop is now grown primarily in Minnesota and California, in addition to a small amount of acreage in Oregon and Idaho. Natural stands of wildrice are still harvested today using the traditional method of canoe and flail. In Canada, stands of wildrice are established in lakes and harvested with airboats. Markets of wildrice are growing steadily, but increased productivity has kept prices steady or declining. Increased competition and several key factors causing yield losses require the continued development and release of improved varieties.

The University of Minnesota hosts the only public wildrice breeding project in the United States. The project objectives are to 1) develop wildrice cultivars, 2) enhance our understanding of wildrice genetics, and 3) evaluate and preserve wildrice genetic resources. Specific breeding objectives are: resistance to seed shattering, resistance to diseases and pests, reduced lodging, and increased harvestable yield. Seed shattering losses are still the primary factor limiting yield in Minnesota. Fungal brown spot disease (FBS) caused by *Bipolaris oryzae* and spot blotch caused by *B. sorokiniana* are the most important foliar diseases. Stem rots have been identified, including those caused by *B. oryzae* and *Nakataea sigmoidea*. Lodging can be so severe as to make combine harvest almost impossible. Phenotypic recurrent selection for these traits within heterogeneous populations has been effective. A recently released cultivar averages 50% higher yield than previous releases and is also resistant to shattering, lodging, and FBS. Early maturity has recently been identified as a need, both for processors and for growers trying to eliminate shattering volunteer plants. Decreased seed length in recent varieties has also been the subject of concern for some marketers.

A molecular genetic map has been developed with marker-assisted selection as the goal. Initial efforts yielded an RFLP map with 121 markers on 16 linkage groups. Most of these markers were previously mapped in *Oryza*. These markers fell into linkage groups that were colinear with 11 of the 12 *Oryza* linkage groups, three of which appear to be duplicated in *Zizania*. Eight traits have been mapped using these markers, including shattering. Three loci (and possibly a fourth) have been identified as having significant association with shattering. These three loci describe almost 50% of the additive genetic variation for shattering. In subsequent mapping, 120 *Oryza* SSR markers have been screened so far, yielding 75 polymorphic markers, 31 of which segregate in a 3:1 ratio. These markers are being integrated into the existing RFLP map, with the expectation of adding 95 SSR markers to the map. In addition, an EST is being developed from the marker most strongly associated with shattering, UMC305. RFLP markers for the other two shattering loci have been converted to PCR-based markers as well, in order to undertake marker-assisted selection for nonshattering at all three loci.

Since wildrice is still undergoing domestication, several unique difficulties hamper research. Preserving seed viability in storage has been uncertain, but protocols are being developed by NCGRP (Ft. Collins) for long-term storage. Seed dormancy is normally broken only after 3 to 5 months of storage in water at 2C, limiting breeding efforts to one generation per year. The fact that breeding populations are open-pollinated (and therefore difficult to isolate) also limits breeding progress. Production practices in Minnesota encourage "natural" reseeding from shattered seeds, which makes changing varieties difficult. Since Minnesota is part of the center of origin for wildrice, disease and insect pressure is high. Predation by blackbirds is common during harvest; waterfowl, muskrats, and deer can also damage research plots. Cultural objections to doing breeding and genetics research on wildrice have been raised by some native Americans.

Field Testing of Rice Cultivars for Early Planting in Arkansas

Gibbons, J.W., Anders, M., Lee, F., and Taylor, K.

Seeding date studies indicate that most rice cultivars produce their highest yields at early planting dates. Farmers tend to plant early for high yields and efficient use of their time for other crops in rotation. Also, water conservation may be improved by capturing early spring rains during rice establishment. Seed germination tests have shown variation in tolerance of rice to cold temperature. Early planting field tests of rice cultivars were performed for 3 years at Stuttgart, Arkansas. Ten cultivars chosen for a range of cold tolerance reaction were planted in 4.5 m^2 replicated plots. Three or four planting dates per year beginning as early as 27 February spaced approximately 10 to 15 days apart were sown. During germination and emergence of the first planting date, soil and air temperatures were about 11ºC. Plant stands, days to emergence and heading, yield, milling quality, and water usage were recorded. Plant stand and yield were reduced at the earliest planting date while days to emergence and heading were increased. Average milling quality was stable across planting dates. Compared with conventional cultivars, cold tolerant lines showed less stand reduction and higher yields at early planting dates. Other problems associated with early planting include avian predation of seeds and seedlings, soilborne disease, and cultural practices designed for warm season management.

Evaluation of the Core Subset of the USDA-ARS Rice Germplasm Collection

Yan, W.G., Rutger, J.N., Bockelman, H.E., and Tai, T.H.

The U.S. rice collection contains over 17,000 accessions from 110 countries and regions, representing nine *Oryza* species, with most accessions being *O. sativa*, the common cultivated rice. A core collection is a subset of a large germplasm collection that contains chosen accessions capturing most of the genetic variability of the whole gene bank. The core subset strategy should increase efficiency in germplasm evaluation and management. A rice core subset was established by the stratified random sampling method: 1) recording the number of accessions from each country of origin in the whole collection; 2) calculating the logarithm (log) index of the number of accessions from each country; 3) randomly choosing the accessions within each country based on the relative log index, with a minimum of one accession per country; and 4) removing duplications by plant introduction (PI) number and cultivar name. This core collection has 1,686 accessions coming from 106 countries and is about 10% of the whole U.S. rice collection of 17,359 accessions. Eight countries had more than 40 accessions, 22 countries had 21 to 40 accessions, 29 countries had 11 to 20 accessions, 32 countries had 2 to 10 accessions, and 15 countries had 1 accession in the core. Theoretically, the core subset should represent over 70% of genetic diversity in the whole collection by this sampling method. Seed stocks of the core are being prepared and stored in the USDA-ARS, Dale Bumpers National Rice Research Center for a comprehensive evaluation, including descriptors in agronomy: days to flowering, plant height, plant type, panicle type and lodging; morphology: awn type, bran color, grain type, hull color, hull cover, kernel length, kernel width, L/W ratio, rough 1000- kernel weight, and brown 1000-kernel weight; grain quality: alkali/spreading value, amylose, aromatic, endosperm type, gelatinization temperature, and protein; pest resistance: blast, sheath blight, and stink bugs; physiology, straighthead; and DNA analysis with as many as possible microsatellite markers for various phenotypic descriptors.

To be useful a core subset must contain most of the genetic diversity of the whole collection. Data on the core from 2002 field evaluations and the whole collection from the current GRIN (Germplasm Resources Information Network) were analyzed for similarity. Days from emergence to heading ranged from 38 to 182 and averaged 97 ± 19 days in the core, while the whole ranged from 37 to 183, with an average of 103 ± 20 days. Plant height ranged from 61 to 212 cm and averaged 126 ± 25 cm in the core, while the whole ranged from 41 to 208 cm, with an average of 118 ± 26 cm. The core was 81% awnless, 5% short and part awns, 5% long and part awns, and 9% long and full awns, while the whole was 62, 26, 5, and 7%, respectively. There were 41% erect plant type, 35% intermediate, 21% open and 3% spreading in the core, and 14, 32, 49, and 5%, respectively, in the whole collection. Panicle type of the core collection was 1% erect, 97% open, and 2% spreading, while in the whole collection, 3% were erect, 89% open and 8% spreading. It can be concluded that this core subset contained most of the genetic diversity in the whole collection in terms of agronomic traits. Evaluations of other descriptors are still ongoing.

Data from all the evaluations will be organized and entered into the GRIN. Scientists nationally and internationally can then extract the information in which they are interested from the GRIN. Germplasm curators can use the information to: 1) assess the genetic diversity of the existing collection and identify gaps for planning acquisition strategies. In particular, calculations of genetic distances can be used to identify special divergent subpopulations that might harbor valuable genetic variation that is under-represented in current holdings; 2) monitor changes in heterogeneity and heterozygosity (genetic drift) as accessions are regenerated and identify duplicate accessions in maintenance; and 3) establish passport data to characterize each accession based on gene, genotype, and genome along with the detailed phenotypic data, which provide accurate and detailed information in both molecular and phenotypic levels.

Rice breeders can quickly find the traits in which the rice industry and rice consumers are interested, i.e. high production-efficiency, premium quality, disease or insect resistance, and stress tolerance. Meanwhile, they will have information on the genetic backgrounds for those desirable traits and genetic distances for those accessions containing the desirable traits from commercial cultivars, so that they can determine strategies for transferring the desirable traits into commercial cultivars. Also, the breeders can choose crossing parents that are genetically distant enough to allow the widest possible crosses in an attempt to gain maximum 'hybrid vigor' or heterosis advantages while transferring the desirable traits, and make marker-assisted selection in breeding for the desirable traits.

Development of a Rice Variety Specifically for Use in Crawfish-Only Systems

McClain, W.R. and Linscombe, S.D.

Even though much of the crawfish production in Louisiana occurs in rotational cropping systems with rice, substantial (and increasing) acreage is devoted to monocropping systems whereby crawfish is the sole crop harvested and where crawfish yields are the greatest. Rice is the preferred forage crop in crawfish monocropping systems because of its desirable characteristics under extended flooded conditions, especially when grain formation does not occur. Although grain production may be unnecessary, or even undesirable, in rice crops planted solely for crawfish production, rice variety selections for these systems are limited to high grain-yielding varieties only, because seed growers are currently producing seed only for the high demand grain varieties. However, current domestic rice varieties are less desirable in crawfish ponds than some of the obsolete, lower yielding varieties. Plant breeders have developed rice varieties for grain production that have higher grain to forage ratios, are shorter in plant height, and are earlier maturing – all traits that render them less desirable as crawfish forage resources. Because of this trend to develop rice varieties for improved grain yield at the expense of forage traits, there is a growing need for development of "crawfish specific" rice varieties with better characteristics for use in high yielding crawfish monocropping systems.

Work was initiated at the LSU AgCenter's Rice Research Station in 1991 to evaluate rice genotypes for forage traits more desirable in crawfish ponds. Over 16,000 lines from the USDA Rice World Collection, as well as current and older domestic varieties, were screened. Desirable traits, such as high forage biomass production, cold tolerance, long maturity cycle, high resistance to lodging, slow senescence rates, disease resistance, and propensity for forage re-growth in early spring, were some of the criteria for selection. Large differences in forage attributes were observed, and three outstanding candidates (originating in Taiwan, Fiji, and China) were selected for further trials and underwent seed increases. The genotypes were simultaneously improved (purified) by mass selection, and lines were evaluated under simulated crawfish production trials in small ponds over four seasons, beginning in 1997. The improved genotypes were also evaluated concurrently for merit as seed producers, which is necessary for the viability of any new rice variety.

Each experimental genotype evaluated consistently exhibited greater forage biomass production, better persistence under crawfish pond environments, and produced more forage re-growth in the spring than the commonly used domestic varieties, 'Mars' and 'Cypress.' The improved lines, however, did not consistently result in greater total yields of crawfish, principally because the domestic varieties (controls) were managed well enough under the controlled conditions of the limited pond trials such that severe food limitations were not manifested as is often the case under commercial conditions. However, average production of the largest, high value crawfish was increased 17% with the experimental genotypes when compared with that from the domestic varieties during the 4-year study. The line originating from China resulted in a 21% increase in large crawfish compared with the domestic average. It is expected that any of the experimental lines would contribute to higher crawfish production and possibly even a greater production of large crawfish under more typical conditions of commercial production where food limitations frequently exist with current domestic varieties, often occurring prior to peak crawfish harvests.

Grain yield for the experimental genotypes under typical rice cultivation conditions proved to be comparable with domestic varieties, indicating each would be a favorable candidate for seed growers. Therefore, based on a combination of desirable traits, the most promising line (derived from the Chinese genotype) was selected for further seed increase and will be considered for varietal release in the spring of 2004 as the first line intended specifically for use in crawfish-only production systems.

Performance of Interspecific Rice Lines from the BG90-2 /*O. rufipogon* Cross in 11 Locations in Latin America

Martínez, C.P., Borrero, J., Almeida, A., Duque, M.C., Carabali, J.S.,
Delgado, D., Silva, J., Giraldo, O.X., and Tohme, J.

New alleles from wild species can provide genetic variability for crop enhancement. There is a wide genetic variability available in rice, but limited use of this variability has been made. Several studies indicated that *O. rufipogon* possesses new alleles on chromosomes 1 and 2 with positive effects on yield and yield components. While early segregating populations (BC_2F_2) and few sites (1-2) were used in these studies, no data are available confirming that yield advantages detected in the BC_2F_2 generation were passed on through generations of selection in pedigree nurseries, nor over a wide range of environments. This report focuses on the performance and stability of advanced breeding lines derived from the cross Bg90-2/*O. rufipogon* across locations in Latin American.

Twenty-five lines (BC_2F_8) derived from the BC_2F_2 generation following the pedigree method were planted in replicated yield trials in 11 locations under irrigated conditions (seven sites in Colombia and one each in Argentina, Surinam, Uruguay, and Venezuela). Transplanting was done in CIAT while direct seeding was done elsewhere. A complete randomized design with three replications was used, and crop management was based on recommended local agronomic practices. Varieties grown locally were used as checks. Data on the main agronomic traits, including grain yield, were taken. A two-way analysis of variance was used for the analysis of grain yield, while a GEBEI package that implements appropriate clustering and ordination procedures and an AMMI model were used in the analysis of the G x E data. DNA of young leaves from the parental genotypes and their progenies was extracted by the Dellaporta method modified for PCR assay by the CIAT Biotechnology Unit. Subsequent molecular assays were performed using 76 SSRs. Traits for yield and yield-related characters were associated with the 76 molecular markers using simple point analysis**.**

A combined analysis of variance across locations showed a highly significant G x E interaction (75%). Although none of the interspecific lines outyielded Bg90-2 in all locations, several lines performed better than Bg90-2 in each location. Analysis of G x E indicated that contrasting and distinct environments were included in these trials. This suggests that the performance of genotypes was dependent on the climatic/soil conditions in each location and that there was a good level of genetic variability present in this group of lines, which explains the better performance of some progenies under specific conditions. Analysis of molecular data from the bulked seed sample of the BC_2F_8 lines confirmed that all of them had introgressions derived from *O. rufipogon*. The number of introgressions ranged from 2 to 18, representing from 2.6 to 23% of the *O. rufipogon* genome. More introgressions were detected in chromosomes 2(14), 5(9) and 7, 12, 3(7); chromosomes 4 and 10 had two introgressions. There was no correlation between number of introgressions and grain yield. Markers RM5 and RM1, located on chromosome 1, were found in some of the highest yielding lines. *O. rufipogon* is known to have a high level of genetic variability and is adapted to diverse climatic/soil conditions. Breeding lines derived from the Bg90-2/*O.rufipogon* cross were subjected to diverse biotic and abiotic conditions, including high disease incidence, acid and infertile soils, cold stress, and good climatic conditions. These sites represent a diversity of excellent and poor environments for rice production. With one exception, all lines did better than Bg90-2, the improved/recurrent parent; and some of them yielded between 15 to 24% more than Bg90-2. A similar yield advantage was observed in the BC_2F_2 population. The stability analysis, based on the method described by Eberhart and Russell indicated that all lines were stable across environments. Data suggest that the superior performance of interspecific breeding lines is due to favorable allele introgressions derived from *O. rufipogon*. These findings suggest that predictions made based on yield data from BC_2F_2 families are valid. Furthermore, bases for further genetic improvement through allele mining from the wild species are in place.

Incorporation of Doubled Haploid Technology with Conventional Breeding in Louisiana

Chu, Q.R., Fontenot, T., Bearb, K., Theunissen, B., Bollich, P.A., Jin, X.,
Conner, C., Howard, A., and Linscombe, S.D.

Doubled haploid (DH) breeding efforts have merged into conventional breeding, focusing on developing new long-grain lines. In 2003, 194 new crosses were made by using bridging parents, which have high yield, resistance to blast and sheath blight, and high regeneration ability. About 12,474 DH plants (DH1) were regenerated. Field evaluation and selection of breeding materials increased to about 31,000 progeny rows compared with 14,000 rows in 2002. These rows consisted of 10,000 DH rows and 10,000 F_3 to F_5 rows and 11,000 F_3 rows from conventional crosses. Among 574 rows harvested, 140 rows showed the row weights surpass 300 grams while conventional check CCDR was 288 grams per row. The Preliminary Yield trial included 200 entries (100 PY and 100 SP). Ten experimental lines were tested in the Uniform Regional Rice Nursery (URRN) among five states and nine locations within Louisiana. An additional 10 lines were tested in the Advanced Yield trial at the Rice Research Station. Data summarized from the yield trial indicated that 57 entries had high yield potential, and 35 lines (>8,960 kg/ha) were better than checks Cocodrie, Cypress, and Cheniere.

Progress in Breeding Hybrid Rice for the Southern United States

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Hybrid rice cultivars have been developed and are grown commercially in China, India, and other Asian countries. In the United States and parts of South America, RiceTec, Inc. and others are developing rice hybrids, but currently, only RiceTec, Inc. markets hybrid rice for commercial production in the western hemisphere. RiceTec, Inc. has been developing hybrid rice since 1989, and marketing rice hybrids to farmers since 2000. The purpose of this report is to summarize heterosis of RiceTec, Inc. rice hybrids in the United States and to show the improvements that have been made in RiceTec, Inc. commercial and pre-commercial rice hybrids since 2000.

Heterosis for grain yield was calculated based on the yield of the male parent as follows: H= (hybrid yield – male parent yield)/male parent yield. Calculation of heterosis based on mid-parent yield is not practical in hybrid rice because the yield of the female parent, which is male sterile, is underestimated. Yield advantage of the best hybrid compared with the best commercial variety was calculated as follows: YB= (yield of best hybrid – yield of best variety)/yield of best variety. As defined here, H describes biological heterosis and YB describes the commercial yield potential of a single hybrid. Generally, the commercial varieties Bengal, Cocodrie, Cypress, Francis, CL161, and Wells were the best varieties in the tests, so depending on the test in question, the yield of these varieties was commonly used in calculating YB. Data used in the calculations described above came from RiceTec, Inc. replicated yield tests in Texas, Louisiana, Arkansas, Missouri, and Mississippi.

During the 5-year period from 1999 to 2003, H ranged from 23 to 49%. Yields of the male parent varied widely; but, in some cases, the yield of the male parent was equal to or greater than the yield of the best commercial variety. Yearly minimum values of H were 26, 37, 32, 23, and 24%, respectively, for 1999 to 2003. Yearly maximum values of H were 41, 38, 49, 42, and 31%, respectively, for 1999 to 2003. The yield advantage of the best hybrid over the best commercial variety (YB) ranged from 22 to 37%. The best commercial variety in the two tests in 2003 was Francis and the best hybrid in those tests had YB of 24 and 33%. In three tests in 2002, the best commercial varieties were Bengal, CL161, and Cocodrie and the best hybrid in the test had YB of 23, 29, and 29%, respectively. The YB of hybrids in the three tests in 2001 were 37, 23, and 23%, respectively, calculated using yields of best commercial varieties Cypress, Cocodrie, and Bengal. Values of YB from 1999 and 2000 are similar to those from 2001 to 2003 and show that the yield advantage of the best hybrids compared with the best commercial varieties ranges from 20 to 30%. In 2000, XL6 became the first hybrid rice to be sold to producers in the United States. The yield potential of XL6 was very good, but the hybrid was very susceptible to lodging and its whole milling yields were poor. In 2002, XL7 and XL8 were sold to producers in the United States and sales continue to date. Compared with XL6, both XL7 and XL8 have improved resistance to lodging and improved whole milling yields, but they do not have the yield potential of XL6. In 2003, RiceTec, Inc. began public testing of XP710, an experimental long-grain hybrid that combines the yield potential of XL6 with the lodging resistance of XL8. The whole milling of XP710 is generally acceptable, falling roughly between the whole milling of XL6 and

XL8. In 2004, RiceTec, Inc. expects to begin public testing of one or two experimental long-grain hybrids. Two years of testing show that the candidates have very good lodging resistance, grain yield equal to or better than XP710 and whole milling yields that are 2 to 3 points better than XL8. As evidenced by the performance of XP710, and new experimental hybrids, RiceTec, Inc. has made substantial progress in developing improved rice hybrids for the United States. Although significant improvements have been made in the performance of rice varieties over the past 5 years, hybrid yield advantage compared with new varieties has remained about 20 to 30%.

Selection of Rice Genotypes for Aroma and Grain Appearance in Early and Mid Generations

Sha, X. and Linscombe, S.D.

The demand for special purpose aromatic rice has increased dramatically over the past two decades. Most aromatic Jasmine and elongating Basmati rice in the U.S. market is imported, and the volume of such imports is increasing every year. Due to limited resources, only a fraction of our overall breeding efforts can be devoted to breeding for aromatic special purpose rices. In order to maintain such a small but productive program, intensive or rigorous selection for specialty traits, such as aroma and grain appearance, in the early and mid generations of well planned recombinant populations is critical. To facilitate such selection, studies were conducted at the LSU AgCenter's Rice Research Station to develop simple, economic, and reliable testing methods for aroma that can handle a great number of small samples in a timely manner and to evaluate different selection schemes for specialty traits.

Two hundred ninety-six specialty progeny rows harvested in 2000 were tested for aroma by chewing dehulled kernels and test tube cooking methods. Out of these samples, 41 randomly selected samples, including the non-aromatic check Cypress and aromatic check Dellmati, were tested for 2-acetyl-1-pyrroline (2-AP) concentration – the determining factor for the "popcorn"-like scent at the USDA-ARS Rice Quality Laboratory at Beaumont, TX. By directly chewing three dried and dehulled kernels, each sample was rated either strongly aromatic, aromatic, weak aromatic, trace or not decisive, or non aromatic. For the test tube method, 1 g of milled rice was put into a 16 x 150 mm test tube containing 10 ml deionized H_2O, covered with a cap, and cooked in a boiling water bath for 10 minutes. After the sample cooled, it was rated as either aromatic, weak aromatic, or no aroma. This method was modified from the method reported by IRRI.

Grain quality that consists of grain dimension, appearance, and uniformity is also important for special purpose rices. It has been reported that grain dimension is highly heritable and selection for it in the early generation is effective. However, the effectiveness of early selection on grain appearance and uniformity remains unknown. A total of 1024 progeny rows of 2003 field selections were analyzed to estimate the heritability of both grain appearance and uniformity and to compare the effectiveness of different parental combinations and different selection schemes.

Ratings from the chewing method had an 88% overall match with corresponding 2-AP contents. However, samples rated strongly aromatic or aromatic and non aromatic by the chewing method had 100% matches with those by 2-AP tests. Ratings from test tube cooking of 1 gram of milled rice had a perfect match with 2-AP contents. By comparing ratings from all 296 samples tested with both chewing and test tube cooking methods, it was found that both methods had an 81% overall match, with the highest matches occurring on samples with strongly aromatic or aromatic ratings by the chewing method (98%). Results from this test suggest that the chewing method is effective in detecting strong aromatic progenies suitable for field selection, while the test tube method is more sensitive, accurate, and works well in laboratory tests. Both methods can work with a large number of small samples.

By parent-offspring regression analysis of visual subjective ratings of both grain appearance and uniformity in four populations, narrow sense heritability of grain appearance was estimated, ranging from 0.10 to 0.53, while that of grain uniformity ranged from 0.02 to 0.27. Early generation selection for grain appearance may be effective for some populations. Our results also showed that early generation selection for aroma may slightly reduce the chance of recovering aromatic genotypes; however, it is well compensated for by eliminating a majority of non-aromatic ones in the early or mid generations.

Achieving Global Registration: Status for Glufosinate-Tolerant Rice

Mitten, D.H.

The *bar* gene is the genetic basis for glufosinate tolerance. It codes for the enzyme, Phosphinothricin-Acetyl-Transferase (PAT). The only target of the PAT enzyme is the active form of the herbicide, L-glufosinate. The sole action of the PAT enzyme is to acetylate L-glufosinate, thereby destroying its herbicidal activity and conveying the phenotype, herbicide tolerance.

Using recombinant DNA technologies, the genetic code of the *bar* gene was cloned from a common soil microorganism. The *bar* gene copy was fused with the 35S plant promoter element and transferred to rice. One transfer event was selected for its solid field performance and stable genetic integration. Known as LLRICE62, this genetic locus has been crossed into many rice varieties by the breeding teams at Bayer CropScience and LSU AgCenter.

An extensive safety data package has been developed for glufosinate-tolerant rice varieties based upon the genetic locus, LLRICE62. To support the commercial sale of these varieties, a review of the safety data package is mandated by regulatory agencies in the countries in which the rice will be grown and in some regions where rice grain derived from glufosinate-tolerant varieties may be imported.

Elements of the safety data package include an evaluation of the grain for use in human food and detailed characterization of the LLRICE62 genetic locus. Food safety evaluations were conducted by comparison of the LLRICE62 grain and rice common in commerce. Side-by-side comparisons were made by analysis of the grain for the key nutrients of rice and measurement of weight gain and health parameters when rice grain is incorporated into the diets of poultry and swine. Rice grain of LLRICE62 was found to be nutritionally equivalent to other rice.

The inserted genetic locus and the DNA of flanking rice chromosome have been sequenced and homology searches demonstrate no potential for unintended effects of the insertion. The integrity of the inserted DNA has been demonstrated in succeeding generations and in crosses with diverse rice germplasm using Southern blot technique. The exact sequence of the inserted DNA is known and in agreement with the intended genetic change. No allergenic or toxic potential has been demonstrated by DNA sequence homology evaluations with known allergens and toxins. In addition, studies with the PAT protein further demonstrate the safety.

The United States Department of Agriculture (USDA) granted non-regulated status for the unrestricted growing of LLRICE62 in the USA in April 1999. The Food and Drug Administration (FDA) completed its review of the safety assessment in August 2000 and confirmed they have no further questions. The Environmental Protection Agency (EPA) is currently reviewing the herbicide registration data package and is expected to grant approval in 2003. The food safety package is proceeding through the review processes in Canada, Mexico, Brazil, and the European Union. Additional submissions are planned for other important trade destinations for U.S. rice.

Recently, the European Union strengthened its rules for consumer-based labelling of foods derived from crops that have been genetically modified (GM) using recombinant DNA technologies. Whole foods, food ingredients, and animal feeds derived from GM must be labeled to allow consumer choice. Exemptions from the labelling requirement include products with less than 0.9% adventitious presence and products from animals that were fed GM feed.

Bayer CropScience has commercialized glufosinate-tolerant corn and canola, which have both been grown widely in Canada and the USA for 6 to 8 years. The PAT protein produced in glufosinate-tolerant crops has been reviewed and cleared for human and animal consumption by numerous regulatory agencies in some countries, including Australia, Argentina, Canada, European Union, Japan, South Africa, and the USA. In the United States, glufosinate-tolerant cotton and rice are the most recent Liberty Link products to complete review by the federal government.

Using Side-by-Side Data to Illustrate Yield Risk Reduction from Planting Rice Hybrids Instead of Varieties

Cuevas, F. and McNeely, V.

Growers consider the relative mean yield and milling performance from replicated multi-location yield trials when selecting which variety to plant. As variety seed costs are similar, this information has sufficed for decision making. However, with the introduction of higher seed-priced hybrids and Clearfield varieties, information on probability of return on investment has become an issue in cultivar selection. This presentation describes an analytical approach using side-to-side yield data from replicated trials to calculate risks associated with planting rice hybrids vs. varieties. A total of 127 replicated trials comparing hybrid XL8 with variety 'Cocodrie' conducted directly by RiceTec or contracted with universities throughout the southern rice belt during 2001-2003 were used. Calculated normal distribution frequencies were used to estimate the probability of occurrence of yield levels and hybrid yield advantages within the observed yield range. Chances of harvesting yields above 7500 kg/ha were four times higher with XL8 than with Cocodrie, whereas those for yields below 6000 kg/ha were six times lower. XL8 outyielded Cocodrie 95% of the time, with a mean of advantage 1000 kg/ha. Under current market conditions, it would take an additional yield of 360 kg/ha to pay for the extra hybrid seed cost. Probability of a grower having 20% returns to investment was estimated at 80%. A regression equation using historical yields of Cocodrie to forecast the expected yield of XL8 was developed with a R2 of 0.57. RiceTec uses this method to set hybrid value proposition and to sharpen grower expectations on hybrid performance.

Current Progress and Status of Doubled Haploid Rice Breeding Research at U of A RREC

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Bulloch, J.M., Blocker, M.M., and Tolbert, A.C.

Doubled haploid (DH) technology is being efficiently used to accelerate rice variety improvement for Arkansas growers. In less than 2 years (June 2001-Dec. 2002), over 5,900 DH lines were produced from anther culture of 46 F_2 populations (2001), 94 F_1s of single crosses, and 36 F_1s of six triple crosses (2002). These crosses were bred for high yields, improved grain quality, blast resistance, cold-tolerance, and straighthead-tolerance. In 2002, field evaluation of 1,206 DH_2 lines produced in 2001 resulted in the selection and advancement of 89 elite lines to a preliminary yield test and 12 elite lines to a straighthead trial in 2003. Seventeen lines showed the potential to become varieties or valuable germplasm (as bridging parents) for further cross breeding. In the 2003 field evaluation of 4,706 DH_2 lines produced in 2002, over 400 superior DH_2 lines were selected for further yield, quality, disease, and straighthead-tolerant tests.

To further improve anther culture breeding efficiency, 88 influential U.S. and exotic rice cultivars and experimental lines were screened for their anther culturability on different culture media in 2001-2002, regenerating 1,705 DH clones. Recovery of DH lines with acceptable phenotype from recalcitrant parents, such as Calhikari-201, Francis, INIAP-12, Maybelle, L-205, Priscilla, RU0101093, RU0002048 (LMT-1), Saber, Teqing, and Zhe733, has been accomplished. These DH-derived parents are being used to increase the anther culturability of crosses derived from these lines.

In 2003, we focused on anther culture of 200 F_1s of 20 triple crosses confirmed with a greenhouse pathogenicity assay and DNA marker-aided selection (MAS) for desired grain quality and blast resistance. Over 100 F_2 plants of 14 single crosses were also sampled for anther culture. Approximately 672,360 anthers were plated for these crosses and over 12,000 green plants have been regenerated by the end of November. For anther culture of triple crosses, MAS greatly facilitated precise selection of F_1 donor plants for cooking quality and the blast resistant *Pi-ta* gene. Using MAS, selection of DH lines for cooking quality was also made easy for triple crosses derived from indica germplasm, such as Cross 020211 (INIAP-12/CCDR//ZHE733). However, the feasibility of combining MAS and DH technology to enhance rice breeding efficiency remains questionable, as selection of donor plants depending on one or a few available DNA markers could exclude genotypes with marker-free but other value-added recombinants.

Are Agronomic Traits Impacted by the Presence of *Pi-* Genes When Blast Disease is Absent?

McClung, A.M., Shank, A.R., Bormans, C., Park, W.D., and Fjellstrom, R.G.

Developing improved cultivars that possess disease resistance genes is an effective way of enhancing and stabilizing yield potential while decreasing producer input costs through decreased use of pesticides. However, some researchers are concerned that the presence of disease resistance genes may actually reduce yield when disease is not present as a result of a metabolic "cost" to the plant for maintenance of resistance. The objective of this study was to determine the affect of *Pi-* blast resistance genes on yield and agronomic traits when development of disease from *Pyricularia grisea* was prevented by the use of fungicides.

Ten genetic populations were developed that were segregating for the major blast resistance genes *Pi-ta*^{2}*, Pi-b, Pi-z,* or *Pi-k*^{s}/*k*^{h}. The populations were advanced for several generations without selection and then were screened for the presence of blast resistance genes using DNA markers closely linked to each of the *Pi-* genes. Standard replicated yield trials were conducted at Beaumont, TX, during 2002 and 2003 using progeny that had been selected only on the basis of possessing resistant or susceptible homozygous alleles of the *Pi-* locus present in each population. The populations ranged from the F_4 to F_7 level of inbreeding, although two populations consisted of near-isogenic lines identified from F_{12} and F_{17} headrow populations. Thirty-eight to 48 lines were evaluated in each population except for one near-isogenic population where only five resistant and five susceptible lines were compared. The trials were sprayed with Quadris and Tilt fungicides according to recommendations to prevent development of diseases. Stand ratings, days to heading, plant height, grain moisture at harvest, test weight, and yield were measured in the trials.

In two of the four trials where *Pi-ta*^{2} was segregating, there was no difference in agronomic traits among progeny possessing susceptible or resistant alleles. For the other two trials, the presence of susceptible *Pi-ta*^{2} alleles, resulted in a small but significant increase in yield of 664 kg/ha (p> 0.086) in one population and 498 kg/ha (p>0.014) in the other. In one population where progeny possessed either the *Pi-k*^{s} or *Pi-k*^{h} allele, there was no significant impact on agronomic traits. However, in the study that evaluated 38 near-isogenic lines from a Madison headrow population, the presence of the *Pi-k*^{h} allele resulted in a small but significant increase in stand establishment and yield (278 kg/ha, p> 0.106) but a slight decrease in days to heading (0.56 days, p>0.037) as compared with the presence of the *Pi-k*^{s} allele. Of the two populations that were segregating for the presence of *Pi-b* alleles, only one demonstrated an impact on agronomic traits. The presence of the *Pi-b* resistant allele resulted in an increase in days to heading (1.47 days p>0.09) and an increase in plant height (6.1 cm, p>0.0001). In another population where both *Pi-ta*^{2} and *Pi-b* were segregating, no combination of resistant or susceptible alleles resulted in a significant impact on agronomic traits. Using a population of 10 near-isogenic lines derived from the cultivar Cala, it was determined that there was no impact on agronomic traits due to the presence of resistant or susceptible *Pi-z* alleles. Thus, in only four of the 10 populations, the presence of *Pi-ta*^{2}*, Pi-b, Pi-z,* and *Pi-k*^{s}/*k*^{h} blast resistance alleles had a statistically significant impact on agronomic traits when disease was not present; however, the magnitude of this effect does not appear to have significance for cultivar improvement programs.

The Application of New Markers for Predicting Blast Resistance and Cooking Quality in Rice

McClung, A.M., Shank, A.R., Kanter, D., Jodari, F., Beighley, D., Chen, M., and Fjellstrom, R.G.

We have been developing DNA markers that are closely linked to traits important to the rice industry and can be used in the relatively narrow germplasm base commonly used by U.S. breeders. Marker-assisted selection will facilitate breeding efforts to develop improved cultivars more efficiently and effectively. Our initial focus has been on simply inherited trait aspects of disease resistance and cooking quality. For any given trait, segregating mapping populations have been generated, chromosomal locations of candidate markers have been identified using public databases, polymorphic PCR-based markers have been developed, hundreds of progenies have been evaluated for phenotype and genotype, and associations between the marker alleles and trait variation have been determined. These markers have then been tested across diverse sets of germplasm (Uniform Rice Regional Nursery entries, historical U.S. rice cultivars, accessions from GRIN, etc.). As a result, we have developed DNA markers that are associated with all of the known major genes commonly found in U.S. germplasm that confer resistance to *Pyricularia grisea* which causes blast disease. The only exception is the *pi-d* gene that confers resistance only to race IB-1 and is associated with the *Pi-k* locus on chromosome 11. Marker RM 224 has been found to be closely linked to the *Pi-k* locus and can discern the presence of the *Pi-k*^{h} (RM 224 = 140nt) and *Pi-k*^{s} (RM 224 = 120nt) alleles. *Pi-k*^{s} confers resistance only to the IB-54 race and is commonly found in southern U.S. medium- grain cultivars but is also in a few long grain cultivars, e.g. Cheniere, Drew, and Ahrent. In contrast, *Pi-k*^{h} confers resistance to IB-54 and three other races of blast and is found in many southern U.S. long grains, including Cypress, Wells, Kaybonnet, Saber, Lemont, and Cocodrie. Markers in this same region can discern the presence of another blast resistance gene, *Pi-Leah,* that conveys resistance to all of the same races as *Pi-k*^{h} except for IB-54. The *Pi-b* gene is located on chromosome 2 and confers resistance to races IB-1, IB-45, IG-1, IC-17, IE-1, and IE-1k. *Pi-b* can be identified by the presence of the 177nt allele using marker RM 208 in cultivars Saber and Bolivar. We have used marker RM 7102 that is tightly linked to the *Pi-ta*^{2} gene located on chromosome 12, which conveys resistance to all predominant races of blast occurring in the United States except IE-1k. We are also using an unpublished marker from Dr. Yulin Jia (USDA-ARS) located within the *Pita* gene which confirms the presence of *Pi-ta*^{2} in cultivars like Kaybonnet, Drew, Madison, and Ahrent that had been previously identified by RM 7102. Developing markers associated with the *Pi-z* gene that are useful across a broad array of U.S. germplasm has been more difficult because this gene is located in an area of chromosome 6 that displays little polymorphism. The *Pi-z* gene is found in several medium-grain cultivars like Bengal, Lafitte, Mars, and Orion and a few long- grain cultivars like Jefferson and Cadet. We have identified markers AP 3540 and RM 527, which closely flank the *Pi-z* gene, but other markers are available in this region if these are not polymorphic in the breeder's cross of interest. AP 3540 is also closely linked to the *Hd-1* gene that is associated with photoperiodism sensitivity in exotic germplasm. Flanking markers for the *Pi-i* gene on chromosome 9 conveying resistance to IH-1 were identified in a cross using L205 as the blast resistance donor. The 188nt allele of the RM 3855 marker and the 196nt allele of the AP 5128 marker identify the *Pi-i* resistance gene, which is found in Dixiebelle, Cocodrie, and Francis, among others.

We have previously reported the identification of DNA markers associated with grain quality traits like amylose content (using marker RM 190 located on chromosome 6) as well as aroma (RG28, RM 223) and elongation (RM44) having markers on chromosome 8. We have recently identified additional markers within the *Waxy* gene that can differentiate between RVA pasting curves of L202 types (weak RVA) and Lemont types (strong RVA). We have developed markers associated with the *Alk* gene on chromosome 6 that can predict alkali spreading value (ASV) scores used to categorize rice cultivars for starch gelatinization temperature. It appears that cultivars categorized as intermediate ASV (values of 4-5) have the 90nt allele for the marker developed at this locus while cultivars with high ASV scores (values of 6-7) have the 92nt allele. ASV scores of 2 to 3 (high gelatinization temperature types) have the 90nt allele and an amylose content of less than 19%.

Developments of DNA markers for these simply inherited traits are now being used on a routine basis in our rice breeding program and are available to the public. These markers can be analyzed using leaf tissue, brown rice, or milled rice. Multiple traits can be determined following one DNA extraction of a sample and marker genotypes can be determined within a few days. All of the markers are co-dominant and, thus, can discern homozygotes from heterozygotes. Once the line is fixed for the desired allele it may no longer require further evaluation of the trait. Markers can also identify genes that are masked by dominance (eg. aroma and semidwarfism) or the presence of other genes (eg. *Pt-ta2* masks the presence of *Pi- k*^{h} in Kaybonnet and *Pi- k*^{s} in Drew). These examples demonstrate the tremendous savings in time, labor, equipment, and trained staff that marker technology can offer.

Virulence Changes in the Rice Blast Pathogen and Implications in Breeding for Durable Resistance

Correa-Victoria, F.J., Martinez, C., Prado, G., Escobar, F., and Aricapa, G.

Rice blast disease caused by *Pyricularia grisea,* the anamorph of *Magnaporthe grisea*, is the main rice production constraint in Latin America. Development of resistant cultivars has been the preferred means of controlling this disease; however, blast resistance is defeated by the pathogen shortly after cultivar release with the exception of the Colombian commercial cultivars Oryzica Llanos 5 released in 1989 and Fedearroz 50 released in 1998. For developing cultivars with durable resistance, we analyzed the genetic structure of blast pathogen populations using MGR-DNA and rep-PCR fingerprinting and studied the diversity, frequency, and changes over time of avirulence/virulence genes in the fungus using a set of rice differentials with known blast resistance genes. These studies are allowing us to identify suitable resistance gene combinations and molecular markers associated with those resistance genes and develop breeding strategies for a durable blast resistance.

The high pathogen variation represented by more than 100 races in Colombia is reported as the main cause of resistance breakdown. This population has been found to be mainly clonal exhibiting few genetic lineages. At present, there are four lineages predominating in the pathogen population (SRL-2, SRL-4, SRL-5, and SRL-6) and their frequencies depend upon the susceptibility and planted area of the commercial rice cultivars by farmers. These genetic lineages exhibit broad spectrum of virulence and together defeat most known blast resistance genes. Studies on the relationship between virulence spectrum and a genetic lineage of the pathogen reveal the existence of resistance genes in rice effective against all members of a lineage. Avirulence genes vary in frequency in the pathogen population and some are highly frequent in several genetic lineages of the fungus. This suggests that these avirulence genes could play an important role in the pathogen or be associated with pathogenic fitness and then the corresponding resistance genes could be more relevant in breeding for durable resistance. This relationship between avirulence genes and genetic groups in the pathogen suggests that avirulence genes may be the factor or main force in the evolution and stability of a genetic lineage. We are identifying and predicting the durability of resistance gene combinations based on frequencies of avirulence genes within a genetic lineage and the possible association of avirulence genes with pathogenic fitness.

Despite this high virulence diversity, breeders at CIAT have been able to develop durable blast resistant cultivars such as Oryzica Llanos 5, indicating that combinations of resistance genes may confer suitable and durable resistance to the pathogen. We have found that the combination of the resistance genes Pi-1 (chromosome 11), Pi-2 (chromosome 6), and Pi-33 (chromosome 8) seems to be the most relevant genes for breeding durable blast resistance in Colombia and several Latin American countries. Frequency of virulence on each gene is high within some lineages but no isolate defeats the three genes. Each one of these genes confers resistance to all the pathotypes of several lineages. We have demonstrated that the combination of the three resistance genes in a single near isogenic line confers complete blast resistance when tested in the field, as well as in greenhouse inoculations. Evaluation and selection of breeding lines at CIAT are carried out under “hot spot” conditions favoring high pathogen pressure and diversity. We have inferred the possible resistance genes present in our blast susceptible rice cultivars and initiated a backcrossing program to incorporate the resistance genes Pi-1, Pi-2, and Pi-33 into Latin American rice cultivars through marker assisted selection using microsatellite and scar markers. Rice lines carrying the combination of these three resistance genes are then tested under controlled greenhouse conditions, as well as our “hot spot” screening site, using a spreader row technique to maintain a high and diverse population of the pathogen in the field. Resistant plants are then selected after several backcrosses based on other desirable traits for their distribution to national programs in Latin America. We will discuss the virulence changes and evolution of the blast pathogen in Colombia and the implications in breeding for resistance.

Traditional and Novel Genetic Mapping of Agronomic Traits from the Interspecific Cross *Oryza sativa* x *O. glaberrima*

Aluko, G., Martinez, C.P., Tome, J., Castano, C., and Oard, J.H.

Wild relatives of cultivated varieties offer new genetic sources for enhancing economic value, but traditional interval mapping techniques have not gained widespread support among applied researchers in the rice community. The objective of this research was to compare interval, multiple regression, bulked segregants, and Discriminant Analysis (DA) approaches for genetic mapping of economically important traits among 312 doubled-haploid lines derived from the cross *O. sativa x O. glaberrima.* Genetic materials were planted in 2001 in replicated field plots in Colombia, and the same lines were evaluated in Louisiana in 2002. A total of 100 polymorphic microsatellite markers were used to construct a linkage map using the MapDisto software program to adjust for segregation distortion. High levels of transgressive segregation were observed for most traits. New markers derived from *O. glaberrima* were detected for percent rice bran, panicle length, and grain yield. Seven QTL for panicle length, tillers/plant, heading date, and 1000- grain weight were detected in both locations. High levels of percent correct classification were obtained for markers identified by the DA procedure vs. other methods. Adjustment for population structure in this controlled cross enhanced classification and improved mapping results. When compared with previous traditional QTL mapping experiments for agronomic traits, DA-selected markers detected in this study pointed to the same and different regions on the rice genetic map. The overall outcome from this study suggests that African rice should be a valuable new source for introgression and improvement of several attributes that affect

economic considerations in different rice export markets. Finally, results from this research suggest that use of non-parametric methods, such as DA, and adjustment for population structure can improve mapping of economically important traits vs. traditional genetic approaches.

Marker-Assisted Selection for the Rice Blast Resistance Gene *Pi-ta*: Development and Use of an Improved Co-Dominant Analysis Method

Johnson, V.A., Redus, M.A., Gibbons, J.W., Moldenhauer, K.A.K., Jiang, J., and Jia, Y.

Fragment analysis with a dominant molecular marker has been in use in the UA RREC Rice Breeding and Genetics Program for DNA Marker Assisted Selection (MAS) to accelerate the development of cultivars with improved rice blast (*Magnaporthe grisea*) disease resistance by monitoring the incorporation of the resistance gene, *Pi-ta*. As the breeders gain confidence in the use of MAS as a breeding tool and begin to analyze ever increasing numbers of samples, it has become necessary to develop and optimize new methods that are faster, more efficient, more accurate, and cost less per sample. A new automated analysis method of a co-dominant *Pi-ta* marker was developed for population screening and to verify the results of rice blast pathogenicity studies.

This PCR-based method capitalizes on the conserved nucleotide length polymorphism of the *Pi-ta* gene within *indica*-derived alleles. The PCR is performed using a three-primer system, two "forward" primers and one "reverse" primer, all obtained from Integrated DNA Technologies (Coralville, Iowa). One "forward" primer specifically amplifies the resistant allele and is modified at the 5-ft end with a fluorescent blue 6-FAM label. The other "forward" primer specifically amplifies the susceptible allele and is modified at the 5-ft end with a fluorescent green HEX label. The "reverse" primer, which is common to both "forward" primers, is unlabeled. Resulting amplification products are approximately 181 bp for the resistant allele and 182 bp for the susceptible allele.

Genomic DNA is extracted from seedling leaf tissue using a modified PEX/CTAB extraction method. The DNA samples are then quantified in a 96-well format. PCR DNA template blocks are prepared containing 86 unknown samples and 10 samples of resistant and susceptible controls and parental lines. All DNA samples are diluted to a 20-ng/µl concentration. PCR is performed and the resulting amplification products are prepared for analysis. Fluorescent fragment separation is performed on an ABI 3700, and subsequent data are analyzed using GeneScan and Genotyper software, all from Applied Bio-systems (Foster City, CA).

Over 2,300 individual samples have been analyzed using this method, enabling the breeders to classify the genotype of advanced breeding lines, confirm pseudo-hybrids in segregating populations, and identify homozygous susceptible materials from the first generation of triple cross (TC_1) and F_3 populations. On average, the breeders have been able to eliminate over a third of the individuals in segregating populations in the first round of MAS, saving valuable time and resources.

Genetic Diversity among West African Rice Varieties for Grain Quality Traits Using Chemical and DNA Marker Analyses

Traore, K., Fjellstrom, R.G., and McClung, A.M.

Development of rice cultivars that are accepted by consumers requires evaluation of both objective and subjective quality factors. Because rice is generally consumed as a whole grain, physical properties, cooking quality, and sensory traits are very important. In some areas of West Africa, rice that has a short cooking time and slow digestibility is preferred by consumers. The objective of this study was to evaluate rice accessions from West Africa for genetic diversity in grain quality parameters and identify genetic resources for novel quality traits relative to U.S. germplasm. Thirty-nine rice varieties were introduced from the West Africa Rice Development Association (WARDA) located in the Ivory Coast. These included upland, rainfed, and irrigated cultivars, as well as "Nerica" varieties which are derived from interspecific crosses with *Oryza glaberrima*. DNA marker analyses were performed at the USDA-ARS Rice Research Unit in Beaumont, TX, using leaf tissue from plants growing in a quarantine greenhouse and milled rice samples obtained directly from WARDA were analyzed for grain quality traits.

The WARDA samples demonstrated a wide range for all quality parameters measured. They included grain shapes similar to long-, medium-, and short-grain classes; aromatics and non-aromatics; red bran cultivars; chalky and translucent grains; etc. Using standard protocols, alkali spreading value (ASV), apparent amylose content, Rapid Visco Analyzer (RVA) pasting properties, Differential Scanning Calorimeter measurements, and cooking time were determined. DNA marker analysis was performed using random fingerprint markers, as well as markers that are associated with the *Waxy* and *alk* loci, which are associated with amylose content and ASV, respectively.

The results showed that ASV varied from 4.0 to 7.0 and amylose content varied from 15.0% for Khao Dawk Mali 105 to 26.1% for CG14, which is an *O. glaberrima* cultivar. Cooking time varied from 11.7 minutes for Pusa Basmati to 24.0 minutes for WAB 56-104. Using the RM 190 marker, which is associated with the *Waxy* gene, alleles common to those found in U.S. cultivars were identified, as well as some rare alleles (103, 114, and 116). The three cultivars that had the 114 allele for RM190 were very similar in grain shape and all other quality measurements but ranged in cooking time by 4.9 minutes. The long-grain cultivar Nerica 5 was unusual in that it possessed an amylose content and *Waxy*-allele like Dixiebelle but had a weak RVA curve similar to L202. Jaya is a chalky medium-grain cultivar that has the same amylose content and *Waxy* allele as Dixiebelle but a much stronger RVA curve. Bieu is a long-grain cultivar with a short (15.5 minute) cooking time and a *Waxy* allele like Lemont; however, it had a high amylose content and a strong RVA curve like Dixiebelle. The fingerprint marker data showed polymorphism among the varieties with markers RM210, RM214, RM224, RM234, RM247, and RM304 having 10 or more alleles among the 39 cultivars. The marker with the lowest amount of polymorphism was MRG6102, which is associated with the *Pi-ta*^{2} blast resistance gene in U.S. cultivars. Many crosses have been made between these WARDA lines and U.S. cultivars to develop mapping populations for further study.

***Waxy* Locus Genetic Variation Associated with Amylose Content in International Rice Germplasm**

Chen, M.-H., Bergman, C.J., and Fjellstrom, R.

Rice end-use quality is strongly impacted by amylose content. The *Waxy* gene on chromosome 6 encodes the granule-bound starch synthase enzyme (GBSS) and controls much of the variation in rice apparent amylose (AA). A microsatellite in the non-coding region of the *Waxy* exon 1 containing a CT simple sequence repeat has been identified, and displays variation associated with the different amylose classes, i.e. high, intermediate, and low AA. A genetic marker for this CT repeat has been developed and is being used by the rice breeders for progeny selection in varietal development. This marker accelerates the breeding process because progeny can be selected at any developmental stage and also enables accurate varietal selection at the genetic level thus minimizing the analysis of grain AA, which is influenced by the environment. Further, a single nucleotide substitution from G to T (G/T SNP) at the first intron 5-ft splice site was identified that is associated with low AA varieties. This mutation reduces the splicing efficiency of the leader intron of GBSS and is associated with differential temperature sensitivity during grain development of low AA varieties. In addition, a sequence alignment of two high- and one intermediate-AA varieties shows a single nucleotide difference in exon 6 (ex6 SNP), which alters the amino-acid codon, and provides separation of the two amylose classes. The objective of this study is to examine the linkage between the CT repeats, the G/T SNP at the leader intron splice site, and the ex6 SNP, and the association of these polymorphic combinations with AA using rice germplasm of diverse origin.

The genomic DNA of rice varieties was extracted from leaf tissues. The CT repeat was determined using the *Waxy* microsatellite marker. The G/T SNP was analyzed by *Acc*I cleavage after PCR amplification. The sequence variation in exon 6 was detected by the dideoxyfingerprinting method, a hybrid between single-strand conformation polymorphism and the dideoxy sequencing method, and was scored against a Nipponbare control.

Of the 150 non-glutinous rice accessions tested, nine CT microsatellite alleles were identified that explained a large portion of the variation in AA. The CT repeats of 17, 18, and 19, which associate with the rice accessions of AA ranging from low- to intermediate-AA classes, can be subdivided into low-amylose haplotypes of 17T, 18T and 19T (combined CT repeats and a T at the G/T SNP), and intermediate-amylose haplotypes of 17G, 18G, and 19G. The high-amylose CT repeats of 8, 10, and 11, and the intermediate-amylose CT repeats of 14, 16, and 20, all have Gs at the G/T SNP. Together, these 12 *Waxy* CT-G/T SNP haplotypes explained more of the variation in AA than the CT microsatellite alone. By itself, the G/T SNP is unable to discriminate the intermediate- from the high-AA class of rice accessions.

The ex6 SNP grouped the 150 non-glutinous rice accessions into two alleles: the Nipponbare allele (N-allele), which associates with high- and low-amylose classes of the rice accessions, and non-Nipponbare allele (M-allele), which associates with all the intermediate amylose rice accessions. By combining the G/T SNP and ex6 SNP, the rice accessions were grouped into three haplotypes: GN (a G at the G/T SNP and N-allele at ex6 SNP), the high-amylose haplotype; GM, the intermediate-amylose haplotype; and TN, the low-amylose haplotype. Together, these three haplotypes explained a comparable amount of the variation in AA as did the *Waxy* CT-G/T SNP haplotypes. These combined G/T and ex6 SNP haplotypes were able to further discriminate the high amylose rice accessions with a CT 20 allele, such as Jodon, L202, A201, from the other intermediate-amylose CT 20 rice accessions. A genetic marker, via allele-specific oligonucleotide PCR, to this ex6 SNP has been developed and is able to discriminate the high- or low-amylose class from the intermediate-amylose class.

In conclusion, a high association was found between both CT-G/T SNP and G/T-ex6 SNP haplotypes and AA across a diverse set of international germplasm. The linkage of these sequence variations on the *Waxy* gene and their association with AA provides breeders with marker choices that can accurately select between amylose classes in diverse genetic backgrounds.

Rapid Identification of Candidate Markers by Discriminant Analysis Associated with Agronomic Traits among Inbred Lines of Rice

Zhang, N., Xu, Y., McCouch, S.R., and Oard, J.H.

Traditional QTL mapping techniques are commonly used to identify loci or intervals linked to traits of interest, but power and precision are often lacking. Studies with human populations employ linkage disequilibrium (LD) mapping strategies to identify single nucleotide polymorphic (SNP) markers associated with candidate genes or simply-inherited phenotypic traits, but non-reproducibility and spurious associations dilute the impact of this methodology. Plant genetic mapping strategies routinely utilize marker genotype frequencies obtained from progeny of controlled crosses to declare presence of putative QTL on previously constructed linkage maps, even though a detected interval of 5-30 cM by this procedure may contain > 50 genes. Mapping of genes contributing to human diseases typically involves unrelated “case” and “control” populations, but the factors that contribute to functional linkage disequilibrium must first be empirically examined for each situation to determine the level of resolution. Population structure, admixture, and other factors often lead to false positive associations and erroneous conclusions using this approach. Discriminant analysis (DA) is a multivariate heuristic approach currently used in numerous human studies to identify molecular markers associated with agronomically important traits among inbred lines of rice. DA was used to identify AFLP markers associated with dry matter content among U.S. sweet potato clones at high levels of accuracy. The principal objective of this research was to evaluate the DA procedure to correctly identify SSR alleles associated with quantitative traits in a rice population composed of U.S. and Asian inbred accessions. A total of 218 lines originating from the U.S. and Asia were planted in field plots near Alvin, Texas, in 1996 and 1997 and agronomic data were collected for 12 traits. DNA profiles of each inbred line were produced using 60 SSR and 114 RFLP markers. Traditional genetic distance and model-based methods revealed population structure among the lines. Use of DA and adjustment for population structure allowed successful assignment of individual inbred lines to pre-defined phenotypic groups of interest. Marker alleles associated with all traits were identified by DA at high levels of percent classification within subpopulations and across all lines. Markers pointed to the same and different regions on the rice genetic map when compared with previous QTL mapping experiments. Results from this study suggest that candidate markers associated with agronomic traits can be readily detected among inbred lines of rice using DA combined with other methods described in this report. Finally, cross validation analysis and a comparison of DA and QTL-selected markers on the rice genetic map suggest that this approach can efficiently identify alleles from multiple germplasm sources for rapid varietal development and future gene discovery efforts.

Linkage Breaking between Liberty Resistance (*bar*) and Hygromycin Resistance (*hpt*) Genes by Selection of Transgenic Taipei 309 Plants

Shao, Q.M., Rush, M.C., Wu, M.S., Zhang, S.L., Groth, D.E., and Linscombe, S.D.

Progeny selection methods from self-crossing (selfing), crossing, and repeated backcrossing were conducted to try to break the linkage between the Liberty resistance (*bar*) and the hygromycin B resistance (*hpt*) genes in transgenic plants over the past several years. More than 100 plants showing resistance to Liberty herbicide, but susceptible to hygromycin B, were selected from thousands of progeny and tested for the presence of the *hpt* gene. Some plants recovered the hygromycin resistance after several further generations, suggesting that gene expression had been silenced. A low percentage of F_2 plants tested showed that the hygromycin gene was present, but had been silenced. The results from PCR and Southern blot showed that only six plants, from all of the progeny tested, were resistance to Liberty herbicide but had lost the hygromycin resistance gene. The other progeny tested had the hygromycin gene present but the gene was not expressed. This research demonstrated that the *hpt* selection gene could be separated from the Liberty resistance gene in transgenic plants after selfing or crossing but only in a low percentage of the progeny.

DNA Markers Assist in Improving Philippine-Released Varieties

Tabien, R.E., Abalos, M.C., Fernando, M.P., Corpuz, E.R., Dimaano, Y.A., Osoteo, G.M., San Gabriel, R.C., Tabano, D.A., Padolina, T.F., Rapusas, H., Rillon, J.P., and Sebastian, L.S.

Most of the rice varieties in the Philippines have the *Xa-4* and *Xa-5* resistance genes for bacterial leaf blight (BLB) caused by *Xanthomonas oryzae pv oryzae* and some have no resistance at all. However, with the identification of new genes like *Xa-21, Xa-22,* and *Xa-23* or the gene from *Oryza minuta (Om),* varieties developed earlier can be improved through the incorporation of the new important genes and extend the use of these popular modern released varieties. New traits or genes have can be introduced through series of backcrossing or gene pyramiding; however, these method can be difficult or impossible using conventional approaches, especially if there is gene masking and/or epistatic effects of the genes being pyramided. In some cases, resistance genes have similar reaction to two or more races or biotypes, thus it is difficult to identify plants with combined genes. Conventional transfer of new genes is being done through series of backcrossing and selection and this procedure needs 7 to 10 years and requires extensive resources. With the generation of DNA markers linked to trait of interest, the long tedious backcrossing, aimed to further improve rice germplasm, can be enhanced, thus shortening the identification of desirable genotypes. BLB genes that had been mapped and tagged using DNA markers can be explored to further improve resistance. There were more than two dozen BLB genes reported and eight genes were transferred or pyramided using marker aided selection (MAS).

MAS was used to improve resistance of three popular released rice varieties of the Philippines namely: IR64, PSB Rc14 and BPI Ri-10 to BLB. Variety IR64 and BPI Ri-10 are two of the most popular rice varieties for transplanted irrigated lowland areas while PSB Rc14 is for direct-seeding. These varieties, however, were susceptible to nine races of BLB prevalent in the Philippines. Three backcrossing (BC) with conventional and marker-aided selections using PCR was done to pyramid and or transfer BLB resistance genes into these modern rice varieties. DNA markers, STS for RG556a linked to *xa-5*, primer OPL 13 for *Om* gene, pTA258 for *Xa-21* and 10 RAPD markers were used in selection to evaluate progenies of the third and last backcross. Selected lines were initially evaluated on-station in yield trials and re-evaluated for resistance to nine races of BLB and grain qualities. Elite lines identified after a series of trials were grown in farmers' fields for final evaluation.

The first group of elite lines was at the initial yield trial after eight seasons, two to four seasons faster than the regular selection protocols. After the first cross in 1995 and three backcrosses, five elite lines are currently in national testing for yield, and one line, AR32-19-3-4, is in farmers' field trials at 22 locations. All elite lines were highly resistant to the nine races of BLB and had grain qualities very similar to the recurrent parent. The most advanced lines had a yield of 5 to 6 t/ha in farmers' wet season trials in BLB endemic areas but had 8 to 10 t/ha yield in favorable farmers' fields.

Single Nucleotide Polymorphism Markers at the Rice *Alk* Locus Controlling Alkali Spreading Value

Fjellstrom, R., Chen, M.H., Bergman, C.J., and McClung, A.M.

Alkali spreading value (ASV) is a standard assay used to classify the processing and cooking quality of rice cultivars. The ASV measurement is a rating of grain dispersion in a 1.5 or 1.7% KOH solution after 16 to 24 hours and provides a simple means of classifying rice into high, intermediate, and low gelatinization temperature types. Classifying rice varieties according to gelatinization temperature is useful in determining ones that are appropriate for use in parboiling, quick cooking, puffing, extruding, and other rice cooking and processing technologies. ASV has been reported to be primarily controlled by the action of one or two genes. The *Alk* locus on rice chromosome 6 has often been cited as a major gene controlling ASV and has recently been found to encode soluble starch synthase IIa (SSSIIa). Our research was aimed at analyzing sequence variation in the *Alk* gene across a wide range of rice germplasm in order to identify possible DNA markers associated with ASV in U.S. cultivars and international rice accessions.

Sequence variation analysis of the *Alk* gene was initiated by searching public database information for genomic sequences that had high similarity with starch synthase genes and mapped near the *Alk* locus on rice chromosome 6. DNA sequence information from the cultivars Nipponbare and 93-11, being sequenced by the Japanese Rice Genome Project and the Beijing Genomics Institute, respectively, were compared to identify candidate *Alk* gene polymorphisms resulting in amino acid changes in the encoded *Alk* protein. These functional single nucleotide polymorphisms (SNPs) could be identified by restriction endonuclease digestion of PCR amplification products, which was used to determine the degree of association between *Alk* gene SNPs and ASV in 190 rice accessions. Sequencing of the *Alk* gene exon regions in eight unrelated medium- and long-grain international cultivars (Lemont, L-202, M-202, Mars, Te-Qing, Khao Dawk Mali 105, Basmati 370, and Phudugey) was also performed to identify any additional sequence polymorphisms not found in Nipponbare and 93-11. Genetic linkage of functional SNPs in the *Alk* gene with ASV was analyzed in F_3 families from two crosses: 1) Panda/M-104, where both parents have low amylose, but have low and high ASV scores, respectively; and 2) Lemont/Jasmine-85, where the parents have low ASV and intermediate amylose and high ASV and low amylose, respectively.

A soluble starch synthase II isoform sequence (GenBank entry AF419099) from an unidentified rice cultivar was found to reside on a BAC (GenBank entry AP003509) located in proximity to the *Alk* locus. As we proceeded in our analysis of this gene, it was subsequently determined by Japanese researchers to be the *Alk* gene encoding the SSSIIa enzyme. Comparing the Nipponbare and 93-11 sequences of the *Alk* gene indicated the presence of only two DNA polymorphisms resulting in amino acid changes between these two rice accessions. The presence or absence of these changes resulted in the identification of three *Alk* alleles (sequence haplotypes): the Nipponbare haplotype, having a mutation at nucleotide 2412 of GenBank entry AF419099; the 93-11 haplotype, having a mutation at nucleotide 2514, and the Lemont haplotype, having no mutations. We have coded these alleles as the NPBR, M202 (which shares the same mutation as 93-11), and LMNT haplotypes, respectively. No other sequence differences resulting in amino acid changes were identified in *Alk* genes of the eight unrelated cultivars that were analyzed. We found that most Japanese varieties with high ASV scores (ASV = 6.0 to 7.0, corresponding to low gelatinization temperature) carry the NPBR haplotype. The M202 haplotype was found in medium-grain cultivars grown in California and the southern US, which typically have high ASV scores. The M202 haplotype was the more common high ASV haplotype in international germplasm. Cultivars with either low or intermediate ASV scores (ASV = 2.0 to 5.0), which includes typical southern U.S. long-grain varieties, possessed the LMNT haplotype. So far, very low ASV scores of 2.0 to 3.0 have only been identified in genotypes having low amylose content (< 20%) with the LMNT haplotype for *Alk*. Waxy rices that had intermediate ASV values all carried the LMNT haplotype and those that had high ASV values commonly carried the M202 or, less commonly, the NPBR haplotypes (as was observed in the non-waxy cultivars). In genetic analyses, for the Panda/M-104 cross the *Alk* SNP marker explained over 91% of the variance in ASV. In the Lemont/Jasmine-85 cross, over 61% of the variation in ASV was explained by the *Alk* SNP marker. An additional 4.1% ($p<0.0001$) of the ASV variation in this cross was explained by a *Waxy* gene marker (RM190), which controlled 74% of the amylose content variation. Evidently, factors like amylose content or environmental effects can alter ASV levels to varying degrees in different crosses, which we are continuing to investigate. Conclusively, the *Alk* SNP markers are successful in explaining most of the variation in ASV. Because of this strong genetic association, we have developed allele specific oligonucleotide primers that allow the direct detection of Alk SNPs for use in marker aided selection of ASV in breeding populations.

Improved Methods for Identifying Fissure Resistant Rice

Pinson, S.R.M. and Osborn, G.S.

Kernel fissuring is one of the leading causes of reduced milling yield. Any reduction in fissuring results in direct increases in yield and profit for both the producer and the miller. Breeder interest in selecting varieties with improved resistance to pre-harvest fissuring rose rapidly in the 1990s after the agronomic value and genetic variability within U.S. rice germplasm for this trait was actualized with 'Cypress.' Breeders soon adopted several methods for comparing relative fissure resistance among rice lines. One method involves exposing dried rice kernels to controlled humid air conditions followed by visual observation of kernel fissures. This method is laborious as it involves careful handling and observation of each treated kernel. Also, grain samples must be evaluated for fissures prior to laboratory treatment so that pre-existent stress and kernel fissuring do not introduce error into the evaluation. A second method breeders use to evaluate fissure resistance is to sequentially harvest seed samples from single plots during maturation and evaluate them for loss of milling quality over sequentially lower grain moisture contents while exposed to actual field conditions. Varieties that exhibit little sequential loss of milling quality have "milling stability" or "fissure resistance." Much seed is required to plant plots large enough to accommodate numerous sequential harvests, and much labor is required to cut, thresh, and evaluate harvest moisture and milling quality of some 15 samples/plot. These fissure resistance evaluation methods require such large amounts of seed and/or labor that they cannot be applied until late in the breeding process, after six or more generation advancements, when much breeding effort has already been invested in each advanced line. Present evaluation methods allow a *reactive* final selection to prevent release of a fissure susceptible line. What is needed is an early-generation *proactive* selection tool. Our plan was to first identify environmental, genetic, and kernel component (physical and chemical) factors that determine fissure response in rice, then learn to "control" them, resulting in an improved selection technique. Before the impact of various environmental and grain components on fissuring could be measured, a "measuring stick" - comprised of varieties with established order of resistance to field fissuring - needed to be established. At the initiation of this project, it was known that Cypress was more fissure resistant than 'Lemont,' and it was suspected but not proven that 'LaGrue' and 'Teqing' were less fissure resistant than Lemont. Our replicated multi-year milling stability data documents that the order of fissure resistance among the following varieties is 'Saber' >Cypress > 'Jodon' ≥ 'Cocodrie' = Lemont = LaGrue >Teqing > 'Jefferson.' Saber was consistently the most fissure resistant line in all replications.

Presently, breeders use the same large plots for studying yield, optimum milling quality, and milling stability. To optimize the plots for yield evaluation, they are planted early (i.e., the first half of April in Beaumont, TX). Present data show, however, that seed harvested from plots planted later (i.e., May) reveal more distinct differences between fissure resistance and susceptibility because of a larger loss of milling quality among fissure susceptible lines. We documented that a wider range in kernel maturity, as indicated by moisture content, was associated with increased field fissuring, and we found that kernel maturity was less uniform in plots planted after May 3. As expected, once average grain moistures reached 16 to 18%, the drier uppermost seed of fissure susceptible rices exhibited more field fissuring and lower head rice yields than the less over-mature seed collected from lower portions of the plot canopy. In contrast, Saber and Cypress exhibited a narrower range of kernel moisture, and the uppermost seed had higher or similar milling quality as lower-placed seed even at low (14%) harvest moistures. This suggests the possibility of reducing the number of seed samples per plot from 15 sequential harvests to a single harvest of paired top- versus bottom- or bulk-harvested seed. If proven valid, the paired-sample method requires such small plots that fissure resistance selection could begin in the F_3 or F_4 generations. The present data do validate a more efficient manner for documenting loss of milling quality within sequentially harvested seed. Percentage whole kernels after dehulling was found to be as accurate as duplicate milled samples for predicting head rice yield, yet required less processing time and as little as 25 g of paddy rice. By reducing the labor and seed required for milling stability evaluation, breeders can now evaluate fissure resistance in additional plots per year.

The current project also verified that the "fissure index" computer model used to evaluate post-harvest fissuring from chemical and physical properties of grain accurately predicts pre-harvest fissuring as well. The model was further improved with inclusion of the third grain dimension, thickness. The contribution of the hull, bran, and endosperm (white rice) toward the overall fissure resistance of various varieties was measured and modeled. The high fissure resistance of Cypress was primarily attributed to hull composition/tightness and bran composition. Saber's high resistance was predominantly from endosperm composition, suggesting that even higher levels of fissure resistance can be attained by combining key attributes of these two varieties through breeding selection.

Abstracts of Posters on Breeding and Genetics
Panel Chair: Q. R. Chu

Molecular Evaluation of Rice Germplasm using SSR Markers

Tai, T.H., Lu, H., Garris, A., Redus, M., Coburn, J., Rutger, J.N., and McCouch, S.R.

Rice germplasm collections serve as a valuable source of genetic materials for use in germplasm enhancement and breeding programs. Phenotypic evaluation of these collections is routinely carried out and provides valuable information for a number of important traits (e.g. heading date, plant and grain morphology, disease resistance). Unfortunately, the large number of accessions and traits of interest to breeders and other rice researchers makes it extremely difficult to efficiently phenotype collections and extract full value from them.

Since the development of molecular or DNA-based markers in the 1980s, many technological advances have led to the use of molecular markers for assessing genetic diversity. In rice, the most well characterized of the crop plants, the sequencing of the genome has provided the ultimate source of DNA markers for detecting molecular differences in germplasm. Of the many molecular marker systems available, microsatellite or simple sequence repeat (SSR) markers have been particularly useful given their relative ease of use, robustness, low cost, and high allelic diversity. The main input cost of developing SSR markers (i.e. the identification of unique primers for polymerase chain reaction amplification of the markers) has been eliminated by the availability of the rice genome sequence and expressed sequence tag data.

Using a set of 169 SSR markers distributed over the rice genome, we have generated genotypic profiles of over 500 rice germplasm accessions. Among these accessions are U.S. ancestral lines, cultivars, and breeding lines, as well as materials from various international breeding programs. Data from these accessions have enabled us to assess the genetic diversity of these materials and the population structure present in various subsets of the accessions. This information provides the necessary foundation for studies aimed at employing linkage disequilibrium or association mapping in rice, which may enable the detection of important genetic loci using germplasm collections as an alternative to structured mapping populations.

This project provides a framework for the molecular evaluation of additional germplasm and insight into an alternative application of germplasm collections for genetic studies in rice.

Molecular Genetic Characterization of the Rice Low Phytic Acid (*lpa1-1*) Locus

Andaya, C.B. and Tai, T.H.

Phytic acid is the primary storage form of phosphorus in the cereal grains and is essential for seed development, seedling growth, and phosphate and mineral availability in foods and feeds. A rice low phytic acid mutant, *lpa1-1*, with reduced phytic acid and a corresponding increase in inorganic phosphate was previously identified. Using two different mapping populations, a high resolution molecular genetic map of the *lpa1-1* locus has been constructed. Analysis of a recombinant inbred line population, derived from a cross between KB1-1 (*lpa1-1*) and Zhe 733 (*Lpa1-1*), indicates that the locus is tightly flanked by the microsatellite markers RM3542 and RM 482, which are located on chromosome 2. RM3542 and RM 482 are 2.9-cM and 4.3 cM away from the locus, respectively. Using an F_2 population derived from a cross between KB1-1 and IR50 (*Lpa1-1*), the *lpa1-1* was mapped between the microsatellite markers RM 208 and RM 482. RM 208 and RM 482 are 1.6-cM and 2.3-cM away from the locus, respectively. RM 208 and RM 3542, which are within 5 kb of each other, are approximately 136 kb from RM 482 based on publicly available rice physical maps and genome sequence. Based on the rice genome sequence of this region, additional microsatellite markers were designed. One marker, CA11, further delimits the region to about 100 kb. Several candidate genes are present at the locus. Progress on identifying the *lpa1-1* gene will be reported.

Herbicide Tolerance in Rice: Search for Potential Donors and Varietal Development

Harper, C., Frank, P.M., Pace, J., and Tabien, R.E.

Breeding rice varieties takes 7 to 10 years, thus continuing efforts to establish populations for selection should be planned ahead. This planning should consider both the farmers' and consumers' demands for certain traits of the variety and quality in the produce. Yield has been the basic criterion for variety adoption and other traits like grain quality, insect pest, and disease resistance follows. Among the traits desired by farmers, herbicide tolerance has not been incorporated in Texas-released varieties. Weeds are perennial problems to farmers in all rice production areas in Texas and the United States in general. Weeds can reduce yield and quality by 17% compared with about 8 and 7% for insects and diseases, respectively. Losses due to weeds were estimated at 34% in Texas, 12% in California and Missouri, and 17% in Arkansas, Louisiana, and Mississippi, valued at $269 million in 1983, thus the release and planned release of herbicide-tolerant transgenic rice and the mutant-derived gene in popular varieties have been a big relief to farmers, especially for the control of red rice.

The number of genes for herbicide tolerance is limited and were all patented, thus gene discovery is continuing. Gene bank collections have been the main source of new genes. Most of the germplasms at USDA-ARS National Small Grains Collection (NSGC) have been evaluated for tolerance to glyphosate and glufosinate, the two most important groups of herbicides while mutation breeding has been useful in generating important genetic resources. It was used to develop herbicide-tolerant crops and was successfully done for rice in Louisiana. Among the mutagenic agents, EMS (ethyl methane sulfonate) and MNU (methyl-nitrosourea) were the most popular chemicals to generate mutants not only in rice but also in other crops. The current search for potential donors is being done through chemical mutation breeding and screening of new germplasm collections. The mutants or accessions that will be isolated will be used in the development of new rice varieties and the improvement of elite lines and popular varieties through the incorporation of herbicide tolerance.

Mutation breeding was initiated using two chemical mutagens, MNU and EMS. Seeds of seven varieties and two elite lines were soaked in three concentrations of EMS (0.4, 0.8 and 1.2%) for 6 hours after 4-hour soaking in water as a pre-treatment. Percent germination, shoot length, root length, and root/shoot ratios of treated seed after 7 days showed differential response among the varieties and lines evaluated. In all cases, higher concentration of the mutagen reduced percentage germination and shorten root and shoot length. All seedlings from these treated seeds were grown in wooden tubs and some were transplanted in the field. At harvest, seeds were generated from 16,200 plants and these are currently being screened for tolerance to Roundup and Liberty. For MNU, florets of TQ 275a, a progeny of Teqing x Lemont cross and Cocodrie were soaked in 1.0 and 1.5 mM for 45 minutes, rinsed in water and kept in the greenhouse to mature until harvest. Grain development after treatment varied in the two genotypes. In 1,954 seeds collected, only 17% was from the LQ 275a and the rest were from Cocodrie. All seedlings from these seeds are now growing in the greenhouse to produce the seeds for herbicide screening. New germplasm from U.S. collections are also currently being screened for Roundup and Liberty tolerance at the seedling stage. Seeds were grown in flats and were sprayed at 3- to 4-leaf stage. Initial screening of more than 500 accessions from 53 countries showed some degree of tolerance in some of the entries but these have to be re-evaluated.

Introduction and Identification of IR36 Rice Trisomic Lines

Eizenga, G.C. and Ho, Q.P.

Trisomic rice (*Oryza sativa* L.) plants (2n=2x=24) are plants that have an additional chromosome (2n=2x=25). Presence of a third chromosome alters segregation ratios that makes trisomic lines helpful for a) locating a gene on a particular chromosome, b) verifying the independence of linkage groups, c) associating the genetic linkage groups with individual chromosomes, or d) incorporating alien variation. Complete series of rice trisomic lines are available worldwide in three backgrounds: IR36 – an indica cultivar developed by IRRI, Nipponbare – a Japanese temperate rice cultivar, and Zhongxian 3037 – a Chinese indica cultivar. In addition to primary trisomic lines with an additional complete chromosome, each of these trisomic series has various secondary trisomic (double chromosome arm) lines, telotrisomic (single chromosome arm) lines and/or alien (non-*O. sativa* chromosome) addition lines.

In an effort to incorporate the IR 36 trisomic series into the U.S. germplasm collection, all 12 IR36 primary trisomic lines, secondary trisomic (1S.1S, 2S.2S, 5S.5S, 6S.6S, 6L.6L, 7S.7S, 8S.8S, 8L.8L, 11S.11S, 11L.11L, 12S.12S) and telotrisomic (2L, 3L, 5L, 7S, 9S, 12S) IR36 lines were obtained from IRRI. These lines were grown in the rice quarantine greenhouse at Fayetteville, Arkansas, using three different grow-outs from 1999 to 2001. When the quarantine plants were near maturity, the supposed trisomic plants were identified based on morphology and heading date. For most trisomic lines, one to three plants were identified from the grow-out.

The selected lines were grown in the field at Stuttgart, Arkansas during the summers of 2000 to 2003. Seed were planted as space plants, one seed per hill. The control, IR36 was planted for comparison at every sixth row or fourth row, 2000-01 and 2003, respectively. In 2003 the row spacing was increased to account for the excessive tillers and lodging problems inherent in IR36 grown in an Arkansas management system. Plants were observed throughout the growing season. Panicles for meiotic analysis were collected as the flag leaf emerged at the R1-R2 growth stage. Later, panicles with mature seed were collected from supposed trisomics based on morphological observation at maturity.

Of the 12 primary trisomic lines selected based on morphology from the quarantine grow-out, 11 had the correct morphology when grown in Stuttgart. To date, the nine primary trisomic lines confirmed by cytological observation are T1, T2, T3, T4, T7, T8, T9, T11, and T12. Of the 11 secondary trisomic lines selected based on morphology in the quarantine grow out, nine had the correct morphology when grown in Stuttgart. To date, the four secondary trisomics confirmed by cytological observation are 7S.7S, 8S.8S, 8L.8L, and 11L.11L. Lastly, of the nine telotrisomic lines grown in quarantine, six had the correct morphology when grown in Stuttgart, with 3L, 7S, and 9S being confirmed by meiotic analysis to date. The plants for 4L are trisomic but the morphology does not match the IRRI description. Meiotic analyses of the panicles collected this summer should be completed during the current year. In questionable cases like the 4L telotrisomic line, the trisomic chromosome will be verified with chromosome arm specific BAC clones using *in situ* hybridization procedures. When this project is complete, all 12 primary trisomic lines and a secondary trisomic and/or telosomic line for at least one chromosome arm representing each of the 12 rice chromosomes should be available for distribution.

Identification of Blast Resistance Genes in Indica Rice Germplasm

Eizenga, G.C., Refeld, H.R., Lee, F.N., Emerson, M., Xiang, G., Jia, Y., and Yan, W.

Rice blast caused by *Pyricularia grisea* (Cooke) Sacc. is a major fungal disease of cultivated rice (*Oryza sativa* L.) in the United States and of irrigated rice worldwide. Indica rice, rice grown in tropical areas is one possible source of additional blast resistance genes (*Pi*-genes) that could be incorporated into U.S. rice cultivars. *Pi-ta* is a major blast resistance gene introduced into the U.S. cultivar Katy from the Vietnamese landrace Tetep and *Pi-b* is another major gene introduced into U.S. cultivar Saber from the Chinese cultivar Teqing. A total of 94 rice accessions were selected from approximately 1,000 rice accessions screened in a field nursery for resistance to blast. In a different study, approximately 550 accessions were genotyped with 180 microsatellite markers. Approximately half of these accessions were U.S. rice cultivars and the other half from a more diverse origin. The main objectives of this study were to determine if new/novel resistance genes are present in the 94 selected accessions utilizing known molecular markers associated with these resistance genes and use microsatellite markers to determine the relatedness of the 94 accessions to each other and adapted rice cultivars.

The accessions used in this study were those being brought through the U.S. rice quarantine system for incorporation into the U.S. rice germplasm collection (Germplasm Resources Information System). Blast inoculations were done in the field using standard protocols. Inoculations in the greenhouse followed standard procedures to identify resistance to the blast races IB-1 (ZN15), IB-49 (ZN52), IC-17 (ZN1), IE-1K (ZN19), IE-1 (ZN6), IG-1 (ZN39), and IH-1 (74L2). Plants were rated at the 4- to 5-leaf stage using a scale 0=no lesions to 9=dead leaves.

Genomic DNA was extracted from leaf tissue using a CTAB method or the DNeasy Plant Mini Kit per the manufacturer's instructions. Three pairs of *Pi-ta* dominant primers, one pair of *pi-ta* recessive primers, and one pair of *Pi-b* dominant primers were used to determine the presence of *Pi-ta*, *pi-ta,* and *Pi-b*, respectively. The presence or absence of these PCR products was visualized on a 1% agarose gel.

The 180 microsatellite markers used to genotype the 94 *O. sativa* accessions were visualized by fluorescent-labeled products, processed by an ABI 3700, and analyzed to detect polymorphisms in the PCR product. Once genotyped, the genetic distance (GD) between the *O. sativa* accession will be calculated using the following equation, GD=1-A/N, where A is the total number of microsatellite alleles shared by two accessions and N is the total number of microsatellite loci scored between the two accessions. GD values can range from zero (all alleles in common) to unity (no alleles in common).

In the field ratings for leaf blast, 89 of the 91 accessions tested had average ratings below 3.0, and 73 of the 77 accessions tested had ratings below 3.0 for panicle blast. In greenhouse testing, 90% or more of the accessions tested had average ratings below 2.0 for the blast isolates tested.

Based on repeated screening, both the *Pi-ta* and *Pi-b* resistance genes were identified in 30 accessions with an additional entry having only *Pi-ta* and 29 accessions having only the *Pi-b* resistance gene. Thirty-four accessions did not have either *Pi-b* or *Pi-ta*. Fifteen of these 34 accessions had ratings of 1.0 or less for all field and greenhouse inoculations. The resistance of seven of these 34 accessions needs to be tested or reconfirmed in greenhouse inoculations. In summary, 15-22 accessions of the original 94 tested are potential sources of new and novel blast resistance genes.

Data from the 180 microsatellite markers used to genotype the 94 accessions will be used to determine the GD between the accessions. The GD data will be subjected to a hierarchical cluster analysis. These analyses will differentiate (GD > 0) the *O. sativa* accessions, and multidimensional scaling (MDS) plots will provide visualization of the GD between the 94 accessions. This analysis will be used to determine relatedness of the 94 accessions. In addition, comparing this analysis with the previous genotyping of adapted varieties will allow rice breeders to select germplasm based on relatedness to the most adapted germplasm.

Evaluation of Rice Mutants in Multi-Location Trials Conducted in the Southeast Asian Region

Eizenga, G.C., Padolino, T., Azam, M., Brar, D.S., Cheema, A.A., Ismachin, M., Ismail, A.,
Koh, H.J., Senghaphan, R., Shu, Q., Tuan, V.D., Wu, D., Zhu X., and Maluzynski, M.

Induced mutation is an important tool for rice breeders to use to incorporate new variation into currently used rice (*Oryza sativa* L.) varieties. The specific objective of this IAEA/FAO sponsored project was to evaluate, identify, and utilize promising rice mutants from the germplasm assembled in the Regional Rice Mutants Multi-Location Trial (RRMMT).

The 11 countries/institutes that participated in this project included Bangladesh, P.R. China, India, Indonesia, IRRI, Rep. of Korea, Malaysia, Myanmar, Pakistan, the Philippines, Thailand, and Vietnam. The entries selected for evaluation included 19 mutant lines, the 16 parent lines the mutants were derived from, and 'IR64' as a universal check. Trials were replicated three or four times over 3 years at 16 locations in nine countries. The entries were compared for yield, days to heading, plant height, and number of productive tillers. Other characteristics observed included lodging, harvest date, management, environmental conditions, and disease pressure. Starch characteristics related to rice quality measured were apparent amylose content, alkali spreading value, gel consistency, and starch viscosity. Data were collected from 46 yield trials with three or four replications at 19 locations in the participating countries over one to four growing seasons (2000 to 2002). Geographically, the locations were spread from 5ºN to 37ºN latitude and 89ºE to 127ºE longitude, with elevations ranging from 2 to 900 m above sea level. Data were analyzed using the SAS procedures General Linear Models and Regression.

Of the 35 entries included in the study, it was determined that parent MutSM-268/PSJ x IR36 (MutSM) and mutant Shwewartun had poor germination. The germination of MutSM was so poor that it was not included in the trial. The parents, Tai Nguyen and Tep Hanh, were photoperiod sensitive so limited data were collected on these entries. Pooled data across countries revealed significant variations among entries. Location mean yield ranged from 2224.6 to 6861.2 kg/ha. Mutant RD25-86-G1-Cs-PTT-31-1-2-1-1 (RD25 mutant) from Thailand produced the highest yield but not significantly different from mutant Binadhan 4 with 6626.1 kg/ha. These two mutants were comparable as to heading date, plant height, and productive tillers. Other top yielding mutants with at least 6000 kg/ha were Binadhan 6 and R3027. R3027 matured about 11 days earlier than Binadhan 6 but Binadhan 6 was taller by 27 cm.

All of these mutants were significantly better in yield than their parent varieties. When compared with the international check, additional mutants and parent varieties gave a significant yield advantage. The mutants, PR26768-PJ(T)4, TNDB 100, THDB, and PR26305-M32 produced yields ranging from 5707.9 to 5818.0 kg/ha or at least a 5% yield advantage over IR64. The parents, Tainan3, IR8, and BR4 showed significantly better yields than IR64 and their mutant progeny.

The yield stability analysis of each entry over all locations was evaluated using the slope of the regression line denoted as 'slope' and root mean square (RMSE). The most stable entry was the international check, IR64, with a slope of 1.06 and a RMSE value of '1,' thus, IR64 showed wide adaptability across environments. The high yielding RD25 mutant and its parent also showed stability, though the response in each environment was more variable. This variability in yield could be attributed in part to reactions to local insect pests and diseases.

The measurement of characteristics related to starch quality showed the mutants to be similar to their original parent in amylose content except for the low amylose mutant, Hwacheong du 2, from Korea. There were no changes in alkali spreading values between mutants and parents. Changes were observed in gel consistency between the mutant(s) and their corresponding parent. The most extreme differences were between parent Basmati 370 and its DM25 mutant, and parent RD25 and its RD25 mutant. For starch viscosity, four mutants, Y1281, PNR381, TNDB 100, and DM 25, were identified with improved starch viscosity.

Overall, 13 of the 19 mutant lines and four of the 15 parent varieties were included in national trials and/or incorporated into breeding programs. Desired traits being introduced from these mutant and parent lines included high yield, reduced plant height, disease resistance, early flowering, and aroma.

Off-Type Evaluation Using DNA Fingerprinting Techniques

Utomo, H.S., Linscombe, S.D., and White, L.M.

Off-types were observed in the foundation plots of several semidwarf rice varieties even though extensive roguing to remove the off-types had been done in the previous year. The off-type is typically taller with lighter green color than the normal cultivar. DNA markers can be used to evaluate the off-type problem. Results from marker analysis can be used for purity verification and determination of mixtures/off-types or possible genetic shift as varieties are propagated in different environments. The objective of this study was to conduct marker evaluation among off-types found in Francis and Cheniere foundation plots. Thirty Francis and five Cheniere off-types, together with their respective checks, were collected from foundation plots. DNA was isolated from leaf tissue from each entry. Multiple unambiguous markers generated from various sources, including 100 RAPD, 700 AFLP, and 50 microsatellite markers, were used in this study. Results indicated that there was a considerable genetic variability among the off-types. The variability was not a result of seed mixture.

Low-Cost High Throughput Marker Detection

Utomo, H.S. and Nash, J.L.

The potential application of marker technology has been limited due to a relatively high cost of marker detection and upfront cost of setting up a laboratory with specialized equipment required to carry out marker-assisted breeding. Our laboratory is conducting a study to explore some possibilities for developing a low-cost marker detection system that will allow genotyping a substantial amount of breeding materials on a timely basis adaptable to a real cycle of breeding processes. A series of DNA isolation techniques, from a commercially standard DNA isolation kit to a simple heating method, with costs ranging from several dollars to a few cents per sample has been evaluated. The heating method is well suited to using a Minibeater that allows processing 96 leaf samples in a few minutes. When isolated DNA was subjected to PCR amplification, the heating method displayed banding patterns, but the results were inconsistent from genotype to genotype and even within the same genotype when replicated. The method has great potential due to its low cost and high speed but needs further improvement to increase its consistency and clarity. The PCR products from microsatellite markers can be visualized following non-denaturing polyacrylamide gel electrophoresis. Ethidium bromide can be added in the running buffer so staining can be done during electrophoresis. Marker visualization using this system costs only a few cents per data point. Development of marker detection that is rapid and inexpensive will increase the application of marker technology and its integration into any existing breeding program.

Anther Culturability of Selected U.S. Rice Cultivars, Experimental Lines, and Exotic Rice Germplasm

Jiang, J., Gibbons, J.W., Moldenhauer, K.A.K., Chu, Q.R., and Linscombe, S.D.

Anther culture is a useful technique in plant breeding for rapidly generating homozygous doubled haploids to shorten the breeding cycle and for enhancing breeding efficiency. It has been documented that rice androgenic response is a complex and genetically controlled character. Therefore, identifying and using bridging parents, genotypes containing desired agronomic or value-added traits and high anther culturability, is an effective approach to improve anther culture breeding efficiency. Toward this goal, a selection of 93 U.S. rice cultivars, experimental lines, and exotic germplasm was screened for their overall anther culturability (AC%) under uniform culture conditions (cold treatment, media, etc.).

AC%, the mean number of green plants recovered from 100 anthers plated, ranged from 0% (Jasmine 85) to 15.8% (PI 560265), with an average value of 2.3% across all 93 genotypes. AC% was found to be not only genotype-specific but also linked to rice grain type. Among 93 genotypes tested were 74 long grains, 12 medium grains, and 7 short grains. On average, short grains had a higher AC% (7.1%) than medium grains (3.6%) or long grains (1.2%), mainly due to the fact that anther-derived calli of short grains had a significantly higher plant regeneration rate (83.1%) than their medium- (30.8%) and long-grain (22.8%) relatives. As typically found, the average AC% for temperate japonica lines was 5.7%, followed by tropical japonica (1.1%), indica (0.6%), and aromatic (0.4%).

AC% is determined by its two components, callus induction rate (CI%) and plant regeneration rate (PR%). In this study, 92 (99%) lines produced calli but only 79 (85%) lines had regeneration ability. Among 29 poorly responsive long-grain lines with a low AC% (below 0.4% or zero), 20 (69%) genotypes, including cultivars 'Cheniere,' 'Drew,' 'Katy,' 'Kaybonnet,' 'Millie,' 'Newbonnet,' 'Gulfmont,' 'Jefferson,' 'Priscilla,' and 'L-202,' produced numerous calli at an acceptable CI% (above 3%) but regenerated only few or no plants. 'Jasmine 85' produced no callus. These results substantiated that callus induction rate and plant regeneration rate in rice anther culture are not directly correlated or linked but are controlled by different genes or loci.

Pedigree analysis helped explain AC% in southern U.S. long-grain rice. Thirteen poorly responsive cultivars and experimental lines, Jefferson, Cheniere, Gulfmont, Priscilla, Drew, Katy, Kaybonnet, Millie, STG00L-03-065, STG99L-40-048, STG99-L-04-010, STG00L-22-021, STG00L-23-006, and STG99P-12-058, shared the same progenitor 'Lebonnet' or its descendants Katy and Drew. Likewise, among 21 long-grain, responsive genotypes with a high AC% (above 1.5%), we found 'Lemont' (1.5%) and its six descendants 'Cypress' (1.8%), 'CL161' (2.5%), 'Cocodrie' (4.4%), RU0001124 (1.6%), PI 560243 (4.5%), and PI 560239 (6.3%) joined by 'LaGrue' (1.6%) with its four descendants RU0101105 (1.7%), RU0101170 (2.0%), RU0101093 (2.4%), and STG99L-02-039 (6.3%), and 'Wells' (4.1%) with its descendant line STG009-20-116 (1.6%). These results demonstrate the importance of incorporating bridging parents into otherwise recalcitrant genotypes or crosses for successful use of doubled haploid technology in rice variety development. Those anther culture-responsive elite genotypes, such as Lemont, Cypress, Cocodrie, LaGrue, Wells and their progeny, could be excellent bridging parents for both haploid and transgenic rice breeding in the future.

Progress in Developing DNA Markers for Milling Yield

Kepiro, J.L., McClung, A.M., and Fjellstrom, R.G.

Milling yield can vary considerably in rice cultivars, and cultivars with poor milling will often be rejected by rice growers. The cultivar Cypress has gained wide recognition for having high and stable milling yields over a variety of grain moisture levels. It would be greatly advantageous to be able to transfer this high milling yield of Cypress into advanced genetic lines that rice breeders are developing for future release. Identifying DNA markers associated with Cypress-type milling yield could allow efficient and cost effective marker-assisted selection of lines with high milling yield potential.

Two populations segregating for milling yield are being examined. Data has been collected for total percentage of grain and whole percentage of grain. Days to head and days to harvest were recorded, along with harvest moisture and milling moisture. Grain dimensions of length (L) and width (W) were measured and the L/W ratio calculated. The first population is a progeny population of 117 offspring derived from a Cypress/Pelde advanced breeding line (with high milling potential) crossed to Jefferson (with moderate milling yield). The milling yields of progeny lines in this population range from 52.8 to 66.2% with 2 years of milling yield data. Fifty-eight SSR (simple sequence repeat) markers were scored in this population. A second population segregating for milling yield is a Cypress x Panda cross. Approximately 250 lines in this population have been analyzed for milling quality. The milling yields of progeny lines in this population ranged from 22.3 to 64.8% with 1 year of milling yield. The Cypress x Panda population has simpler parentage, is larger, and has a wider range of milling yield values than the Cypress/Pelde x Jefferson cross. Therefore, it has been chosen for detailed mapping and QTL (quantitative trait loci) analysis. Analyses to determine the percentage of amylose content and alkali spreading value have also been conducted for progeny lines of the Cypress x Panda population.

Additional segregating markers are being identified for genetic mapping and QTL analysis. The strategy is to map the Cypress x Panda population with AFLP (amplified fragment length polymorphism) markers and use SSR markers with known locations to anchor the AFLP markers onto chromosomes. The Invitrogen/LifeTechnologies AFLP System II kit (with E+2 IRD-labeled primers and unlabeled M+3 primers) is being used to generate AFLP markers from leaf extracted genomic DNA of parents and progeny. A Li-Cor 4200 genetic analysis system and multiplexed PCR enables analysis of two differently labeled primer combinations simultaneously by producing two separate images from a single gel. The AFLP System II will allow screening of 256 primer combinations, each producing approximately 100 scorable bands per gel image. Preliminary tests indicated that each primer combination (two per gel) is producing 2 to 4 scorable polymorphisms (4-8/gel). Screening the primer combinations with two replicates of six progeny and the parents will allow selection of primers that produce the highest quality markers (reproducible and scorable) and the maximum number of polymorphisms per gel. The map will be generated using JoinMap 3.0 for linkage analysis of markers from DNA extracted from a single plant of approximately 120 progeny lines in the population. QTL single locus analysis and interval mapping will be done using MapQTL 4.0 and utilize markers scored from a bulk of individuals in each line.

The 117 lines and 58 SSR markers in the Cypress/Pelde x Jefferson population were analyzed for whole kernel percentage by single locus analysis using MapQTL 4.0. The *WAXY* locus (which controls grain amylose content) showed the highest significance in both years that data were collected. No other large effects were consistently observed, although some markers did show association with the percentage of whole kernels after milling. We are presently looking within amylose classes (fixed for the *WAXY* locus) for markers significantly associated with milling yield. Grain shape and dimension are also being investigated. Results will be presented for these QTL analyses and the progress in AFLP marker generation.

Milling Yield Variation among Five Different Rice Varieties at Differing Harvest Moistures and Dates

Bulloch, J.M., Taylor, C.K., and Gibbons, J.W.

Milling yield is an important component of monetary returns to rice farmers and knowledge of milling quality can help in their decision of cultivar selection. Time of harvest affects milling yields. Early harvest can result in excess drying fees to the farmer, while late harvest can result in poor milling quality due to environmental moisture variation. Cultivars differ in how they respond to non-optimal harvest dates. Five different rice cultivars and lines (one medium- and four long-grain), RU0001151, RU0001124, Wells, Cocodrie, and LaGrue, were grown in 2003 at the Rice Research and Extension Center in Stuttgart, Arkansas. They were harvested at optimum harvest date, 7 days before optimum, and at 7 and 14 days after optimum. The grain was oven dried to about 12% moisture and milled to determine percent total and head rice yields. Harvest moisture at the first harvest date varied from 30.7% for RU0001151 to 19.1% for Wells. At the fourth date, harvest moisture varied from 17.9% for RU0001151 to 15.2% for LaGrue. Total Rice Yield (TRY) varied from 68.26% for Wells to 64.11% for LaGrue in the first harvest. Head rice yield (HRY) in the first harvest varied from 63.82% for RU0001124 to 55.63% for LaGrue. In the fourth harvest, TRY ranged from 70.37% for Wells to 69.35% for RU0001151, and HRY ranged from 64.63% for RU0001151 to 57.23% for Wells. Cocodrie and RU0001124 were stable in milling quality across all harvest dates.

Induction of Early Maturing Indica Mutants

Rutger, J.N. and Beaty, B.A.

Several long-grain indica lines have shown grain quality comparable with U.S. standards but mature much later than current U.S. cultivars. Six such experimental indica lines obtained from G.S. Khush of IRRI, IR65629-22, IR65629-67, IR65629-157, IR65450, IR53936, and IR60864 (the first three are different selections from the same cross), were irradiated in order to induce early mutants.

In 2000, 400 grams of seed of each line were treated with 250, 300, or 350 Gy of gamma radiation. In the 2000/2001 M1 generation in Puerto Rico, about 1000 panicles were randomly selected from the 250 and 300 Gy dosages. Only about 300 panicles were taken from the 350 Gy dosage due to severe stand reduction. In order to save space, the M1 panicles were planted panicle-to-hill. One hundred one early heading M2 plants were identified and tagged within hills. The M3 generation was grown in the 2001-2002 Puerto Rico winter nursery. The M4 was grown in 2002 at Stuttgart, and selections were made that uniformly headed in $\leq$111 days from the effective planting date, which reduced the total to 49. The M5 was planted in 2002-2003 at Puerto Rico, and 20 panicles were bulked together to plant large plots to look for uniformity in 2003 at Stuttgart.

In 2003 at Stuttgart, each selection was planted in 4.5 m long, 6-row non-replicated plots. The 6 IRRI parents and the Arkansas cultivar Francis were included for comparison. Of the 49, 20 were selected on the basis of earliness, uniformity, and resistance to lodging. These 20 selections ranged from 9 to 34 days earlier than their respective parents. For reference, the Arkansas cultivar Francis headed 99 days after planting. IR65629-22 headed in 126 days and had one mutant that headed in 92 days. IR65629-67 headed in 126 days and had mutants that headed in 94, two at 103, and 104 days. IR65629-157 headed in 122 days and had one mutant that headed in 103 days. IR65450 headed in 126 days and had mutants that headed in 101 and 111 days. IR53936 headed in 133 days and had mutants that headed in 108, 109, five at 110, 111, 114, and 120 days. IR60864 headed in 131 days and had mutants that headed in 120 and 122 days. Average heading of the 20 selections was 108 days, which was down from an average of 127 days of the six parents.

Thus significant progress was made on selections for early maturity in all six parent genotypes. These mutants provide indica materials that have heading dates that are more manageable under Arkansas conditions than the parent materials. The parents had grain quality similar to U.S. standards. It is not anticipated these grain quality factors will be changed in the mutants.

Establishment of the Genetic Stocks – *Oryza* (GSOR) Collection

Rutger, J.N. and Bernhardt, L.A.

Genetic stocks are useful tools both in applied plant breeding, such as locating traits in relationship to other traits with an identified marker, for speeding up research cycles with early-flowering mutants, and in basic genetic studies for determining gene location and function. Genetic stock collections help preserve materials that otherwise might be lost as researchers retire and/or grants terminate. Model genetic stocks collections in the United States have been set up in tomatoes, maize, barley, and wheat. In August 2003, the Genetic Stocks – *Oryza* (GSOR) was established at the USDA-ARS Dale Bumpers National Rice Research Center, at Stuttgart, Arkansas.

The GSOR will include materials produced at Stuttgart such as dominant and recessive male sterile mutants, various morphological mutants, cytogenetic tools such as trisomics and telotrisomics, and an RIL set of about 350 F_{10} lines from the cross Kaybonnet *lpa*1-1/Zhe 733. Materials produced by cooperators, including other USDA-ARS units, universities, industry, and some NSF-supported projects, will also become part of the GSOR. The GSOR collection will make seeds and information for each stock available through GRIN to U.S. and international rice researchers. The respository homepage (url = http://www.dbnrrc.ars.usda.gov/gsor) will be maintained and will facilitate disseminating information about the collection contents.

Transgene Expression in Site-Specific Integrant Rice Lines

Ariza-Nieto, M., Wilson, A., and Srivastava, V.

Site-specific gene integration method based on a heterologous system, such as Cre-*lox,* has the potential to stabilize transgene expression. The molecular strategy allows the production of site-specific integration locus but it doesn't prevent random integrations. Therefore, two types of integrant lines are produced single- and multi-copy. The objectives are (1) to test stability of transgene expression and (2) to determine whether random integrations are linked to the target locus in transformed plants. Consistent transgene expression (*gus*) was observed in single-copy lines, whereas high variability was observed in multi-copy lines. Progeny analysis of single-copy lines was carried out on three lines, which revealed stable inheritance of the locus and a positive gene dosage effect i.e. homozygous plants contained twice as much expression level as hemizygous plants. Molecular and genetic data will be presented to demonstrate consistent and stable transgene expression in site-specific integrant lines. Molecular detail of the strategy will also be presented.

Comparison of Kernel Measuring Devices

Blocker, M.M., Tolbert, A.C., and Moldenhauer, K.A.K.

In 2002, the breeding program at the University of Arkansas Rice Research and Extension Center began using a scanner in conjunction with Seedle software to analyze seed size of experimental lines. Kernel measurements have been reserved for more advanced lines due to time constraints using a micrometer. In 2003, we used 10 lines to do a comparative study of rice kernel measuring devices, using an image analyzer, a scanner using Seedle software, and a micrometer. The objective is to compare the accuracy, information obtained, and time requirement of each device. The correlation for the kernel length between the seedle scanner and micrometer readings had an r^2 = 0.971 compared with a correlation of r^2 = 0.725 between the image analyzer and the micrometer. The kernel width measurements were not as highly correlated as the kernel length measurements between the micrometer and the seedle scanner or the image analyzer having r^2 values of 0.747 and 0.619, respectively. It takes approximately 70 seconds to run a 100- grain sample through the seedle machine compared with approximately 90 seconds per sample through the image analyzer. We were able to do Kernel measurements on 1117 lines in 2002 and 1204 lines in 2003.

Genetic Variation at the Waxy Locus Associated with Starch Pasting Properties in International Rice Germplasm

Chen, M.H., Bergman, C.J., and Fjellstrom, R.

Rice starch pasting properties are used to characterize the processing and cooking qualities of rice (*Oryza sativa* L.). The Rapid Visco Analyser (RVA) has become the standard method for determination of rice pasting properties. The *Waxy* gene on rice chromosome 6 encodes the granule-bound starch synthase enzyme, which controls much of the variation in grain amylose content, and reportedly has major effects on starch pasting properties. Amylose content, however, does not explain all of the variation in rice pasting characteristics. Some varieties with similar apparent amylose content have very different pasting viscosities. Rexmont, a *javanica* type rice with a strong pasting curve, has a characteristic single nucleotide substitution resulting in an amino acid change in exon 10 of the *Waxy* gene (ex10 SNP). We are studying 164 diverse rice accessions with apparent amylose contents ranging from 0 to 27% and determining the sequence variation in the *Waxy* gene to identify associations between pasting properties and genotypes and its linkage to the *Waxy* CT-repeats microsatellite marker.

Genomic DNA of rice varieties was extracted from leaf tissues. The CT repeat was determined using the *Waxy* microsatellite marker. The sequence variation in exon 10 was detected by the dideoxyfingerprinting method, a hybrid between single-strand conformation polymorphism and the dideoxy sequencing method, and was scored against a Nipponbare control. The rice pasting properties were determined by RVA.

Two allele-types of the ex10 SNP, namely the RXMT-type allele associated with a strong RVA curve (S-RVA allele), and the NPBR-, or Jodon-type, allele associated with a weak RVA curve (W-RVA allele), were identified from 164 rice accessions, including non-glutinous and glutinous varieties. A mean comparison of the individual characteristics of the RVA curve demonstrated that the S-RVA allele has significantly (alpha = 0.05) higher hot paste viscosity, cool paste viscosity, and setback than those of the W-RVA allele, regardless of the amylose content. A genetic marker, via allele-specific oligonucleotide PCR (ex10-ASO), to this ex10 SNP has been developed and is able to discriminate a strong RVA curve of the RXMT-type from a weak RVA curve of the NPBR-, or Jodon-type. In addition, this S-RVA allele is linked to *Waxy* CT 11 repeats, suggesting that both ex10-ASO and the *Waxy* microsatellite marker are suitable to be used in breeding programs for varietal development of pasting properties.

Amylose content did contribute to the pasting properties of the RVA curve of the rice accessions with the W-RVA allele, excluding the glutinous varieties. The amylose content is negatively correlated with the RVA of peak viscosity, hot paste viscosity, and breakdown ($r = -0.85^{***}$, -0.75^{***}, and -0.79^{***}, respectively) and is positively correlated with the setback ($r = 0.76^{***}$).

In conclusion, the high association of ex10-SNP and Waxy CT repeats to rice starch pasting properties as observed in the evaluation of the diverse international germplasm suggests these ex10-ASO and *Waxy* microsatellite markers can be used as markers in varietal development programs using international accessions. Since RVA is environment dependent and requires 3 g of flour from mature rice kernels, the availability of markers will accelerate and increase accuracy in progeny selection in the breeding program.

Correlation Study on Yield Components of Doubled Haploid Lines in the Advanced Yield Trial

Kibanda, N.J.M., Chu, Q.R., and Linscombe, S.D.

Estimation of inter-correlation between yield and yield components is more necessary for efficient simultaneous selection of yield components than would be for a single trait selection. Several workers elsewhere have studied correlation on yield components of conventional breeding materials. To date, no information is available on the association among yield components of the already developed U.S. long-grain doubled haploid (DH) lines. The objective of this study is to establish the association of inter-correlations between yield and its attributes by which concentration could be made in selection for increased yield.

Twenty-three genotypes (18 DH lines and five commercial varieties) were evaluated in the advanced yield trial with three replications in a 1.4 x 4.9 m plot area at the LSU AgCenter's Rice Research Station. Data recorded included total number of spikelets/panicle, fertility, productive tillers/0.8 m^2, and yield. Data were sampled from a randomly placed quadrat area except for yield, which was obtained from the gross plot area. Data were analyzed by SAS PROC CORR.

The number of tillers/0.8 m^2 revealed a significant positive correlation with yield, indicating that increase an in number of tillers/0.8 m^2 would result in a significant increase in yield. Although total number of spikelets per panicle had a significant positive correlation with % filled grains, both traits had significant negative correlations with yield. These results suggest that the materials tested, increasing the % filled grains tended to increase the total number of spikelets/panicle but with significant reduction in yield. This could be due to an unfavorable interaction between the total number of grains/panicle and % filled grains to yield. Rather, these lines have less tillers whose increase would result in a significant increase in yield. The above results indicate that there are two scenarios for further improvement of DH lines. The first scenario would be to increase the number of tillers/0.8 m^2, and the second scenario would be to alter the architecture and physiology of the DH lines to counter the negative interaction of total number of spikelets/panicle and % filled grains with yield.

Comparison of Yield Components of 18 Long-Grain Doubled Haploid Lines with Five Commercial Varieties

Chu, Q.R., Kibanda, N.J.M., and Linscombe, S.D.

Yield component studies have focused on two main areas, 'super rice' and "the ideal type rice." A preliminary study in 2002 at the LSU AgCenter's Rice Research Station indicated that U.S. commercial long-grain rice varieties are mainly composed of two plant types. Louisiana types (Cocodrie, Cypress, and Cheniere) have multiple tillers with intermediate panicle size, while Arkansas types (Francis, LaGrue, and Wells) possess a larger panicle size but moderate tillers per plants. Current developed doubled haploid (DH) lines are characterized to be in between the two U.S. types. This study aims to identify and compare the performance of major yield components of DH lines influencing yield under irrigated conditions.

Twenty-three genotypes (five commercial varieties and 18 lines) were planted in a randomized complete block design with three replications during 2003. Data, including plant height, panicle length, number of productive tillers/0.8 m^2, number of grains/panicle, percent filled grains, and 1000-grain weight, were recorded from a randomly placed quadrate area in each plot. Yield and vegetative vigor were recorded from the total plot area (4.9 x 1.4 m). Data were analyzed through SAS PROC ANOVA, and means were compared with the Duncan's multiple range test (DMRT).

Results indicated that there were significant ($P \leq 0.05$) differences in all the traits among the genotypes. Highest yield performances obtained from DH lines 004372/00447277 and CCDR/98LL0401 were due to possession of relatively high % filling ability, setting of total number of spikelets/panicle, and in 1000-grain weight compared with commercial varieties. Also, line CCDR/98LL0401 demonstrated a high number of tillers/0.8 m^2 in addition to the above mentioned traits. Although most entries were within the acceptable levels of plant height range (79-97 cm) and seedling vigor ratings (3-5), some falling within this group exhibited lodging, including the variety Wells. This suggests that improvement on lodging resistance is required to minimize yield loss and quality deterioration. These results indicate that development of DH lines improved total number of spikelets/panicle, 1000-grain weight, and tillers/0.8 m^2. Lines 0043752/0047277 and CCDR/98LL0401, with average vigor and resistant to lodging, are the elite lines with the highest yielding ability because of high total number of spikelets/panicle, % filled grains, and 1000-grain weight.

Incorporating Guichao into U.S. Rice Cultivars

Counce, P.A., Qin, Z., Bryant, R.J., Gravois, K.A., Thompson, V.A., Blocker, M.M., Tolbert, A.C., and Moldenhauer, K.A.K.

Guichao is a high yielding South China rice cultivar. We sought to determine the physiological reason or reasons for its high yield. Guichao is a pubescent rice line with a grain not really fitting within any U.S. rice classification. Guichao has a midday photosynthetic depression absent in Lemont and other U.S. rice lines. Research has indicated that part of the midday depression of photosynthesis is related to a difference in amounts of xanthophyll cycle carotenoids that protect from various forms of oxidative damage to plants. U.S. rice lines had higher leaf xanthophyll cycle carotenoids than South China line Qiguizao, which was derived partially from Guichao. Guichao is also more susceptible to various types of photooxidative stress than most U.S. rice cultivars, including U.S. long-grain cultivars. Further research in our project indicated Guichao and Qiguizao shared increased susceptibility to low temperature/high light stress compared with U.S. rice cultivars. Guichao has also been found to be allellopathic to rice weeds, including barnyardgrass. Later in the program, we sought to incorporate the knowledge we gained from our work into breeding higher yielding Arkansas rice cultivars. We did field, greenhouse, and laboratory experiments with Guichao and U.S. cultivars.

The enzyme sucrose synthase either breaks down or produces sucrose, depending on the plant tissue in which it is found. In the filling rice grain, sucrose synthase breaks down sucrose forming two sugars (UDP-glucose and fructose) that are then incorporated into starch. The breakdown of sucrose is a potential rate-limiting step in filling the rice grain. Consequently, we sought to determine the activity of the enzyme in Guichao relative to U.S. rice cultivars. We did field and greenhouse experiments over 3 years and found consistently higher sucrose synthase activity (on a per grain and on a per mg protein basis). Our working hypothesis thus became that the high yield of Guichao was, at least partially, related to the higher sucrose synthase activity for Guichao endosperm.

We sought to learn why the sucrose synthase activity was higher, and to this end, we began purifying sucrose synthase from Guichao rice endosperm. Our work purifying sucrose synthase required extensive experimentation to find a set of separation methods to yield purified proteins. In the final purification protocol, we utilized an anion exchange column, a hydrophobic interaction column, and a refined (Resource Q) anion exchange column. We have isolated four isoforms of sucrose synthase from the endosperm from Guichao at the R6 growth stage. We are now seeking to characterize the enzyme isoforms and compare them with published reports. Research to identify genes associated with the high yields of Guichao is continuing.

Field tests revealed that the yield of Guichao was consistently higher than the yield of U.S. rice cultivars Bengal, Adair, and Lemont. The yield component most notably superior in Guichao is tiller number. Guichao yields more culms per unit area and tillers per plant than most U.S. cultivars in our tests.

A collection of F_2 derived lines from reciprocal crosses of Guichao and Lemont were developed and brought to near homozygosity. Field experiments to determine yield, height, and maturity of these lines were conducted in 2001-2003. In addition, crosses were made between two of the promising lines and LaGrue, and one line looks particularly promising.

In conclusion, research to determine the physiological yield-limiting factor in Guichao has been extensive and intensive. The work has both practical and basic components. We have purified four isoforms of sucrose synthase from endosperm of Guichao. Breeding work has yielded several promising breeding lines and one line that may be considered for further cultivar development. This research is being continued.

Anther Culture to Develop Rice Germplasm with Disease Resistance

Chu, Q.R., Groth, D.E., Rush, M.C., Linscombe, S.D., and Shao, Q.M.

Blast [*Pyricularia grisea* (Cooke) Sacc.] and sheath blight [*Thanatephorus cucumeris* (Frank) Donk.] are two major diseases in Louisiana and the southern United States. Annual yield losses range from 10 to 15%, with losses in individual fields reaching 40%. Presently, fungicides are used to control these diseases, but this is expensive and raises environmental issues. The more economical and environmentally friendly control method is host resistance. Host resistance breeding is a major objective in most rice breeding programs. Using anther culture to develop doubled haploid (DH) lines that are homozygous (no longer segregating) will greatly reduce the time required to develop disease-resistant cultivars. Several hundred anther culture lines were developed and field screened for sheath blight and blast resistance, good agronomic characteristics, and high yield potential in 1997-2003. Several dozen DH lines scored between a 3 to 4 rating after sheath blight inoculation. In field tests, 11 sheath blight resistant lines with good yield potential and long-grain quality were selected. Two lines, 02SP298 and 02PY675, had grain yields of 8,843 and 8,132 kg/ha, sheath blight ratings of 2.5 and 3, and rotten neck blast ratings of 3 and 0, respectively. These homozygous lines will be used as sheath blight-resistant germplasm in the long-grain rice breeding project. Three years of testing on the DH line, 66601, had a sheath blight resistance rating of 4.5. This line was used as a parent to develop a DH mapping population for identifying new molecular markers of sheath blight.

Development of Genetic Markers for Semidwarf Plant Height and Photoperiod Insensitivity for Marker Aided Selection in U.S. Rice

Fjellstrom, R., McClung, A.M., Gibbons, J., and Deren, C.

Plant height and photoperiod sensitivity are important characteristics of rice that have a large effect on cultivar acceptability for crop production in the U.S. Semidwarf cultivars commonly have increased resistance to lodging and photoperiod-insensitive cultivars are able to flower during the long day-length summer growing season of the U.S. Exotic rice cultivars are often tall and can be day-length sensitive, resulting in susceptibility to lodging and a lack of seed set due to late fall heading. These characteristics of exotic cultivars make them difficult to use in U.S. rice breeding programs and can overshadow beneficial characteristics they may possess, like disease resistance, high yield potential, and specialty grain quality traits. DNA markers tagging semidwarf plant height and photoperiod insensitivity could be used to efficiently select for breeding lines carrying these traits in crosses between exotic lines and U.S. adapted cultivars.

The genes encoding semidwarf plant height (s*d-1*) and photoperiod insensitivity (*hd-1* or, alternatively, *se-1*), located on rice chromosomes 1 and 6, respectively, have both been cloned. However, knowing the DNA sequences of these cloned genes in itself does not provide markers useful for selection of these traits. We surveyed substantial DNA sequence database information to identify polymorphisms in and around these two genes as sequence data became available through efforts of the International Rice Genome Sequencing Project (IRGSP) and the Beijing Genomics Institute. PCR primers were developed that flanked candidate sequence polymorphisms and were tested for PCR amplification repeatability, straightforward polymorphism scoring, and close linkage with the target gene. Genetic linkage analysis of markers with traits was analyzed in a cross between Khao Dawk Mali 105 (KDM-105), a tall and photoperiod-sensitive cultivar, and Jasmine-85, a semidwarf and photoperiod-insensitive cultivar. DNA marker polymorphisms were also analyzed for their association with plant height and flowering date in URRN entries and GRIN accessions.

PCR primers developed to amplify polymorphic regions within the *sd-1* and *hd-1* genes performed unsatisfactory by producing numerous and weak amplification products. However, PCR primers flanking microsatelllite sequences near these genes consistently gave repeatable results and unambiguous scoring. Several polymorphic microsatellites were found close to the *sd-1* gene. One tightly linked microsatellite found on the same BAC sequence as the *sd-1* gene appears ideal for marker aided selection of this trait. The *hd-1* gene also had several microsatellites in its vicinity but displayed far less polymorphism than those around the *sd-1* gene. The measured segregation of plant height and heading date in over 200 early generation progeny from the KDM-105/Jasmine-85 cross indicates that a large proportion of the variation in these traits is explained by the *sd-1* and *hd-1* genes, respectively, and the markers linked to them. There was excellent association between plant height and *sd-1* microsatellite markers among URRN entries and GRIN accessions, where nearly all shorter cultivars shared a common pool of microsatellite alleles not found in taller cultivars. There was poor association between heading date and *hd-1* markers in comparing URRN entries with a sample of 15 photoperiod sensitive GRIN accessions. Nevertheless, *hd-1* markers could still be readily used for selection of photoperiod-insensitivity in crosses between the U.S. and exotic germplasm.

QTLs for Panicle Blight Resistance and Their Association with Resistance to Other Diseases

Pinson, S.R.M., Shahjahan, A.K.M., and Rush, M.C.

After the discovery of the bacterial pathogen *Burkholderia glumae* as the cause of panicle blight disease in rice, an inoculated nursery screening procedure was established at the LSU AgCenter's Rice Research Station in Crowley, LA, for identifying genetically resistant germplasm. Major genes and QTLs conferring resistance and/or tolerance to other rice diseases were previously mapped by various researchers within a set of >Lemont=/=Teqing= recombinant inbred lines. Genetic loci associated with resistance to sheath blight (SB, causal org. *Rhizoctonia solani)*, bacterial leaf blight (BLB, causal org. *Xanthomonas oryzae),* and several races of blast (causal org. *Pyricularia grisea)* are now known within this gene-mapping population. The aim of the present study was to identify genetic loci conferring resistance to bacterial panicle blight (BPB) within this well-studied population of 300 RILs.

The Lemont/Teqing RILs were evaluated for BPB severity in inoculated field plots in 2001 and 2002 with three replications each year. Susceptible checks within the study included >Bengal= (2-yr average disease severity rating = 7.1), >Cocodrie (avg.= 6.7), and Lemont (avg. = 6.1). Resistant lines were >Nipponbare= (avg. = 4.4) and Teqing (avg. = 4.3). Disease severity among the RIL plots ranged from 3 to 8. Rep-to-rep correlation coefficients for both 2001 and 2002 data were as low as 0.4 to 0.5. The 2001 and 2002 yearly averages were poorly correlated as well (r = 0.4). Evaluations of disease resistance are often hampered by the appearance of resistance among genetically susceptible plots that escape disease. In spite of weekly application of *B. glumae* in order to inoculate each plot according to its individual optimum timing and growth stage, escapes were apparent within the present BPB evaluation. When we re-evaluated our ratings and removed low (resistant) scores when a particular RIL appeared more susceptible (rating increase. 2) in the other two replications in that year, the rep-to-rep correlation coefficients increased to r = 0.7 to 0.8, but the year-to-year correlation remained low with r = 0.4.

QTLs are identified and mapped through statistical association between phenotypic data and molecular marker/allele data. This statistical association weakens with every error in the phenotypic or molecular data sets. The low year-to-year correlation in our phenotypic data was thus of some concern. We elected to conduct marker linkage analyses using several sets of phenotypic data - individual year plus 2-Yr averages of actual ratings, ratings adjusted for escapes, and maximum ratings per year. The raw, adjusted, and maximum data sets all identified similarly located loci, though they did differ for LOD size and percentage variance explained. Five BPB-QTLs (on chromosomes 1, 3a, 3b, 8, and 10) were solidly identified (LOD > 2.4) from analysis of 2-Yr-Averages. All five QTLs also acquired LOD. 2.0 in analysis of 2001 and 2002 individual year data, indicating that their resistance was expressed/effective in both years. An additional BPB-QTL on chromosome 11 was identified from 2002 and 2-Yr average analyses but was not evident in the 2001 data. The BPB-QTL near RG348a on chromosome 3b had the largest effect in each of the data sets, explaining from 10 to 17% of the total variance. This locus, plus the BPB-QTLs located on chromosomes 8 and 11 are co-located with QTLs reportedly conferring resistance to both SB and BLB, with the resistance allele originating from Teqing in each case. Resistance at the BPB-QTLs on chromosomes 1 and 3b originates from Lemont.

We report a total of six BPB-QTLs. Though they must yet be considered putative in that they have been identified in a single population using data with relatively low reliability (year-to-year r = 0.4), confidence in three of the BPB-QTLs is increased by the fact that they are co-located with SB and BLB resistance QTLs.

Performance of Agronomic Traits of 10 Doubled Haploid Lines in Nine Locations in Louisiana

Chu, Q.R., Fontenot, T., Conner, C., Howard, A., Theunissen, B., Bearb, K., and Linscombe, S.D.

Ten doubled haploid (DH) lines (entry 240-249) were entered in a Commercial Advanced yield test (CA) in 2003. This test was conducted in nine locations, including the Rice Research Station and Jeff Davis, Vermilion (2), Acadia, Evangeline, East Carroll, Morehouse, and Richland parishes in Louisiana. The experiment was arranged in a randomized complete block design with three replications and a plot size of 1.4 x 4.9 m. The agronomic traits recorded were seedling vigor, 50% heading date, plant height, and yield. Five commercial varieties (Cocodrie, Cypress, Cheniere, Wells, and Francis) were used as checks. A significant genotype difference in grain yield was found ($F<0.01$). Entry 249 (CCDR/98LL0401DH3), entry 248 (CCDR/98IM0151DH3), and entry 244 (AC122DH4) have shown mean grain yield of 8,313, 7,860 and 7,796 kg/ha, while Wells, Cocodrie, Francis, and Cheniere were 8,312, 8,094, 7,966, and 7,834 kg/ha, respectively. The Duncan's multiple range test was used to compare means for grain yield, and there were no significant differences among the three DH lines compared with the commercial checks. This suggests that the DH lines developed possess good yield potential.

Population Development for Rice Gene Discovery and Characterization

Tai, T.H., Andaya, V.C., Colowit, P.M., Snyder, L.J., and Aragones, D.V.

Identification of genes controlling important traits is dependent on the availability of natural or induced genetic variation. Development of genetic mapping and mutagenized populations provides the materials necessary for gene discovery and functional characterization. Traits of interest to our research program include, but are not limited, to cold tolerance, resistance to stem rot and aggregate sheath spot, grain quality, competitiveness (e.g. seedling vigor), phytic acid content, and silicon content.

In order to identify genes controlling these traits and ultimately to characterize how the genes function, a number of genetic materials are being developed. Since many of the traits of interest are quantitative and influenced by environment and genetic background, it is necessary to have populations that enable phenotypic evaluations to be replicated. To address this need, several recombinant inbred line (RIL) populations are under development from crosses between temperate and tropical japonica germplasm as well as between japonica and indica subspecies. In addition, an advanced backcross population derived from a cross between a medium-grain California cultivar and the wild species *Oryza rufipogon* (accession number 100912) is being developed for genetic studies of stem rot and aggregate sheath spot resistance. Together these populations will be used to genetically dissect various traits of interest and to develop enhanced germplasm for U.S. rice breeding programs. The use of indica and wild species may be particularly valuable to develop germplasm as these unadapted materials are not routinely used by breeders. The various populations under development will be described and their utility for genetic studies will be discussed.

Rice mutants are another powerful resource for gene discovery and characterization, as well as for the development of enhanced germplasm (e.g. semidwarf, early flowering, glabrous). The availability of mutagenized populations enables forward and reverse genetic screens aimed at identifying important genes and determining the functional significance of genes identified by genomic approaches. Here, we report our progress in developing chemically mutagenized populations using ethyl methane sulfonate and a combination of sodium azide and methyl nitrosourea to treat elite materials (primarily California cultivars). The effectiveness of these treatments and the possible utility of these populations will be discussed.

Enhancing Cold Tolerance of Rice for Temperate Environments

Andaya, V.C. and Tai, T.H.

The response of rice to low temperature stress ranges from poor germination and delayed growth to spikelet sterility and poor grain quality. In California, a major objective of rice breeders is to develop improved varieties that will produce stable yields under temperate conditions. The goals of our research are 1) tagging of major genetic loci conferring cold tolerance at the seedling and reproductive stages using molecular markers, 2) isolating the genes underlying these traits, 3) determining the function of these genes, and 4) developing rice germplasm with enhanced cold tolerance for use in breeding programs.

We have developed a recombinant inbred line (RIL) mapping population (currently F_8 generation) from a cross between M-202 (cold tolerant) and IR50 (cold sensitive) and generated F_3 families for fine-mapping major loci for cold tolerance using microsatellite markers. For cold tolerance at the seedling stage, lines were subjected to low temperature stress under two regimes in a growth chamber: 1) $9^{\circ}C$ constant temperature for 10 to 14 days and 2) $25^{\circ}C/9^{\circ}C$ day/night temperature. Cold injuries were manifested as wilting and leaf yellowing, depending on the treatment used. Previously, one major QTL each for cold-induced leaf yellowing and wilting was mapped on chromosomes 4 and 12, respectively. Each QTL explains at least 40% of the phenotypic variance for the given trait. Presented here are results of our fine-mapping of the QTL using the F_3 families and the development of phenotyping procedures that are quick, reliable, and amenable to high-throughput screening.

In addition to seedling cold tolerance, the M-202/IR50 RILs are also being assembled into maturity groups with similar heading dates to examine cold tolerance at the reproductive stage. Screening for cold-induced spikelet sterility requires that the stress be imposed at the critical reproductive stage (i.e. micro-sporogenesis). Previously, we identified reproductive stage cold tolerance QTL using growth chamber screening. Using the RILS, the effect of the QTL will be tested in the field. RILs within the same maturity group are more likely to be uniformly exposed to the stress, thus yielding more reliable data on reproductive stage cold tolerance. The current status of this work will be presented.

Performance of Promising Experimental Clearfield Rice Lines under Louisiana Conditions

Sha, X. and Linscombe, S.D.

Clearfield rice offers a non-GMO alternative to effectively control red rice in the southern United States. The combination of a Clearfield variety with use of the NewPath (*imazethypr*) herbicide can be used in a program to selectively eliminate red rice in a commercial rice field. In the past 3 years, a Clearfield rice program has demonstrated to not only give great control of red rice but also good yield potential. Over 89,000 ha of Clearfield rice were grown in the southern U.S. states in 2003. It is predicted that Clearfield rice will exceed 162,000 ha in 2004. Since the majority of the acreage was planted with CL161 (a Cypress mutant), there is a great potential to improve Clearfield rice production by the development of new Clearfield varieties.

The Rice Breeding Project at the LSU AgCenter's Rice Research Station has being actively involved in the development of new Clearfield lines that combine the high level of herbicide resistance, high yield potential, and good agronomic characteristics. The three Clearfield varieties (CL121, CL141, and CL161) released by BASF were originally developed in this project. Due to the limitation of both mutation and backcross breeding, conventional pedigree breeding has continued to be the primary method for the development of new Clearfield rice varieties. Crosses are continuously made to combine the high level of *imazethypr* resistance of CL161 and its derived experimental lines with high yield potential of conventional long-grain varieties or lines. Over the past several years, a great number of new experimental Clearfield lines have been developed at the Rice Research Station. On- and off-station (on-farm) trials were conducted to evaluate these lines in a typical breeding trial for yield, milling, and agronomic performance. These trials were also treated with the herbicide Newpath to evaluate resistance levels. In each of the trials, *imazethypr* was applied at a rate of 140 g/ha at emergence after drill seeding then again at the 3- to 4-leaf stage.

In 2003, a total of 101 experimental Clearfield lines were tested in three trials at five locations. In Trial 1, 22 advanced lines and the check varieties CL121, CL141, and CL161, were tested at the Rice Research Station and in Jefferson Davis and Evangeline parishes (Louisiana); Trial 2, consisting of 38 lines and the same three checks, was conducted at the Rice Research Station and in Vermilion Parish; while Trial 3, consisting of 41 lines and checks CL121 and CL161, was tested at the Rice Research Station. Standard agronomic practices were used for all trials. The experimental design was a randomized complete block with two to three replications for each location. Plot size was 1.42 x 6.92 m.

Significant differences on main crop yield, ratoon yield, days to 50% heading, height, and sheath blight rating were found among different experimental lines for all trials. Significant genotype x location interaction was also observed for main crop yield in trials 1 and 2. Check CL161 consistently yielded higher than CL121 and CL141 in all trials. In Trial 1, 12 of 22 entries yielded higher than the check CL161 on main crop. Entry 20 developed from the cross CFX-18//AR1142/LA2031, recorded the highest average main crop yield of 7,688 kg/ha, a 5.4% increase over CL161. In Trial 2, four of 38 entries outyielded CL161 on main crop yield. Entry 2, developed from the cross CFX-18//AR1142/LA2031, had the highest average main crop yield of 8,286 kg/ha, a 5.0% increase over CL161. Entry 29 of Trial 3 showed the greatest promise with the main crop yield of 10,352 kg/ha, an 8.2% yield advantage over CL161.

Rice *Pi-ta* Gene Confers Resistance to Two Major Pathotypes of the Rice Blast Fungus in the United States

Jia Y., Wang, Z., Fjellstrom, R., Moldenhauer, K., Flowers, C., and Rutger, J.N.

Blast is a serious rice disease in the southern United States. The *Pi-ta* gene in rice prevents the infections of *Magnaporthe grisea* isolates containing the avirulence *AVR-Pita* gene. *Pi-ta* encodes a putative cytoplasmic receptor that appears to bind to a predicted processed AVR-Pita to elicit a defense response. The landrace cultivar Tetep was the donor for the *Pi-ta* gene for the U.S. cultivar, Katy. Subsequently, Katy was the *Pi-ta* donor for the additional U.S. cultivars Drew and Kaybonnet.

The objective of this study was to determine the role of *Pi-ta* in resistance to contemporary blast pathogen races in the southern United States. Field surveys have indicated that the races IB-49 and IC-17 are the most common in the southern United States. We observed that all of the *Pi-ta* containing cultivars were resistant to both major pathotypes IB-49 and IC-17 of *M. grisea.* The presence of *Pi-ta* as determined by DNA markers for the *Pi-ta* gene completely correlated with resistance to both IB-49 and IC-17.

The resistance was further investigated using a marker for the resistant *Pi-ta* allele in a F_2 population of 1345 progenies of a cross with Katy. Resistance to IC-17 was conferred by a single dominant gene, and *Pi-ta* was not detected in susceptible individuals. Another F_2 population of 377 individuals of a reciprocal cross was used to verify the conclusion that resistance to IC-17 was conferred by a single dominant gene. In this cross, individuals resistant to IC-17 were also resistant to IB-49. The presence of *Pi-ta* and resistance to IB–49 were also correlated with additional crosses involving another *Pi-ta* containing rice culitvar. A pair of primers that specifically amplifies a susceptible *pi-ta* allele was developed to verify the absence of the dominant *Pi-ta* gene. These data suggest that *Pi-ta* is responsible for resistance to IB-49 and IC-17. The correlation of *Pi-ta* with resistance to both *M. grisea* pathotypes suggests they contain functional *AVR-Pita* genes.

Currently, structural and functional analyses of *AVR-Pita* alleles from IB-49 and IC-17 are in progress. Completion of this task will enhance the understanding of molecular evolution of the *AVR-Pita* gene. In the future, DNA markers for *Pi-ta* can be used to follow the incorporation of *Pi-ta* into advanced breeding lines containing additional blast resistance genes to reach a broad spectrum of resistance to different fungal isolates.

Recipe and Protocol of Culture Medium for Regenerating U.S. Long-Grain Rice

Chu, Q.R.

Successful regeneration of rice doubled haploids depends largely on the genotype, pollen stage, pre-treatment of anthers, and culture media. Rice anthers respond differently to concentrations of medium components. Although rice anthers respond to many basic media, such as N6, MS, LS, R4, SK, and He 5, the medium compositions required by *japonica* and *indica* are different. *Japonica* crosses respond well to N6 medium, while *indica* crosses respond to He 5 medium. Several media have been tested for callus induction and plant regeneration for U.S. long-grain rice, but the anther culturability is less than 1%, which is unacceptable. Southern U.S. long-grain crosses are composed of mostly *javanica* germplasms. By comparison of medium compositions, we have specifically designed a basal medium, designated as Chu, for rice anther culture of southern U.S. crosses.

Pooled data from 1998 and 2003 indicated that Chu basal is more effective on callus induction of U.S. crosses than N6, MS, SK, and R4. The mean callus induction rate of 54 long-grain F_1 populations on Chu medium was 13.5%, which is a 3-fold increase compared with that on N6 medium. Years of practice using Chu's media at the LSU AgCenter's Rice Research Station have shown acceptable anther response with U.S. long-grain rice. This media became popular in rice anther culture labs in Arkansas, Rice Tec, and Guatemala. The composition of Chu medium is KNO_3 3000 mg/l, $(NH_4)_2SO_4$ 300 mg/l, KH_2PO_4 500 mg/l, $MgSO_4$-$7H_2O$ 200 mg/l, $CaCl_2$-$2H_2O$ 150 mg/l, $ZnSO_4$-$4H_2O$ 3 mg/l, $MnSO_4$ 5 mg/l, H_3BO_3 2 mg/l, $CuSO_4$-$5H_2O$ 0.025 mg/l, KI 0.83 mg/l, $NaMoSO_4$ 0.25 mg/l, $CoCl_2$-$6H_2O$ 0.025 mg/l, Na-EDTA 28 mg/l, $FeSO_4$-$7H_2O$ 21 mg/l, Inositol 100 mg/l, glycine 10 mg/l, thiamine-HCl 4 mg/l, pyridoxine-HCl 2 mg/l, and nicotinic acid 2 mg/l.

A detailed protocol of preparing Chu's stock media and chemical concentrations of each stock (A-E) will be presented. Chu's callus induction media is composed of 10 ml/L of stock A to E, sucrose 40 g/L, D-sorbital, 20g/L; casein enzymatic hydrolysate, 1 g/L, 2,4-D 1 mg/L, zeatin 0.5 ml/L, and agar 6 g/L. The regeneration medium consists of 10 ml/L of stock A-E, sucrose 30 g/L, sorbitol, 20 g/L, casein enzymatic hydrolysate, 1 g/L, 6-BA 2 mg/L, NAA 0.5 ml/L, and agar 6 g/L.

Abstracts of Papers on Economics and Marketing
Panel Chair: M.E. Salassi and N.W. Childs

USDA's 2004 Domestic Baseline Projections

Childs, N.W.

USDA's 2004 long-term annual supply and demand projections for the U.S. rice industry are presented. Emphasis is placed on forecasting area response, yield growth, export levels, growth in domestic use, and the season-average farm price. Underlying economic factors driving these projections are explained. Because more than 45 percent of the U.S. rice crop is exported annually, expectations regarding the world rice market—including trading prices—affect domestic baseline forecasts as well.

Changing market conditions necessitate annual long-term baseline projections, as market participants and policy makers need updated forecasts for planning and decision making. Each year, USDA presents both a domestic and international long-term supply and demand forecast for rice. The projections are made assuming normal weather over the forecast range and that current farm policies remain in effect. The baseline forecasts are made under given assumptions regarding global and domestic population and income growth, interest rates, and exchange rates. The 2004 baseline forecasts were developed in November 2003.

The 2004 baseline projects relatively stable U.S. rice acreage after 2005. The combination of market returns, loan deficiency payments, and marketing loan gains for rice producers is projected to exceed expected returns from alternative crops, primarily soybeans in the Delta. The U.S. yield growth is projected to be about 1 percent annually through 2006 then taper off to around 0.75 percent for the remainder of the baseline period. The yield growth is driven primarily by increased adoption of newer, higher-yielding long grain varieties in the South. U.S. rice production is projected to decline slightly from 2004/05 to 2006/07—a result of smaller plantings—then increase fractionally for the remainder of the forecast period. Imports are projected to continue to increase each year.

Domestic use is projected to continue expanding each year at more than twice the rate of population growth. Food use is expected to account for nearly all of the expansion in domestic use, with per capita rice consumption increasing each year. Imports share of domestic use is projected to slowly increase over the next decade. With domestic use rising at a faster pace than production, exports are projected to decline each year after 2004/05. With total use and total supplies growing about the same rate each year, ending stocks are expected to remain at 1.08 to 1.17 metric tons (24-26 million cwt) throughout the baseline period. The stocks-to-use ratio is projected to remain relatively stable at 10 to 11 percent over the next decade.

Global trading prices—which were at near-15-year lows during 2002/03—are projected to slowly rise over the next decade, largely due to modest increases in world trade and stronger demand for higher quality rice. Despite the expected increase, global prices are not projected to exceed the U.S. loan rate over the forecast period, indicating U.S. producers will remain eligible for marketing loan benefits. Higher world prices and increasing domestic use are responsible for rising U.S. farm prices during the forecast period. U.S. prices are expected to rise at a slightly faster pace than international prices, causing the U.S. price difference to widen. Despite expectations of higher U.S. prices, the U.S. season-average farm price is not projected to exceed the loan rate until 2010/11.

USDA's International Agricultural Baseline Projections for Rice, 2004/05-2013/14

Aaronson, A.C.

Long-term international agricultural baseline projections are typically made in conjunction with the detailed U.S. sector analysis and the President's Budget analysis. The long-term projections analysis was conducted by interagency committees in USDA and reflects a composite of model results and judgmental analysis. Commodities covered in the analysis include wheat, rice, corn, coarse grains, soybeans (meal and oil), cotton, beef, pork, and poultry. The projections were reviewed by the Interagency Agricultural Projections Committee, chaired by the World Agricultural Outlook Board (WAOB). The major USDA participants in the trade analysis and review include the WAOB, the Economic Research Service, and the Foreign Agricultural Service.

USDA's long-term agricultural projections are based on a number of key assumptions including:

- U.S. and international macroeconomic conditions;
- U.S. agricultural and trade policies;
- Growth rates of agricultural productivity, both in the U.S. and abroad; and
- Normal (average) weather.

Changes in any of the assumptions can significantly affect the projections, and actual conditions that emerge will alter the outcomes. This paper highlights the long-term global rice supply and use analysis.

Global rice trade is projected to grow at about two percent during the baseline period with trade reaching nearly 35 million metric tons in 2013/14. The largest import markets during the projection period are projected to be in Indonesia, Sub-Saharan Africa, Central America/Caribbean, Mexico, and the Middle East. Global production and consumption are expected to stay nearly in balance during the projection period at a rate of growth of about one percent. During the projection period the global stocks-to-use ratio will fall from 20.3 percent in 2003/04 to 11.6 percent in 2013/14. Global stocks are expected to remain relatively tight during the entire period. Thailand is expected to remain the largest exporter followed by Vietnam, India, and the United States. Thailand's exports are expected to reach nearly 10 million metric tons at the end of the period. Global rice prices are expected to increase at about 2.5 to 3 percent per year.

Analysis of Rice Trade Protection and Trade Liberalization

Wailes, E.J.

The rationale for this study is to estimate the effects of domestic and trade policy distortions on global rice trade and prices. Rice is one of the most important food crops in the world, accounting for about 20 percent of total calories in the world and an even higher share of total calories in low-income and food deficit countries. Yet, despite its importance as a basic food staple, trade is only 6.5 percent of consumption. Such limited trade is due partly to preferences for specific types and grades of rice but also to protectionist import policies based on food security objectives or price and income support to producers. These policies lead to greater domestic price variability, which comes with closed borders, or to large government expenditures on stocks used as a buffer against production shortfalls. Protection is greatest in high-income Asia--Japan, the Republic of Korea, and Taiwan, China. However, many developing countries also have high tariffs to protect domestic producers. The trade weighted average import tariff on rice was 43 percent in 2000, and tariff escalation occurs in many nations who desire to protect their rice milling sectors. A number of rice market and production characteristics make rice prices more volatile than most other commodities. Much of the Asian rice production is subject to monsoon climates, resulting in uncertain rice yields and rice supplies. Global rice trade is highly segmented by rice type (long and medium), degree of processing (milled, brown, and paddy) and quality (generally pertaining to the percent of broken kernels). As a staple food, the demand for rice is not very responsive to price and income changes. The combination of a high degree of protection, geographic concentration, market segmentation, inelastic supply response to price and an inelastic demand response to price and income results in volatile rice prices and volumes traded. Domestic policy distortions exist in a number of major rice trading nations, including the United States, the European Union, and Japan. In the case of the United States and the European Union, domestic supports result in implicit or direct export subsidies. In Japan, the government's commitment to support rice prices is based upon an aggressive rice land diversion program and a tightly managed tariff rate quota (TRQ).

Global rice trade liberalization results in significant expansion of rice trade and price adjustments. Estimates of the impact of the elimination of import tariffs and export subsidies were generated through the use of a spatial equilibrium model, RICEFLOW (Durand-Morat and Wailes) and the AGRM dynamic econometric model (Fuller, Wailes, and Djunaidi). For this study, RICEFLOW was more completely disaggregated by rice type and degree of milling and the baseline trade flows and elasticity estimates were updated through the year 2000. The AGRM structure is based on equations for supply—expressed in terms of equations that estimate area harvested and yields; and for demand—expressed in equations for domestic consumption, exports, imports, and ending stocks. Rice prices are endogenized, with world reference equilibrium prices for long- and medium-grain rice. AGRM results are presented for the years 2005 through 2012.

Policy reforms to eliminate protection in the global rice economy are estimated in this study to result in an increase of economic welfare of over USD 7.4 billion per year. Most of these gains can be achieved through the elimination of tariffs on imports. Consumers in importing countries gain USD 32.8 billion while producers in importing countries lose USD 27.2 billion. Importing country governments lose USD 2.9 billion tariff revenue but gain USD 2.7 billion by eliminating domestic supports. The net welfare gain to rice importing countries is estimated to be USD 5.4 billion. Producers in exporting countries gain USD 70.2 billion while consumers in exporting nations lose USD 68.8 billion. Imports by the exporting countries result in a loss of tariff revenue of USD 5.3 million and elimination of domestic supports saves USD 598 million. The net welfare gain in importing countries is USD 2 billion.

With global policy reform, rice trade is estimated to increase by 10 to 15 percent. Prices received by exporters would be expected to be higher by 25 to 35 percent. Prices paid by importers would be expected to decline by 10 to 40 percent, depending upon the type of rice. Rice trade, despite the expansion, would remain relatively thin. Complete policy reform would result in an increase of rice trade from the current level of 6.5 percent of consumption to 8.4 percent by 2012. Thus, one of the major sources of world rice price instability is likely to remain after liberalization. Global rice stocks have also declined over the past three years by 30 percent. Thus, the ability of stocks to buffer supply shocks has been markedly reduced. The implications of global rice trade liberalization for lower income, net-importing countries that would become more reliant upon world rice trade are not attractive. Political and food security is likely to be reduced.

Detection Methods in the Agricultural Biotechnology Industry

Shillito, R.D.

Detection methods are used in the Biotechnology and Agricultural Industry for a number of reasons. Analysis for the presence of products derived from modern biotechnology in the grain and food and feed supply is not a safety issue. These crops undergo extensive regulatory review and have been consumed for more than 6 years. Testing methods are not required by the regulatory agencies to be submitted in the USA, although labeling regulations that have been proposed in the European Union and some other countries will be important in labeling food and will affect trade. Thus, analysis for the presence of these products is an issue for end-users and consumers, although not a safety issue.

The presentation will describe some of the methods available, with an emphasis on testing grain shipments and on rice. When testing for the presence of these products, sampling is critical, and the methods tend to be for a specific product or group of products so that no single method will detect all products.

Methods range from a herbicide spray test, through Lateral Flow Strips, and ELISAs to detect proteins, and PCR to detect specific DNA sequences. Each method has its own limitations. For example, although testing for the presence of a protein is the quickest method, the PAT protein in Liberty Link rice is degraded in parboiling and cooking, in which case, PCR-based test methods may be the best option. However, PCR is not necessarily a reliable approach, as processing can degrade DNA, and many substances in plants can interfere with detection, so that methods must be validated for each matrix.

Bayer CropScience is committed to the responsible development and ultimate introduction of Liberty Link rice. While Liberty Link rice is in the pre-commercial development phase, all field sites are carefully managed to ensure the material is responsibly handled, performs well, and is properly harvested and stored. In addition, pollen dispersal studies have confirmed that current certified seed isolation practices are sufficient to prevent outcrossing with commercial rice. Thus, we do not foresee a need for routine testing of rice at this time. However, to facilitate future handling of Liberty Link rice, Bayer CropScience is developing monitoring and detection tools.

For Liberty Link rice, Bayer CropScience has developed a PCR method specific for the product, the test can detect the unique DNA sequence associated with the registered transformation event, LLRICE62 in both raw and processed matrices. Access to the method is via contract with Bayer CropScience. In contrast, Lateral Flow Strips, which can detect the PAT protein in rice grain (uncooked) and leaves, are available through public vendors and can detect the PAT protein present all Liberty Link crops.

An On-Farm Economic Comparison of RiceTec XL8 Hybrid Rice and the Cultivar Wells

Greenwalt, B.

RiceTec, Inc. released its second generation commercial rice hybrid, XL8, to U.S. farmers in 2002. RiceTec's advertising said the hybrid would generate increased net returns through a combination of higher rough rice yields, lower seeding rates, and a milling quality similar to conventional cultivars. The objective of this analysis was to compare the profitability of XL8 with the cultivar Wells using data from one commercial farm.

Partial budgets were constructed using data collected from rice fields produced on the Greenwalt Company Farm in 2002 and 2003. The farm is near Hazen, Arkansas, which is located in the northern part of the Arkansas Grand Prairie. The revenue section of the partial budgets included the total revenue per acre given the farm's dry rough rice yields and the price per dry rough bushel paid by Riceland Foods. The Riceland Foods price was based on the milling yield of the lot of rough rice. The cost section of the partial budgets included only the items that varied between XL8 and Wells: seed, nitrogen fertilizer, fertilizer aerial application, fungicide, fungicide aerial application, rice drying, and hauling rice from the farm to the receiving elevator.

In 2002, XL8 yielded 958 kg/ha (19 bu/A) more than Wells [9,785 kg/ha (194 bu/A) for XL8 vs. 8,827 kg/ha (175 bu/A) for Wells]. However, a lower milling yield (57/70 for XL8 vs. 64/73 for Wells) offset some of the XL8 yield advantage. Overall, XL8 generated $63.18/ha ($25.57/A) more revenue than Wells.

The 2002 specified cost for XL8 was $127.36/ha ($51.54/A) more than for Wells. Overall, the net return above specified cost for XL8 was $64.17/ha ($25.97/A) less than the net return for Wells.

In 2003, XL8 yielded 202 kg/ha (4 bu/A) more than Wells [8,978 kg/ha (178 bu/A) for XL8 vs. 8,776 kg/ha (174 bu/A) for Wells]. The milling yield for XL8 and Wells was the same (57/70). Overall, XL8 generated $32.57/ha ($13.18/A) more revenue than Wells.

The 2003 specified cost for XL8 was $81.57/ha ($33.01/A) more than for Wells. Overall, the net return above specified cost for XL8 was $49.00/ha ($19.83/A) less than the net return for Wells.

Two years of production on this one farm showed that RiceTec's XL8 had a higher rough rice yield potential than Wells, and in one year, a comparable milling yield. In each year, XL8 had a higher variable cost of production – primarily because XL8's higher seed cost more than offset its lower fungicide cost. In each year, XL8 had a lower net return than Wells.

Rough Rice Price Transmission Asymmetry in Louisiana Milled Rice

No, S.C., Salassi, M.E., and Gauthier, W.M.

For over three decades, agricultural economists have tested various markets for evidence of retail price asymmetry. Tests are designed to determine whether the retail price response to price increases at a lower market level is similar to the retail price response to price decreases at the same market level. If the retail price response is the same, the market is symmetric. If the response differs, the market is asymmetric. The majority of previous empirical studies have focused on farm-retail price transmissions. However, the price transmission effects between the farm and processor level are as important as the price transmission effects between the farm and retail level for field crops, especially rice. Milling transforms rough rice into the more desired milled rice. Farm-milled price spreads are sensitive to changes in rough rice prices. The millers are able to increase their margins as farm prices increase and similarly decrease margins as farm prices fall. It is the milled price that transmits changes in farm prices to the final consumers.

The objective of this study is to determine whether price transmission asymmetries exist between the farm and mill levels in Louisiana. More specifically, this study reports on a test of the null hypothesis that decreases in milled prices resulting from decreases in farm prices leads to increases in the milling margins that are as fast as increases in milled prices resulting from increases in farm prices in Louisiana. The data used in this study is based on 168 monthly observations of farm and mill prices for rice in Louisiana for the marketing years between 1987/88 and 2001/02. Farm prices were obtained from the Louisiana Department of Agriculture and Forestry. Milled prices were obtained from the 2002 ERS/USDA publication, *Rice: Situation and Outlook Yearbook.*

To examine rough rice price transmission asymmetry in milled rice, the study adopted a newly developed econometric methodology, momentum-threshold autoregressive model (M-TAR). The M-TAR methodology is a more general specification of error-correction models (ECM) found in the cointegration literature; it encompasses the ECM when price adjustment is symmetric. Using Engle-Granger two-step procedure to error-correcting modeling, the M-TAR approach first estimates an OLS regression of the long-run equilibrium between the milled rice prices (RP) and farm prices (WP): $RP_t = c + b*WP_t + u_t$. Secondly, it estimates the M-TAR equation (1): $u_t = I_t\rho_1 u_{t-1} + (1-I_t)\rho_2 u_{t-1} + \varepsilon_t$, where I_t is referred to as the Heaviside indicator function such that $I_t = 1$ if $u_{t-1} \geq 0$ or $I_t = 0$ if $u_{t-1} < 0$. If the values of ρ_1 and ρ_2 are the same, M-TAR methodology reduces to the traditional symmetric ECM specification. If the values of ρ_1 and ρ_2 are not the same, an asymmetric ECM specification is needed to capture M-TAR properties.

The Engle-Granger co-integration analysis indicated that the farm and mill prices in Louisiana were co-integrated. Given that the price series were co-integrated, the null hypothesis of symmetric adjustment was tested using Equation 1. The estimation results showed that the null of symmetric mill price adjustment ($\rho_1 = \rho_2$) was rejected. This indicated that there was asymmetric adjustment of the mill price to changes in the farm price. In accordance with M-TAR methodology, this finding necessitates an estimation of an asymmetric error correction models for Louisiana farm-mill prices. Estimates for the asymmetric ECM documented that, within a month, mill prices adjusted so as to eliminate approximately 21% of a unit negative change in the deviation from the equilibrium relationship created by changes in farm prices. On the other hand, mill prices adjusted by only 7% of a positive change in deviation from the equilibrium created by changes in farm prices. These findings suggest that increases in farm prices resulting in the reduction of the milling margins were passed on to mill prices faster than reductions in farm prices leading to increases in the milling margins in Louisiana. Moreover, the estimation of symmetric ECMs for mill prices showed that the error-correction terms were significant at the 5% level of significance, implying that mill prices converged towards long-run equilibrium.

To sum up, Louisiana mill prices converged towards long-run equilibrium. However, they responded differently to negative deviations than to positive deviations under the long-run equilibrium. In other words, the Louisiana mill prices responded much faster when the milling margins tightened due to farm price increases than when the margins became wider due to farm price decreases.

Econometric Analysis of Effects of Quality Factors on Louisiana Rough Rice Prices

No, S.C., Salassi, M.E., and Gauthier, W.M.

Price differences based on quality have been the subject of considerable research in agricultural commodities. Most of the empirical works have been conducted using hedonic price models. Estimated hedonic price functions included a composite of some set of embodied attributes, along with government grades, to explain price differences in commodities. The government grading system was implemented to facilitate trading in grain after the 1916 Grain Standards Act was passed by Congress. Economic purpose for grades was to transmit information about attributes or characteristics embodied in a commodity. However, considerable disagreement exists over the economic efficiency of the U.S. grading system to explain the variations in grain prices. The objectives of this study are to specify and estimate a hedonic price model for Louisiana rough rice prices and to examine whether or not the information conveyed by Government grades can better explain the observed price variation than quality characteristics. This study, because of its use of the most recent data, would be useful in addressing the efficiency of current federal grading and pricing practices for rough rice.

A hedonic pricing model for Louisiana rough rice (FP) was specified as: FP = F(HEAD, BROKENS, PECK, RED, CHALK, GRAD), where HEAD, BROKENS, PECK, and CHALK define the percent by weight of: three-fourths or greater whole kernels in the sample, less than three-fourths of whole kernels, kernels damaged by stinkbugs, and whole kernels one-half or more chalky, respectively. RED is percent by weight of whole or broken kernels or rice on which there is an appreciable amount of red bran, and GRAD reflects government grades, one through six. A log-linear function between the price and attributes was used for analysis.

The model was estimated using both ordinary (OLS) and generalized least squares (GLS). The OLS procedure was used to verify whether the expected autocorrelation was present. The numbers of usable observations for the marketing years 1994/95 and 1998/99 were 478 and 426, respectively. OLS estimator was used for three regression models: (1) $\ln(FP_t) = b_0 + b_1G_{1t} + b_2G_{3t} + b_3G_{4t} + b_4G_{5t} + b_5G_{6t} + u_t$, (2) $\ln(FP_t) = b_0 + b_1HEAD_t + b_2BROKENS_t + b_3PECK_t + b_4RED_t + b_5CHALKt + v_t$, and (3) $\ln(FP_t) = b_0 + b_1G_{1t} + b_2G_{3t} + b_3G_{4t} + b_4G_{5t} + b_5G_{6t} + b_6HEAD_t + b_7BROKENS_t + b_8PECK_t + b_9RED_t + b_{10}CHALK_t + w_t$. Durbin-Watson *d*-statistic indicated that autocorrelation problems exist for all three regression equations. Thus, GLS estimator was used for estimation, and the autocorrelation problems could not be found.

All GLS estimates for equations 1 and 2 had statistically significant coefficients with expected signs. In Equation 3, GLS estimates had consistent signs with a prior expectation at the 5-percent level of significance with two exceptions. In other words, the positive sign on Government grade 1 was correctly estimated, which means a premium with respect to Grade 2. But *t*-value for the parameter estimate was lower than the critical value. The other exception was an unexpected positive sign on RED, which is undesirable characteristic for rice. However, the parameter estimate is not statistically different from zero (t-value=1.26). Given robust estimation results, the hypothesis to be examined was whether or not the information conveyed by Government grades can better explain the observed price variation than four quality factors. For the marketing year 1998/99, Equation 1, relative to Equation 2 evaluates this hypothesis. Adjusted R^2 values of 0.77 and 0.15 associated with equations 2 and 1, respectively, suggest that four quality factors together offer a more powerful explanation of observed price variation than Government dummy variables combined. Similar results were found for the marketing year 1994/95. Equation 3 measures the explanatory power associated with Government dummy variables and four quality factors jointly. Adjusted R^2 (0.774) associated with Equation 3 is slightly higher than the adjusted R^2 (0.772) associated with the four quality factor Equation 2. The estimation from pooled data for the marketing years 1994/95 and 1998/99 was attempted but not appropriate according to the Chow test results.

Several observations emerged from the empirical results. First, the current government grading is quite limited in explaining the price variation in Louisiana rough rice, given the statistically lower adjusted R^2 value associated with the government grading equation. Currently, not all four quality factors considered for the study are factored into government grading. As suggested by a significantly high *t*-value in Equation 2, factoring an additional quality factor, such as PECK into grading would improve the efficiency of government grading to explain the price variation. Secondly, diverse or more grades would enhance the efficiency of the grading, partly because more than 60% of the observations are clustered between grades 2 and 3.

Determinants of Cost Variation in U.S. Rice Production

Foreman, L.F. and Livezey, J.

The control of production costs influences rice producers' competitiveness. This study used regression analysis to find factors associated with the differences in the rice cost per cwt. among U.S. producers and to estimate the factors' impact on costs. The variation in rice production costs for California producers was examined separately from southern rice producers since rice production differs significantly in these two regions.

U.S. rice producers' average cost of rice production was $0.140/kg ($6.38/cwt) while California rice producers averaged $0.155/kg ($7.07/cwt) and southern rice producers averaged $0.135/kg ($6.16/cwt). California producers had a narrower range of rice production costs than southern rice producers. California producers' rice production costs ranged from just over $0.088/kg ($4/cwt) to slightly under $0.242/kg ($11/cwt). In contrast, the rice production costs for southern producers ranged from just over $0.044/kg ($2/cwt) to over $0.330/kg ($15/cwt).

The data used in this analysis were derived from the rice version of the 2000 Agricultural Resource Management Survey (ARMS) and from the variables created to construct the Economic Research Service (ERS) rice cost of production estimates. ARMS provides a wealth of information on farm and producer characteristics, production practices, and financial performance.

Characteristics and Production Costs by State of U.S. Rice Farms

Livezey, J. and Foreman, L.

This paper uses data from USDA's Agricultural Resource Management Study (ARMS) to compare rice production costs and returns by state in 2000. Production practices and characteristics of rice farms by state were also examined.

Data from the rice production survey showed that the average cost of producing a kilogram (kg) of rice in 2000 was $0.132 ($6.00/cwt), ranging from $0.118 ($5.37/cwt) in Arkansas to $0.160 ($7.29/cwt) in Texas. Arkansas and Mississippi had the lowest costs of rice production and Texas and California had the highest. Regional differences in rice production practices and farm and operator characteristics were major influences on production costs among rice producers. Major differences among states included costs for chemicals, fertilizer, irrigation water, and custom operations. Texas and California had the highest costs for all of these items and were the only states to have costs for purchased irrigation water. Arkansas, where nearly half of the rice was produced in 2000, had the lowest costs for chemicals and custom operations. Mississippi had the lowest costs for fertilizer.

Rice farms also differed by type of rice grown, method of planting, and diversity of commodities produced. Arkansas and Mississippi rice farms had the most diverse operations. Percentage of rice to total production value was 43 percent on Arkansas rice farms and 36 percent on Mississippi rice farms compared with 61 percent for Louisiana farms and 87 percent for California farms.

Factors Influencing Rough Rice Storage Decisions for Louisiana Rice Producers

Salassi, M.E., Gauthier, W.M., Street, A., and No, S.C.

Rough rice marketing options for rice producers in Louisiana have traditionally focused on the decision of whether to sell rice at harvest time or store it for later sale. How this important decision is made varies greatly across producers. Many growers use timely rice market information for the current crop year and base their selling and storage decisions on projected changes in the rough rice price over the marketing year. Some producers use predetermined selling strategies, which specify the portion of the harvested crop to be sold in particular months, irregardless of current or projected market price levels. Still other producers appear to have no specific marketing strategy, holding large portions of the harvested rice crop very late into the marketing season. Although income tax considerations and other factors can have some influence on when a rice crop is sold, selling rice to maximize net returns above storage and interest costs is a decision that should be carefully evaluated by producers. Net return gains from careful attention and close management of the crop in the production phase can be erased or offset by net return losses from insufficient attention of when to sell the crop in the marketing phase.

A study was designed to evaluate alternative rough rice marketing strategies related to the storage of rough rice and timing of the cash sale within the marketing year. One of the primary objectives of the study was to identify key factors that rice producers in Louisiana could consider at harvest time in deciding whether to sell rough rice early in the marketing year or store it for later sale. Twenty years of actual monthly Louisiana rough rice prices, over the 1980/81 to 2000/01 period, were used to estimate net returns per hundredweight above storage and interest costs for each month of the marketing year. A combination of mathematical programming and simulation procedures were used to identify optimal rough rice marketing strategies based on actual monthly price history.

A mathematical risk programming model was developed and used to evaluate timing of cash sales over the marketing year with the objective of maximizing market net returns above storage and interest costs while incorporating price risk associated with monthly rough rice price changes. As expected, results indicated that price risk could be minimized by spreading crop sales over a period of several months throughout the marketing year. These strategies also resulted in somewhat lower average net returns compared with other marketing strategies. Marketing strategies generating the highest net returns were those associated with selling a large portion of the crop at harvest time or very early in the marketing year. Results for these selling strategies split total rice sales between the months of August and November. Marketing strategies modeled within this framework were considered to be fixed strategies, inflexible to the current market price level in a given year. To incorporate marketing decision flexibility in the analysis, a simulation model was developed that permitted the evaluation of marketing decisions that could vary with the current market price level.

Simulation analysis evaluated fixed and flexible marketing strategies. Fixed strategies were defined for various combinations of monthly sales irrespective of market price level. Flexible marketing strategies were defined for scenarios in which the timing of sale was dependent on the current market price level, as well as several other factors. Factors evaluated included the current market price level in the first few months of the marketing season in relation to the long-run average price, changes in the USDA rice acreage and production forecast, and changes in world rice production, exports, and ending stocks from the previous year. General results of the study indicated that flexible marketing decisions, those which vary with the market price level in a given year, generate higher average net returns and fixed strategies. Changes in world rice production from the previous year was found to be the most important factor in deciding how long to store rice before sale. In years when world rice production decreased from the previous year, higher net returns could be gained from storage of rough rice for sale in February or later. Increases in world rice production resulted in maximum net returns for much shorter periods of storage. Domestic market price levels in the first few months of the marketing year were also found to be important factors to evaluate. In years when harvest time market prices are above long-run average price levels, average net returns could be maximized by selling rough rice early in the marketing year to capture sales at these higher price levels. During such years, it was found that when harvest time prices are above average, rough rice prices during the remaining months of the marketing year tended not to rise enough to cover additional storage and interest costs.

Economic Evaluation of Rice-Based Cropping Systems under Alternative Management Practices

Watkins, K.B., Anders, M.M., Windham, T.E., and Hill, J.L.

Arkansas rice producers face an uncertain production environment. Low farm prices and high production costs have made many rice producers dependent on government payments to maintain profitability. Rice producers also face declining groundwater availability in many areas of the state and uncertainty about future regulations on sediment transport from fields. This uncertain production environment forces many producers to consider changing their management systems (shifting to different rotations, changing tillage practices, or switching to a different crop mix) to sustain or improve profitability. However, rice producers are reluctant to try new management practices without information about the potential economic outcomes.

This analysis uses data from a long-term rice-based cropping systems study at the U. of A. Rice Research and Extension Center (RREC) near Stuttgart, Arkansas, to determine how various production components like rotation, tillage, and fertility affect rice system profitability in the Arkansas Grand Prairie region. Crop yields and net returns are compared for 12 production systems differing by rotation (continuous rice; rice-soybean; rice-corn), tillage (conventional till versus no-till), and fertility (standard versus enhanced) for the years 2000 through 2003. The Duncan Multiple Range Test is used to determine significant differences in mean yields and returns across rice system components. Return variability is evaluated for each production system using the coefficient of variation, and a simple safety-first criterion is used to identify production systems preferred by risk-averse rice producers.

Fertility had no significant impact on either average crop yields or average net returns across rice systems, implying little economic gain from applying fertilizer above recommended levels. Rice-soybean systems produced the largest average net returns due to lower production costs for soybeans in the cropping sequence, while rice-corn systems were the least profitable due to low corn yields. Crop yields and net returns were smaller on average for no-till than for conventional till rice systems. However, no-till rice-soybean systems exhibited the least return variability. A conventional till rice-soybean rotation using standard fertility was the most profitable of the 12 systems evaluated (average net return = $357/ha, coefficient of variation = 48), while a no-till rice-soybean rotation using standard fertility produced the lowest net return variability (coefficient of variation = 11, average net return = $261/ha). The safety-first criterion indicated that a risk-averse rice producer would be indifferent between using either rice system.

Land Tenure and Production Decisions: Projected Cost Structures and Decision Support Aid for Texas Coastal Bend Rice Landlords and Producers

Falconer, L., Jahn, R., and Anderson, D.

The increased contribution of decoupled government payments on rice base acreage to landowner revenue has led to a major change in land tenure agreements for rice land in the Texas Coastal Bend. This paper describes how information was developed and presents a decision support aid to help landlords and tenants make sound land tenure arrangements. Cost of production estimates for rice production in the Texas Coastal Bend are generated and used in a decision support aid that allows landlords and tenants in reaching sustainable land tenure agreements for rice production.

Data related to the production practices for rice in the Texas Coastal Bend are obtained from three main sources. These sources include interviews with producers to obtain information on machinery complements employed, labor utilized, indirect cost information, and size of operation. Input suppliers are interviewed to provide cost information for inputs and custom operations. Texas Agricultural Experiment Station and Texas Cooperative Extension (TCE) personnel are also interviewed to provide information related to water utilization, pesticide, and fertilizer utilization rates. These data are then processed using the Mississippi State University Budget Generator to create cost of production report estimates.

It is important to provide landlords, as well as tenants, with information related to expected costs of production for representative production technologies employed in the area. This information serves as a base for producers and landlords to begin to address the land tenure question, as they can then tailor the general information to their specific situation.

The land tenure decision support aid utilizes cost of production information, along with base acres, program yields, direct payments, and expected counter-cyclical payments, to develop expected returns to land under user specified cash and share lease arrangements. The decision support aid adjusts payments for under-planting of base acreage and couples that revenue stream with expected production receipts to calculate total revenue per acre. This revenue stream is joined with cost of production information to arrive at a net return to land. This net return can then be compared with a user input target value for net return to land. If that target is not reached by the specified cost and return structure in that scenario, the decision support aid allows users to easily modify the input data to attempt to reach an acceptable land tenure arrangement.

Assessment of Broiler Litter Use on Cut Rice Fields in Arkansas

Young, K.B. and Wailes, E.J.

Land leveling can increase both irrigation efficiency and rice yield. However, in some soil areas in Arkansas, rice yields decline sharply after leveling. The decline varies with the depth of cut. Application of broiler litter helps to maintain rice yield after leveling, thus, providing a high-value, niche market for broiler litter in these areas.

The economics of broiler litter use on cut rice land is evaluated for the Arkansas delta as part of a more general economic study of excess broiler litter disposal from northwest Arkansas. Field experiments were conducted in eastern Arkansas over a 2-year period involving varying combinations of commercial fertilizer and litter on cut rice land. Cuts varied from shallow (10.16 to 15.24 cm) to deep (1.21 to 1.82 m). Returns from litter application are evaluated in terms of the increased rice yield in Year 1 when litter supplemented a basal commercial fertilizer of phosphorus, potassium, and zinc.

Results with the basal fertilizer application alone are 1,796 kg/ha (40 bu/A) on the deep cut land and 4,670 kg/ha (104 bu/A) on the shallow outland. Supplementation with 0.45 to 1.81 metric tons of litter increases rice yield to a level of 2,737 to 4,311 kg/ha (61 to 96 bu/A) on the deep cut land and 5,074 to 5,658 kg/ha (113 to 126 bu/A) on the shallow cut land. Estimated return per ton of litter is $140 to $210 on deep cut land and $55 to $90 on shallow cut land.

Abstracts of Posters on Economics and Marketing
Panel Chair: M.E. Salassi and N. Childs

To What Extent Do Cultural Practices Impact Rice Milling Yields and Farm Returns?

Hill, J.L., Watkins, K.B., Anders, M.M., Grantham, J.D., and Holzhauer, J.H.

Field yield is generally recognized as the most important component of revenue to a rice farmer. Milling yield may not receive as much attention as field yield, but it is also important in determining revenue because it determines the price received for the rice. Milling yield is the estimate of whole kernels and total kernels (whole + broken) in a rough rice sample after the hull and outer bran layers have been removed. The loan rate price a farmer receives for a load of long-grain rice is determined by the estimate of whole kernels and broken kernels in a sample taken from the load, where whole kernels have a 2003 loan rate value of 0.2348 $ kg^{-1} ($10.65 cwt^{-1}) and broken kernels have a value of 0.1175 $ kg^{-1} ($5.33 cwt^{-1}). The objective of this analysis was to analyze the possible impacts of crop rotations, tillage practices, fertilizer rates, and variety on milling yields and farm revenues.

Data for this analysis were obtained from the 2003 rice crops in a long-term cropping systems study at the University of Arkansas Rice Research and Extension Center (RREC) in Stuttgart, Arkansas. The study is composed of three crop rotations: (1) continuous rice rotation, (2) rice-soybean rotation, and (3) rice-corn rotation. Each rotation is also divided into: (1) conventional till and no-till sections, (2) standard fertility and enhanced fertility sections, and (3) Wells and LaGrue rice varieties. Field yields for 2003 were averaged over four replications. Milling information was obtained by 24 milling samples (3 systems * 2 tillage * 2 fertility * 2 varieties), which were sent to both Riceland Foods and Producers Rice Mill for appraisal. The average of the results from the samples graded by Riceland and Producers was used as the milling yield and grade. Rice prices were calculated based on the milling yields from the samples collected and the 2003 loan rates for whole and broken long-grain rice. Production costs were estimated with partial budgets based on field operations performed on the long-term study during 2003. The Duncan Multiple Range Test was used to test for significant differences in means across (1) rotation, (2) tillage, (3) fertility, and (4) variety for head kernel yield (HY), total milling yield (TY), broken kernel yield (BY), loan rate milling yield value (MYV), field yield (FY), gross returns (GR), and returns above variable costs (RAVC).

Significant differences were found across rotation and tillage for FY, GR, and RAVC. These differences suggest that the lower field yield for the continuous rice rotation resulted in lower gross returns and lower returns above variable costs. The same is also true for the lower field yields in the no-till rice systems versus the conventional till systems. Fertility was found to be significant for RAVC only, implying that additional fertilizer resulted in higher costs without the benefit of higher yields. The most significant differences were found between varieties. HY, TY, MYV, FY, GR, and RAVC were found to be significantly different between varieties, but BY was not significant. Based on these results, it is clear that variety is an important determinant of both milling yields and farm revenues.

Does the U.S. Rice Industry Qualify for Trade Adjustment Assistance?

Beckman, J., Wailes, E.J., Hoffman, L., and Childs, N.

The Trade Act of 2002 established a new program, Trade Adjustment Assistance (TAA), for farmers. The USDA provides certain assistance for farmers that are determined eligible for the program such as cash, technical assistance to help compete with imports, and employment and training services. To be considered for such aid, groups of at least three farmers must submit a petition to the Economic Research Service (ERS) who completes a field study and determines if that particular commodity qualifies for assistance. If the commodity qualifies for assistance, farmers have 90 days to contact the Farm Service Agency (FSA) to apply for assistance.

The basis on whether or not the commodity qualifies for assistance is determined by criteria set by the USDA. The criteria include that there has been a 20% decline in the national average price of the commodity over the last five years and that imports of that commodity have contributed to the decrease in the national average price.

Rice can easily be shown to qualify for the first criteria if the prices of 2002 are used. This is because the price of rice had declined substantially from 1996-2001. The average for those years was $0.150/kg ($6.83/cwt), with a 20% decline being $0.120/kg ($5.46/cwt). Since the price in 2002 was $0.093/kg ($4.22/cwt), petitions based on 2002 prices would meet the first criteria. However, the price of 2003 is projected to be between $0.154 and $0.165/kg ($7.00 and $7.50/cwt). The average price for the five years before was $0.127/kg ($5.78/cwt). Therefore, even using the lowest projected price for 2003, this criterion would be hard to meet if based on 2003 prices. The two different scenarios are both presented because the ERS does not specify when they use the new year's price.

The second criteria can be shown to fit some types of rice better than others. For example, U.S. long-grain rice is projected to produce 6.59 million metric tons (145.3 million cwt) of rice in 2003 and only import 476,269 metric tons (10.5 million cwt). Since, hypothetically, there will be 7.77 million metric tons (171.5 million cwt) of supply (including beginning stocks) in the United Stated with imports making up only 6.1% of total rice, it will be difficult to prove that imports had a large effect on long-grain rice. Medium- and short-grain rice production is projected to be 2.35 million metric tons (52 million cwt) in the United States in 2003, with imports at 249,474 metric tons (5.5 million cwt). Total supply is projected to be 3.02 million metric tons (66.7 million cwt), including beginning stocks. This puts the percentage of imported rice at 8.2% of the U.S. market.

U.S. imports are primarily aromatic rice varieties that are not produced in the United States. Farmers that grow any of these varieties, Jasmine and Basmati, domestically could probably make the case that imports do drive down their U.S. price. Before a group of farmers decides to submit a petition, there are several considerations to be made. For one, producers cannot receive cash benefits under this program and another trade adjustment program. The payments under this program cannot exceed $10,000 during any 12-month period and producers cannot have an average adjusted gross income for the three preceding tax years exceeding $2.5 million.

An Analysis of the Relationship between Soil Variations and Yield

Greenwalt, A., Jayroe, C., and Baker, B.

Soil variation can be a direct source of yield differences due to the diverse ratios of sand, silt, and clay. These differences affect the water holding capacity, nutrient leaching, and plant root stability in soils. For this analysis, electrical conductivity was observed over several Arkansas rice and soybean fields with a Veris EC_{a}. A final analysis was made with yield data, and correlations were based on developed interpolations developed from each data layer in a GIS. Correlations between yield and EC_a measurements were more significant with soybean yield than rice. However, in fields that had been precision leveled, patterns were distinguishable in both. Special attention will be directed to areas where "cuts" have been made, and alternatives are being considered where severe yield reductions are a result.

Application of Variable Rate Fungicides with the Use of Multispectral Imagery

Jayroe, C., Baker, B., Greenwalt, A., Cartwright, R., Stiles, S., and Hamilton, M.

In Arkansas, over 30% of the 607,020 ha (1.5 million A) of rice planted are susceptible to sheath blight and other fungi. Treatments for these inputs typically cost in excess of $49/ha ($20/A), making fungicides the most expensive input in rice production. In the past, multispectral imagery has shown significant results for identifying areas of plant stress. This study examines the possibility of using multispectral aerial imagery as a tool in identifying signs of fungus infestation. The imagery was acquired during the vegetative stages of growth and terminated at panicle initiation. The fields were observed weekly for any instances of stress, disease, or infestations identified by the multispectral imagery. The objective of this project was to refine the use of multispectral imagery and determine its usefulness in making variable rate prescriptions and/or midseason decisions. The economic impact on rice production was considered from a variable rate perspective and, in this study, yielded a 63% savings.

Abstracts of Papers on Plant Protection
Panel Chair: M. Stout

Aspects of the Ecology of Rice Stem Borers in Arkansas

Bernhardt, J.

The rice stalk borer, *Chilo plejadellus* Zincken, was discovered in rice for the first time in extreme southeastern Arkansas (Chicot Co.) in 1981. A survey in 1989 documented the expansion of the infestation to all counties with rice except three in extreme west-central Arkansas with very small amounts of rice. The biology of *C. plejadellus* was found to be similar to other stem borers: adults oviposit on the leaves on the upper portions of rice canopy; larvae chew entry holes into the plant behind leaf sheaths of tillers or the main culm; infested vegetative plants have dead tillers and/or dead main culms (deadhearts) due to larval feeding on the interior portions of the stalk; infested reproductive plants also have larval feeding on the interior of the stalk that result in partial or full blanking of the florets on panicles (whiteheads). Only rice stalk borers were found during the 1989 survey and in all subsequent field tests from 1988 to 2003 at the Rice Research and Extension Center near Stuttgart. However, in 2003, limited larval collections discovered larvae of the sugarcane borer, *Diatraea saccharalis* (F.), in southeastern Arkansas (Desha Co.).

Beginning in 1998 and conducted every year since, rice plots have been planted to evaluate the susceptibility of cultivars to the rice stalk borer. A split-plot design was chosen with and without insecticide as main plots and cultivars as subplots. A seed treatment of Icon 6.2FS at 0.042 kg ai/ha was used to suppress damage by the rice stalk borer. Rice was drill seeded at 100 kg/ha for long-grain cultivars and 112 kg/ha for the medium-grain cultivar 'Bengal.' Plots were nine rows with 17.8-cm (7-inch) spacing by 7.6 m (25 ft). Cultivars received recommended amounts of urea in a 3-way (1998-2000) or 2-way split (2001-2003). Depending on weather and soil conditions each year, two to four planting dates were accomplished during these times: late April, early May, mid May, late May, or early June. The density of whiteheads/plot was taken about 2 weeks after heading and served as an indicator of susceptibility to the rice stalk borer.

Planting date had a profound influence on infestation density. Rice planted early in the season, regardless of cultivar, had fewer whiteheads than did rice planted late in the season. Combined data over all years yielded an exponential increase in average number of whiteheads from a low in rice planted in late April (2/plot) to a high in early June (137/plot).

In general, cultivars differed in susceptibility to infestation and/or damage and the insecticide Icon reduced the number of damaged plants by 40 to 60%. For tests from 1998 to 2000, Bengal and 'Drew' had similar densities of whiteheads/plot. For example, the averages were 1.5, 3, 10, 35, and 231/plot for late April, early May, mid May, late May, and early June, respectively. 'Cypress' averaged 7, 12, 55, 143, and 331 whiteheads/plot for similar ranges in planting dates. In 1999, 366 m of the rouging row was searched for whiteheads in Drew, 'Wells,' Cypress, and 'Cocodrie' foundation seed fields at the Rice Research and Extension Center. Whiteheads were counted if found 1 m on either side of the rouging row. The total number of whiteheads for the four cultivars was 6, 3, 12, and 50, respectively. Also, 366 m of paddy edge, bar pit, and levee were searched for whiteheads. The total found in the three locations for Drew, Wells, Cypress, and Cocodrie was 23, 36, 132, and 671 whiteheads, respectively. Percentages in the three locations were 44, 33, and 23%. These data supported the relative susceptibility found in the small plot tests but also emphasized that the preferred oviposition site of adults was along the patty edge and levees in rice fields.

For tests from 2001 to 2003, Cocodrie replaced Cypress and Wells was added to the field tests. Cocodrie was found to be very susceptible to infestation and averaged 14, 32, 78, and 154 whiteheads/plot for early, mid, and late May, and early June plantings, respectively. Bengal averaged 5.6, 9.5, 31, and 96/plot; while Wells was found to very resistant and averaged 1.4, 1.8, 3.5, and 8.6 whiteheads/plot for the same planting times.

For tests in 2002 and 2003, ‘Ahrent’ and ‘Francis’ were added to the field tests. Both were found to be very susceptible to infestation. Ahrent averaged 7.3, 32, 76, and 99 whiteheads/plot for the early, mid, and late May and early June plantings, respectively; Francis averaged 8.3, 38, 88, and 150 whiteheads/plot; and Bengal for 2002 and 2003, averaged 9.5, 15, 31, and 96 whiteheads/plot for the same four planting times. Growers would be encouraged to plant during the early part of the season to avoid excessive yield losses from rice stalk borer. Growers should also avoid planting highly susceptible cultivars during the late part of the season.

Stalk Boring Insects in Rice: A Case of Expanding Insect Populations

Castro, B.A. and Stout, M.J.

Injury and damage caused by stalk boring insects in rice have increased in recent years in Louisiana. Stalk boring insects currently affecting rice in Louisiana involves several lepidopterous species (Lepidoptera:Crambidae), which include the sugarcane borer (SCB), *Diatraea saccharalis* (F.); the rice stalk borer (RSB), *Chilo plejadellus* Zincken; and more recently, the European corn borer (ECB), *Ostrinia nubilalis* (Hübner). The SCB was observed to cause approximately 95% plant destruction to a rice field in central Louisiana in 2002. During the same year, approximately 20% of rice fields in central Louisiana suffered significant damage as a result of SCB attack. The ECB was reported to cause 75% infestation to a north Louisiana rice field in 2003. A fourth borer species, the Mexican rice borer (MRB), *Eoreuma loftini* (Dyar), currently not present in Louisiana, has maintained an eastbound migratory pattern from rice fields in southeastern Texas, threatening the main rice producing areas of southwest Louisiana. The MRB was reported to cause up to 50% yield reduction in experimental rice fields in Texas. There are no economic threshold levels established for borer infestations in rice in Louisiana, and no insecticides are currently labeled against borer insect pests in rice in our state.

A field experiment was conducted in 2003 at the Macon Ridge location of the LSU AgCenter’s Northeast Research Station, near Winnsboro, LA. The objective was to assess the efficacy of selected insecticides against native stalk borer infestations in rice. Rice seed was drilled in a Gigger-Gilbert silt loam on June 23 at a rate of 112 kg/ha (100 lb/A). The experimental design consisted of a randomized complete block with 1.52 x 4.57 m plots (5 x 15 ft), seven rows per plot and four replications. The field was flushed on June 25 and nitrogen was applied as urea at a rate of 179 kg N/ha (160 lb N/A) prior to permanent flood, which was established on July 11. Treatments included Icon 6.2FS at 0.039 kg ai/ha (0.035 lb ai/A), Intrepid 2F at 0.112 kg ai/ha (0.10 lb ai/A), Confirm 2F at 0.112 kg ai/ha (0.10 lb ai/A), Karate-Z at 0.033 kg ai/ha (0.03 lb/A), Mustang Max 0.8EC at 0.022 kg ai/ha (0.02 lb ai/A), Prolex 1.25CS at 0.016 and 0.033 kg ai/ha (0.015 and 0.03 lb ai/A), and an untreated control. Icon was applied as a seed treatment prior to planting. All other insecticides were applied as foliar sprays on August 27 using a CO_2-charged backpack system calibrated to deliver 140 l/ha (15 gpa) at 2.1 kg/cm^2 (30 psi) through four flat-fan nozzles at 50.8-cm (20-inch) spacing between nozzles. Rice plants were at pre-boot stage at time of spraying (5-cm average panicle length, non-emerged). Field sampling prior to insecticide spraying revealed a larval borer population consisting of 99% SCB and 1% RSB on rice plants. Borer injury data were collected on September 19. Data collected included number of whiteheads and partial whiteheads per plot. Yield data were collected by mechanically harvesting plots on October 24.

All insecticide treatments, except Icon and Intrepid, significantly ($P = 0.011$) reduced number of whiteheads per plot compared with non-treated plots. Only Karate and Prolex (at 0.033 kg ai/ha) significantly ($P = 0.027$) reduced the number of partial whiteheads per plot. Significant differences in yields were not observed ($P = 0.238$) among treatments and the untreated control.

Improved Integration of Insecticides into California Rice for Rice Water Weevil Management

Godfrey, L.D. and Lewis R.R.

Insecticides are an important means to control rice water weevil (RWW), the most important insect pest in California rice. Cultural controls provide partial management of this pest, but severe infestations require insecticides to minimize yield losses. A switch from the use of preventative, preflood applications of insecticides to the use of postflood applications of insecticides occurred during the last 5 years. This change in management approach has been efficiently enacted by growers and crop consultants. However, questions have arisen as to ways to better integrate these postflood insecticides into rice pest management. The goal of this research was to optimize use patterns for the postflood insecticidal controls such that efficacy can be maximized, costs could be reduced, and management activities refined.

Determining the need for treatment, i.e., threshold, was one of the primary needs for managing RWW with postflood applications. The applicability of the floating barrier trap (developed at the Univ. of Arkansas) for monitoring adult RWW populations was studied at nine locations in each of 2001, 2002, and 2003. The research had two primary objectives: 1) determine the ability of the trap to capture weevils under a range of grower field conditions and 2) evaluate the relationship between adult captures and the resulting larval infestation. The highest capture of adults during any collection period in 2003 was 3.1 adults/trap/day. Adult weevils were captured at eight of the nine study sites. The majority of the captures were during the first 10 days of flooding and actually the first 4- to 5-day period was the most critical.

Selected California rice varieties (nine in total) were evaluated and compared for susceptibility and response to RWW in 2001 thru 2003. The goal was to determine if all varieties are equally susceptible to RWW infestation and to quantify the effect on yield given an equal RWW larval infestation level. Some varieties may be more attractive to RWW adults for feeding and egg-laying and similarly some varieties may regrow roots more vigorously, partially mitigating the damage. In 2003, for adult feeding, M-206 was the most preferred variety, M-401 was equal to M-202, and all the other varieties (including long-grain, short-grain, and specialty rice cultivars) were less preferred for RWW adult feeding. M-205 and M-202 had the highest RWW larval densities with larval populations being considerably lower (~½) in all the other varieties.

Studies were conducted to answer the question of how long during the season is RWW control needed to protect yield, i.e., what is the cost:benefit relationship of making one or more insecticide applications for RWW. Plots were infested with RWW adults from the 2- to 8-leaf stages at moderate and severe levels. Data were collected on plant scarring by adult RWW, larval numbers, rice grain yield, rice plant gas exchange (including photosynthetic rates), plant growth and development (including panicle emergence timing), and yield parameters (panicles/m^2, kernels/panicle, etc.). Scar incidence from RWW adults generally reached 100% in the high infestation regime plots. RWW larval counts responded well to the infestation treatments and larval populations peaked at 9.4/core sample. Rice grain yields were significantly reduced by severe, early RWW feeding. Uninfested ring plots averaged about 6330 kg/ha. With infestations of adults at the 2-leaf stage, yields were reduced by about 50%. Yield losses averaged about 15% more when the infestations were delayed by 1 week. The later infestation timings had no consistent effects on yield. Data on plant growth (dry weight) showed similar results.

Recent Stem Borer Research in Rice in Texas

Way, M.O., Wallace, R.G., Nunez, M.S., Reagan, T.E., McCauley, G.N., and Vawter, L.J.

Pheromone trapping in 2002 and 2003 revealed that the introduced pest, Mexican rice borer (MRB), *Eoreuma loftini* (Dyar), has spread into all rice-producing counties on the Texas Upper Gulf Coast, except those east of Harris County where Houston is located.

In 2002, selected rice varieties were evaluated for susceptibility to the MRB and sugarcane borer (SCB), *Diatraea saccharalis* (F.), at Ganado, TX, where stem borers are serious pests. This replicated, small plot experiment was designed as a split plot with varieties as main plots and treated or untreated for stem borers as subplots. Treated plots were sprayed multiple times during main crop production with lambda-cyhalothrin. For the main crop, whiteheads were most to least abundant in Priscilla, Lemont, Saber, Cocodrie, Jefferson, CL121, Cypress, Bolivar, XL7, and XL8. For the ratoon crop, whiteheads were most to least abundant in Cocodrie, Saber, Priscilla, Cypress, CL121, Bolivar, Jefferson, Lemont, XL8, and XL7. Across subplots, XL8 produced the highest yields in the main crop, 10,353 kg/ha, and XL7 produced the highest yields in the ratoon crop, 2066 kg/ha. Across main plots, treated plots had 96 and 38% fewer whiteheads than untreated plots in the main and ratoon crop, respectively. Across main plots, treated plots outyielded untreated plots 1407 and 175 kg/ha in the main and ratoon crop, respectively.

In 2003, two putative Lepidoptera-resistant transgenic lines and their controls were evaluated for stem borer activity at Ganado. This replicated, small plot experiment was designed as a randomized complete block. Seedling vigor was excellent in all plots. A very heavy natural infestation of SCB uniformly infested the plots beginning at about panicle differentiation. Average number of bored culms per plant was about 15 for the control lines and 0 for the insect-resistant lines. Average number of dead SCB larvae per plant was 0 for the control lines and 29 for the insect-resistant lines. Yields of the control lines averaged 233 kg/ha compared with 5613 kg/ha for the insect-resistant lines.

A Degree Day Model to Predict the Emergence the Rice Water Weevil from Over-Wintering Sites in Louisiana

Zou, L., Stout, M.J., and Ring, D.R.

The rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, is the most destructive insect pest of rice in the United States. Degree-day models were developed to predict the emergence date of adults from overwintering in spring. The best-fit parameters for the model describing the emergence of weevils from overwintering sites were: low temperature threshold, 60^{o}F; start date for accumulating degree days, 33 Julian days; cumulative catches of weevils in light traps, 6. Using these parameters, emergence of weevils occurred after accumulation of 250.5 degree-days (°F × Day). The model predicted emergence of weevils in 2001, 2002, and 2003, with an error of 4, 7, and 1 days.

Screening the Uniform Regional Rice Nursery (URRN) for Rice Blast Resistance

Boza, E.J., Correll, J.C., Lee, F.N., Gibbons, J.W., Moldenhauer, K.A., and Ouedraogo, I.

Over 200 entries in the 2003 URRN germplasm collection were screened for resistance to the rice blast pathogen, *Pyricularia grisea.* The germplasm was screened against nine isolates representing seven physiological races of the pathogen. The isolates (and races) used were 49D (IB49), 24 (IG1), A264 (IC17), ZN46 (IC1), A598 (IB49), TM2 (race k), A119 (IB49), ZN15 (IB1), and ZN7 (IE1). The isolates represent several MGR586 DNA fingerprint groups, as well as the two most commonly encountered races, IC17 and IB49.

The URRN entries were grown in the greenhouse in a 40 cell/tray format for approximately 4 weeks and fertilized 1 to 2 times with Peters 20-20-20 (approximately 1 g/tray) after 2 to 3 weeks. Also, ferrous sulfate at 1 g/tray. The cultivar M201 was included in all inoculations as a susceptible control. Seedlings at the 3- to 4-leaf stage were then inoculated with the rice blast pathogen at 200,000 spores/ml to which 0.5 ml of 2% Tween 20 was added to 50 ml of inoculum as a sticking agent. Inoculum was produced by growing the isolates on a rice bran agar medium under continuous lights for 7 to 10 days. Inoculated plants were incubated at approximately 22 C for 24 h, and then returned to the greenhouse.

Plants were scored for disease reactions 7 days after inoculation using a qualitative and quantitative disease rating scale of 0-9 where 0 = no evidence of infection; 1 = pinpoint infections, hypersensitive response; 2 = infections with open centers, lesions < 2 mm; 3 = infections with open centers beginning to expand but <3 mm; 4 = susceptible type lesions (expanding/open centers) on < 10% of the leaf area evaluated; 5 = susceptible type lesions on 10 to 25% of the leaf area; 6 = 26-50%; 7 = 51-75%; 8 = 76-90%; and 9 = >90%. A disease reaction of 0 to 3 was considered a resistant reaction whereas a reaction of 4 or greater was considered a susceptible reaction. The entries were ranked as highly resistant (HR) if the entry was resistant to all isolates examined; resistant (R) if resistant to all but one isolate; moderately resistant (MR) if resistant to five or seven isolates; moderately susceptible (MS) if susceptible to five or seven isolates;. susceptible (S) if susceptible to all but one isolate; or highly susceptible (HS) if susceptible to all isolates examined.

A wide range of disease reactions was observed among the genotypes examined. The susceptible cultivar M201 had a range of disease reactions in the various tests of 6 to 8. The cultivar M201 was considered to be highly susceptible in all tests conducted. Among the 200 URRN entries, 19 were ranked as HR, 18 as R, 52 as MR, 28 as MS, 37 as S, and 45 as HS. Isolate 49D (race IB49) was the most aggressive isolate tested with only 32 entries ranked as resistant. A total of 31 of the most resistant entries were identified and run in several additional tests to evaluate resistance. The disease reactions observed should assist rice breeders in selecting advanced germplasm with blast resistance and should help in the development of rice cultivars with improved rice blast resistance.

An Update on the Genetic Diversity of the Rice Blast Pathogen in Arkansas

Correll, J.C., Boza, E.J., Cartwright, R.D., Ouedraogo, I., and Lee, F.N.

When screening for disease resistance to the rice blast pathogen, it is important to know the spectrum of genetic diversity in the contemporary population. In an effort to characterize genetic diversity in the rice blast population in Arkansas, 300 to 500 monosporic isolates of the pathogen *Pyricularia grisea* are recovered and stored for characterization annually. The isolates are recovered from numerous fields, from both symptomatic leaf and panicle tissue from numerous commercial cultivars.

The isolates of *P. grisea* are characterized using a number of tests including DNA fingerprinting, mitochondrial DNA RFLPs, mating type, vegetative compatibility, and virulence. Although up to eight different MGR586 DNA fingerprint groups have been identified from Arkansas in archived collections, we have only identified four MGR586 DNA fingerprint groups (groups A, B, C, and D) since we have been monitoring populations beginning in 1990. These four DNA fingerprint groups correspond with four distinct genetic groups or vegetative compatibility groups (VCGs). Thus, it is evident that the rice blast pathogen population in Arkansas is largely made up of four distinct clones of the pathogen. However, there is some virulence diversity within each of the genetic groups identified. Although not extensively evaluated, there clearly is a bias for certain groups in some locations and/or on some cultivars.

A total of 337 monoconidial isolates were recovered from eight rice growing counties in Arkansas during the 2003 growing season. The isolates were recovered from both symptomatic leaves and panicles. The isolates are being characterized for molecular (MGR586DNA fingerprints), genetic (vegetative compatibility), and virulence diversity in greenhouse inoculation tests. Isolates recovered from the 2003 season predominantly belonged to the A fingerprint group and VCG (US01).

Importation of Rice Seed for Propagation from Argentina into Southern United States: Qualitative, Pathway-Initiated Pest Risk Assessment

Cuevas, F. and Miller, R.

Safeguarding American crops from potential pest introductions requires frequent reviews of plant quarantine regulations to effectively address current and emerging threats. Importation of seed rice into the United States from all foreign countries and localities except the Republic of Mexico has been prohibited since November 23, 1933. Restrictions were established to protect the U.S. rice industry from importation of "injurious fungous diseases of rice, including downy mildew (*Sclerospora* (syn. *Sclerophthora*) *macrospora*), leaf smut (*Entyloma oryzae*), blight (*Oospora oryzetorum*), and glume blotch (*Melanomma glumarum*). Since then, downy mildew and leaf smut have been reported in the United States as minor diseases, Melanomma glumarum has been reported as the cause of glume blight, a disease already found in the United States. caused by *Phoma sorghina* (Sacc.), and the genera *Oospora* has been declared obsolete. The threat of diseases included on the original restricted list has become increasingly hard to justify on any scientific basis and, thus, are at risk of being viewed as impediments to free international trade. New disease threats and new areas of cultivation may have emerged for which risks of introduction must be assessed. While other major crops (e.g., soybean and maize) take advantage of off-shore seed multiplication to speed up marketing advanced technology, the U.S. rice industry is constrained by the current blanket prohibition of importation from all origins. Updating the risk potential requires country and region specificity. Argentina, already cleared for importation of seeds of other crops, is our first choice for speedy analysis of rice seed importation safety. Three rice pathogens reported in Argentina were given special attention:

bacterium *Pseudomonas fuscovaginae* with no formally documented occurrence in the United States and fungi *Pyricularia grisea* and *Gibberella fujikuroi* that are known to be highly variable and were recently introduced to California. *P. fuscovaginae* was isolated in Colombia from discolored grains originated in Argentina in the mid 1980s; however, no evidence of field symptoms or isolations from recent seedborne microorganism surveys has been reported. Its low risk of introduction and economic importance suggest no need for phytosanitary regulation. *P. grisea* Sacc. is endemic to the southern United States; however, the U.S. rice crop may be vulnerable to the introduction of new races to which current commercial varieties lack genetic resistance. Races of IA types are found in Argentina and not sampled from contemporary U.S. blast population. Overall risk associated with these new fungal strains was estimated as medium, suggesting need for specific phytosanitary measures. *G. fujikuroi* strains found in Argentina are not capable of infesting rice, thus, no risk assessment was required. No potential for insect pest introduction was identified either. Risk of weed introduction through seed rice importation from Argentina is restricted to one species (*Mimosa pigra* L), which has the potential to invade a hardiness zone outside the rice growing areas. Economic and environmental risk potential was estimated as medium and the likelihood of introduction as low. Risk levels associated with importing from Argentina could be managed through phytosanitary regulations for *P. grisea* and *M. pigra* L.

Sheath Blight Epidemic Initiation and Fungicide Application Timing: Implications for Disease Management

Groth, D.E. and Frey, M.J.

Rice diseases pose a major threat to rice production. The two major diseases, sheath blight and blast, cause significant yield and quality reductions that cost farmers millions of dollars each year. Disease resistance is the best control, but often, it is not available or breaks down after varietal release. Most long-grain varieties are susceptible to sheath blight, and several major varieties are susceptible to blast. Cultural control can reduce disease development, but reducing inputs can limit yield, too. As a result, rice farmers often rely on fungicides to control diseases. Several new fungicides are available, and timing is critical for maximum return. Each disease has its own life cycle, and often, control practices are only effective at certain stages when the pathogen is susceptible to the chemical control and before irrevocable damage occurs. The objective of this study was to determine when sheath blight damage occurs and how fungicide timing affects sheath blight damage.

Experiments were conducted at the LSU AgCenter's Rice Research Station, Crowley, LA, in 2002 and 2003. Small plots (4.9 x 1.2 m), variety 'Cocodrie,' consisted of seven drill strips with 18-cm row spacing. Planting dates, seeding rates, fertility, and pest control followed current recommended practices. Experiments were arranged factorially, with inoculation timing as one factor and fungicide timing as the other. The treatments were organized into a randomized complete block design with four replicates. Sheath blight epidemics were initiated at green ring (GR), panicle differentiation (PD), early boot (EB), or boot split late boot (LB) and included uninoculated checks. Quadris fungicide, applied at 0.168 kg ai/ha with a backpack sprayer delivering 93 l/ha of water, was applied at either 7 days after PD (PD+7), boot (B), or 50 to70% heading (H). Sheath blight severity was assessed 2 to 4 days before harvest, and disease incidence was determined at the same time by counting the number of tillers infected with sheath blight. Plots were combine harvested, and yields expressed in kg/ha at 12 g/kg moisture. Milling samples were collected and total and head rice percentages determined.

Disease severity was light in uninoculated plots. In unsprayed inoculated plots, sheath blight severity, infection levels, and yield reductions were similar at all inoculation growth stages when compared with the uninoculated check. Fungicide applications did not improve yield or grain quality of any uninoculated treatments. All fungicide timings significantly controlled sheath blight and maintained rice yield and milling in inoculated plots. Boot applications appeared to have slightly better disease control than the PD+7 and H applications. Fungicide applications at PD+7, B, and H maintained yields and controlled sheath blight similarly when applied either pre- or post-infection.

With increasing rice varietal blast susceptibility and the greater damage potential from blast epidemics, more emphasis is being placed on fungicides for blast control than sheath blight. Previous studies indicate that blast fungicide application timing at 50 to 70% H is critical, and the effective blast control application window is narrower than that of sheath blight. Current recommendations indicate that fungicide timing should target blast in varieties that have moderate sheath blight resistance but are susceptible to blast. In a like manner, fungicide timing should target sheath blight in varieties that are susceptible to sheath blight but resistant to blast. Problems arise when varieties are susceptible to both sheath blight and blast. Results of these studies indicate that fungicide application can be delayed until the blast timing without greatly diminishing sheath blight control and yield protection. Therefore, when growing a sheath blight and blast susceptible variety, fungicide timing can be delayed to target blast development rather than sheath blight development. This will reduce the need for two fungicide applications to control both diseases. However, the delayed fungicide application must be accurately timed because as little as a 5- to 10-day delay in this H application can severely reduce efficacy and cause yield reductions by sheath blight and blast.

Proteomic Analysis of Rice after Challenge with the Fungal Pathogen *Rhizoctonia solani*

Lee, J. and Oard, J.H.

The rice genome has been recently sequenced and assembled by whole-genome shotgun methods. Moreover, equipment, chemicals, and image analysis software for Two Dimensional Electrophoresis (2-DE) have developed rapidly for subcellular analysis of host-pathogen interactions at the protein level. Sheath blight, caused by the fungus *Rhizoctonia solani* Kuhn, is the most devastating foliar disease for rice in Louisiana and the southern United States. The objective of this research was to identify proteins produced in rice after challenge with *R. solani* under controlled greenhouse conditions. Crude leaf-sheath protein samples were extracted 24 hr post inoculation from LSBR5, a somaclonal variant with known high levels of tolerance to *R. solani*, at the late tillering stage in the greenhouse. Non-inoculated samples from LSBR5 were also collected. Two independent protein samples were collected in separate experiments to reduce environmental and experimental error. In addition, seven to nine individual plants were pooled for each treatment, from which three replicated gels were produced. Leaf sheaths were ground in liquid nitrogen and precipitated in cold acetone to prohibit proteinase activity and to remove phenolic compounds. The protein extract was lyophilized to a dry powder and suspended in extraction buffer containing 7M urea, 2M thiourea, 4% CHAPS, 0.5% ampholytes, and 1% DTT followed by centrifugation. The supernatant was kept at -80C until initiation of 2-DE experiments. A total of 300 µg of crude protein sample was loaded onto a pH 4-7 immobilized pH gradient (IPG) strip (Bio-Rad) since most proteins were located within this pH range. After first dimensional electrophoresis, the IPG strip was placed on top of a 12% LDS polyacrylamide gel and run at 30mA for ≥4 hr and stained with Sypro-Ruby fluorescent dye (Bio-Rad). Gel images were analyzed by PDQuest image analysis software (Bio-Rad). Approximately 1,000 protein spots were detected on each gel. Protein patterns across gels were reproducible that allowed quantification of proteins of interest. A total of 43 protein spots were found to be upregulated in LSBR5 when challenged with *R. solani.* This study is the first to evaluate the rice-*R. solani* interaction at the proteomic level. Future research will involve the identification and characterization of selected proteins.

How Does the Rice Blast Pathogen Defeat a Resistance Gene?

Correll, J.C., Jia, Y., Boza, E.J., Singh, P., and Lee, F.N.

In practice, the term “durable resistance” is typically applied to a resistance that remains effective over a wide area for a long period of time in the presence of disease and favorable environmental conditions for disease development. In Arkansas, the *Pi-ta* resistance gene can be considered a durable resistance gene. The cultivar Katy, which contains *Pi-ta*, was first released in the early 1980s as a blast-resistant cultivar. Although isolates have been identified that can overcome the *Pi-ta* resistance gene in Katy and other cultivars, there have not been any documented epidemics where a cultivar with *Pi*-ta has suffered a yield-reducing epidemic in a commercial rice field. Therefore, *Pi-ta* still remains effective in Arkansas. The objective of this study was to examine the mechanism by which isolates of the rice blast pathogen overcome the *Pi-ta* resistance gene.

We have recovered field isolates and greenhouse-generated “race shift” mutants that can overcome the *Pi-ta* resistance gene under greenhouse screening conditions. The field isolates with this phenotype were recovered from different areas of the state and all belong to a single MGR586 DNA fingerprint group (group B). In addition, the frequency of the race shift mutants with this phenotype recovered in greenhouse studies was much higher in the group B isolates. In an effort to determine how isolates overcome *Pi-ta* resistance, we have focused on how the avirulence gene *AVR-Pita* is altered in both field and greenhouse isolates.

Evidence thus far indicates that field isolates virulent on lines with the *Pi-ta* resistance gene are lacking *AVR-Pita*. Also, although *AVR-Pita* can be detected in avirulent field isolates, the race shift mutants virulent on lines with *Pi-ta* recovered from these parental strains lack the *AVR-Pita* gene. Thus, PCR amplifications and southern blotting indicates that all or a significant portion of the *AVR-Pita* gene is deleted or becomes undetectable in these isolates.

There are several hypotheses that could explain the durability of *Pi-ta* in Arkansas. One hypothesis is that environmental conditions are variable and not necessarily conducive for disease development each year and Pi-ta has not been adequately challenged; a second hypothesis is that isolates that lose *AVR-Pita* and become virulent on lines with *Pi-ta* also have reduced fitness and do not become established in the population.

Gene Pyramiding and Marker Evaluation of Blast Resistant Lines

Utomo, H.S., Linscombe, S.D., Groth, D.E., and Chu, Q.R.

Rice blast is a serious disease affecting many rice growing areas and is often a severe problem in Louisiana rice growing regions. Blast resistant genes have a unique spectrum against blast races and some of them have overlapping spectra. One resistance gene sometimes can phenotypically mask other genes that confer resistance to the same blast race. Markers can identify an individual blast gene; therefore, they can be used to pyramid blast genes that would otherwise be difficult to accomplish through conventional breeding methods. The objectives of this study were to (1) develop more durable blast lines using elite Louisiana breeding lines and (2) verify available blast markers using Louisiana advanced lines. Fifty multi-way crosses and backcrosses were made to transfer blast resistant genes from different sources to the leading cultivars and some elite lines. Progenies carrying multiple blast genes were selected. To recover good agronomic characters from the recurrent parents, a large number of BC1 populations were developed for selection. Thirteen blast markers were used to survey a total of 40 advanced lines that have been rated 0 and 1 for blast resistance under field conditions. Results indicated that the number of blast genes in the advanced lines varied from single to multiple genes.

Root Zone Dissolved Oxygen Mediation of Flood-Induced Blast Field Resistance

Lee, F.N., Singh, M.P., Counce, P.A., and Gibbons, J.H

Much empirical and some experimental evidence indicates rice blast, incited by *Pyricularia grisea*, incidence and severity are enhanced by low soil moisture conditions, such as that in upland rice, and are reduced by high soil moisture conditions of intermittent rains or continuous irrigation. The nature of this flood-induced partial blast resistance is poorly understood. We investigated the nature of induced blast field resistance with emphasis on links between dissolved oxygen (DO) and hypoxic stress signals generated from the root zone.

In numerous field studies, the degree of flood-induced blast resistance was observed to vary with cultivar, flood depth, and duration of continuous flood. Of various variables evaluated, DO content at the soil consistently changed with flood depth. Subsequent greenhouse and laboratory experiments were conducted with blast lesion type used to evaluate treatment response and to calculate a blast index (BI). These tests confirm a positive correlation between lowered root zone oxygen (hypoxia) and reduction in leaf blast in test cultivars. Cultivar BI and floodwater DO decreased with increased flood depth. Cultivar BI was positively correlated with DO and reflected relative susceptibility of test cultivar. DO was documented in nutrient solution tests as the independent significant variable associated with variation in blast resistance. Total lesions per leaf were 3.4, 2.9, and 1.9 times greater for cultivars M-201, LaGrue, and Cypress, respectively, when growing in an aerated solution (5.0 ppm DO) than when growing in a hypoxic solution (0.1 ppm DO).

Our research defines root zone soil moisture regulated DO as the mediating component for partial blast resistance expression in flood responsive cultivars. We observed that the changes in blast severity associated with soil moisture changes are in reality the plant response to variation in soil aeration (DO) with subsequent modification of hormonal factors, likely ethylene, which signal for expression of blast resistance.

Control of Bakanae Disease of Rice in California

Oster, J.J.

Bakanae disease of rice, caused by *Gibberella fujikuroi*, was discovered in California in 1999. Since then, it has spread throughout the California rice production area. Since the disease is seed borne, control is achieved primarily through seed treatment. Overwintering inoculum is not a major source of infection. Cultural practices can also affect disease frequency.

Early research found that bakanae seedlings first appear 2 to 3 weeks after planting. Ninety percent of seedlings died by 3 weeks after symptom expression. Newly symptomatic plants continued to appear throughout the growing season but in decreasing numbers. Affected mature plants usually set very little seed and represent about 10 to 20% of all symptomatic plants. Seed assays were developed. Varieties differ in susceptibility to the disease. L205 and A201 were among the least susceptible. Medium grains were intermediate in susceptibility, with M206 being least susceptible and M205 most susceptible. S201 was slightly more susceptible than the medium grains. Calmati 201 was by far the most susceptible variety.

Later research focused on cultural practices and seed treatment materials. Both seed soak and drain times affected disease incidence, but drain time was the most important. Drain time should be 24 hr or less to prevent significant spore multiplication in seed lots. Planting of dry seed greatly reduced disease incidence. Temperatures of 20 to 25C during soak/drain times resulted in more disease than 30 to 35C. Prolonged field drainage immediately after seeding also increased disease incidence. The present registered seed treatment recommendation is with a 5% solution of 6% NaOCl for 2 hours, 22 hours in a water rinse followed by a drain period. This treatment provided 85 to 90% control. Other treatments that are economical and likely to be environmentally benign are 5% hydrogen peroxide (alone or with peroxyacetic acid), 0.25 to 0.5% phosphorous acid, and various acidified materials (1%) with surfactants (0.125-0.25%) added. Control was better than 95% with these materials, and no rinse was necessary.

Bakanae disease should be largely controllable with suitable seed treatment chemicals, reasonable modifications to seed handling procedures (such as limiting duration of drain time), limiting very early season field drainage, and encouraging straw decomposition.

Rice Sheath Blight Control Using Liberty Herbicide as a Fungicide on Transgenic Cypress Rice

Shao, Q.M., Rush, M.C., Xiao, Y., Zhang, S.L., Groth, D.E., and Linscombe, S.D.

Liberty herbicide was highly effective for controlling rice sheath blight when applied to transgenic rice after disease infections were established. The effects of Liberty on hyphal growth of *R. solani* were investigated using electron microscopy. Liberty greatly restricted the hyphal growth of *R. solani* on the surface of PDA medium. Hyphae grew very slowly and many short, stunted branches were produced on medium amended with Liberty. Hyphae growing on the surface of diseased leaves after inoculation rapidly spread across the surface and showed typical right angle branching. After application of Liberty in field tests, hyphal growth was significantly reduced. Irregular hyphae of *R. solani* were observed on the leaf surface, and there were fewer hyphae on the surface of treated leaves than on diseased non-treated leaves. After Liberty was applied to the plants, hyphal growth inside of infected tissues of treated leaves was greatly reduced. Mesophyll cell damage by *R. solani* inside treated leaves was reduced and mesophyll structure was more regular. Ball-like structures were present on the surface of leaves after spraying with Liberty. The function of these balls and their involvement with Liberty application to rice needs to be studied further.

Ultrastructural, Cytochemical, and Biochemical Aspects of Silicon-Mediated Rice Blast Resistance

Rodrigues, F.Á., Datnoff, L.E., Benhamou, N., Jones, J.B., and Bélanger, R.R.

Although silicon (Si) is not considered an essential element for plants, it has enhanced the growth and the development of several plant species. Silicon has provided effective control of several diseases in many different crops. In rice, the mechanism of Si-mediated resistance to blast, caused by the fungus *Magnaporthe grisea*, has been reported to be the result of a physical barrier resulting from Si polymerization *in planta*. This is believed to be the reason that the number of sporulating lesions, lesion size, rate of lesion expansion, diseased leaf area, and number of conidia per lesion are dramatically reduced. In cucumber-powdery mildew and *Pythium* interactions, Si has played an important role in reducing disease intensity. The major host cell defense response in these interactions was the accumulation of phenolics and a flavonol aglycone phytoalexin. These findings suggest that the role of Si might be physiological and/or a biochemical. Consequently, several mechanisms of Si-mediated resistance to *M. grisea* in rice may be operating together.

Rice plants ('M-201'), amended or not with calcium silicate slag [0 and 20 g/pot (20 mt/ha)], were inoculated with a conidial suspension of race IB-49 of *M. grisea* (4×10^5 conidia/ml) at the time of emergence on the seventh leaf from the main tiller. The cultivar M201 has no known major or minor gene resistance to race IB-49 of *M. grisea*. A total of 25 to 30 leaf pieces, approximately 30 mm^2 in size and containing individual infection sites, were randomly collected from the fourth, fifth, and sixth leaves at 96 h after inoculation and processed for light and transmission electron microscopy. Ultra thin sections were also used for cytochemical labeling to localize chitin and cellulosic β-1,4-glucans, respectively, over fungal and host cell walls. Harvested leaf-material was also used to extract free and glycosylated phenolic compounds, diterpenoids, as well as aglycones released after acid hydrolysis. Compounds in leaf extracts were analyzed using HPLC and the presence of phytoalexins was verified based on their retention time, ultraviolet absorbance spectra at 212 and 272 nm, as well as Co-chromatography with the authentic standards for momilactone A, momilactone B, sakuranetin, oryzalexin A, and oryzalexin C.

Results from these studies provide the first cytological and biochemical evidence that Si–mediated resistance to *M. grisea* in rice was associated with specific leaf cells reaction that interfered with the development of the fungus. The accumulation of an amorphous material that stained densely with toluidine blue and reacted positively to osmium tetroxide was a typical feature of cells reaction to infection by *M. grisea* in samples from Si^+ plants. As a result, the extent of fungal colonization was markedly reduced in samples from Si^+ plants. In samples from Si^- plants, *M. grisea* grew actively and colonized all leaf tissues. Cytochemical labeling of chitin revealed no difference in the pattern of chitin localization over fungal cell walls of either Si^+ and Si^- plants, indicating limited production of chitinases by the rice plant as a mechanism of defense response. On the other hand, the occurrence of empty fungal hyphae, surrounded or trapped in amorphous material, in samples from Si^+ plants suggests that this amorphous material played a primary role in rice defense response against infection by *M. grisea*. Support for a close association between accumulations of osmiophilic material, likely composed of phenolics, and host cell wall protection is illustrated by the differential pattern of cellulose labeling in host cells of samples from both Si^- and Si^+ plants. Cellulose hydrolysis, one of the mechanisms involved in the degradation of rice cell walls by *M. grisea*, was apparently reduced in samples from Si^+ plants, even in colonized areas. This observation suggests that the impregnation of phenolic-like compounds in or beneath the rice cell walls may have contributed to the delay in colonization by *M. grisea* by reinforcing and protecting the cell walls from the deleterious action of both degrading enzymes and toxins produced by this fungus, which together induce characteristic necrosis on the leaves. Higher levels of momilactone phytoalexins were found in leaf extracts from Si^+ plants inoculated with *M. grisea* than in leaf extracts from Si^- inoculated plants or non-inoculated Si^+ and Si^- plants. On this basis, the more efficient stimulation of the terpenoid pathway in Si^+ plants, and consequently, the increase in the levels of momilactones appear to be another factor contributing to enhanced rice resistance to blast.

In conclusion, the results of this study strongly suggest that Si plays an active role in the resistance of rice to blast rather than just the formation of a physical barrier to penetration

Screening for *Pythium* Resistance in Cold-Tolerant Rice Genotypes

Rothrock, C.S., Sealy, R.L., Lee, F.N., Gibbons, J., Cartwright, R., and Anders, M.

Stand problems consistently cause significant production and management losses in Arkansas rice fields. Previous research identified the role of environmental factors and soilborne plant pathogens, especially *Pythium* species, in limiting rice stand establishment. *Pythium* spp. significantly reduced stands and growth of rice, especially at cooler temperatures. In greenhouse studies, at a range of 18.5 to 27.3°C (65 to 81°F) only 9 of the 92 isolates tested were moderately virulent or greater (≤60% emergence), while at 15.5°C (60°F) in growth chamber studies the number of isolates exhibiting moderate to severe virulence (≤40% emergence) increased to 39 of the 92 isolates tested. These studies also demonstrated that *Pythium* seedling disease decreases plant development over a greater range of temperatures than observed with stand loss. As growers look to planting earlier with an increased risk of cool soil temperatures, rice seedlings will have to overcome low soil temperatures and also the increased activity of *Pythium* spp.

This research examined the value of cold-tolerant genotypes for the control of *Pythium* seedling disease. Cold-tolerant genotypes and standard genotypes of rice were planted at three to four planting dates, beginning in mid-February, with and without seed treatment fungicides. In the field plantings, an obvious interaction between cold tolerance and inherent seedling disease resistance was observed when comparing plant stands for planting under early and optimal conditions. In general, cold sensitive genotypes were classified as entries that did not respond to fungicide treatment and established useful stands only under optimal conditions. An intermediate group, characterized as cold tolerant but seedling disease susceptible, only established a suitable stand when treated with an efficacious fungicide. A third group was identified as being tolerant to cold and to seedling disease by the ability to establish a stand for early plantings in the absence of a fungicide.

Selected rice genotypes with a range of reported cold tolerance also were evaluated for susceptibility to *Pythium* isolates in the growth chamber using infested and noninfested potting media. Genotypes were found that varied in susceptibility and percent relative stand of the infested to the noninfested control at the temperatures used, 15 or 20°C (59 or 68°F). Cold sensitive and some resistant genotypes were found that were susceptible at 15°C (0-6% stand) and susceptible (0% stand) or moderately resistant (38-62% stand) at 20°C. However, several cold-tolerant genotypes were found to be moderately resistant at 15°C (32-43% stand) and resistant at 20°C (75-100% stand). This research suggests that genotypes can be selected that improve plant stand under colder soil temperatures and increased *Pythium* pressure.

Ethephon-Induced Field Resistance to the Rice Blast Disease

Singh, M.P., Lee, F.N., and Counce, P.A.

Rice blast, incited by *Pyricularia grisea* Cav., is less severe when plants are growing in continuous flood irrigation than when growing in an intermittent flood or in upland conditions. Our recent research indicated that root zone hypoxia signaled activation of the plant defense response conferring rice blast field resistance likely by means of enhanced ethylene perception.

The interaction of flood depth and plant response to treatment with ethylene producer ethephon (2-chloroethylphosphonic acid) in blast resistance expression was evaluated in greenhouse tests. In a flood depth experiment simulating field conditions, we covered the bottom of a 60-cm high 375-l reservoir with 10 cm of field soil. Test plants were positioned in the reservoir at desired flood depths on plastic coated wire stands. Differential depth-growth regimes established were: 1) upland, with test plants partially placed into the flood but with the pot soil surface being 5 cm above the flood surface; 2) a shallow flood of 7.5 cm; and 3) a deep flood of 20 cm relative to the soil surface. Seven days following inoculation with multiple *P. grisea* races, the treatment responses were evaluated and a blast index (BI) calculated.

With untreated plants of the blast susceptible cultivars M-201, Newbonnet, LaGrue, Mars, and Cypress, the BI decreased as flood depth increased. A single foliar-drench application of 50 µL/l ethephon lowered the BI of susceptible cultivars growing upland to levels comparable with the BI recorded for untreated plants growing in the 7.5-cm flood depth. A trend in lower BI was evident with combination ethephon-depth treatments. Also, an additional decrease in the BI of test entries at the 7.5- and 20-cm depths occurred as the flood duration was extended. In a dose-flood depth experiment, treatment response to 25, 50, and 75 µL/l ethephon were not significantly different. However, the response to ethephon was enhanced with addition of the surfactant Tween-20 (0.05%) in foliar applications or with addition of EDTA (100 µL/l) in soil drench treatments.

Our data demonstrate the role of flood depth in establishing field resistance in responsive cultivars. Also, the data show ethephon treatment induces useful levels of field resistance in plants growing upland and enhances resistance expression in flooded plants. These data suggest that treatment with ethylene-inducing compounds, such as ethephon, may have practical application potential in managing rice blast either as a means to enhance inherent cultivar resistance and/or as a means to complement traditional fungicide treatment.

Development of Molecular Strategies to Control Major Rice Fungal Diseases in the United States

Jia, Y., Singh, P., Winston, E., Wamashe, Y., Correll, J., Lee, F.N.,
Moldenhauer, K., Gibbons, J., and Rutger, J.N.

Blast disease caused by the hemibiotrophic *Magnaporthe grisea* pathogen and sheath blight disease caused by the necrotrophic *Rhizoctonia solani* pathogen are serious diseases for U.S. rice industry. Common strategies for disease control are the use of resistant cultivars and pesticides in a integrated pest management system. Over the years, major resistance genes to blast have been identified from landrace cultivars and wild relatives of rice for blast control. Recent molecular characterization of two major blast resistance genes has facilitated the development of molecular markers from resistance genes for marker-assisted selection. In contrast, the complete resistance to sheath blight is not available in cultivated rice, and minor resistance genes have been used for sheath blight control.

The current effort of the Molecular Plant Pathology program at Dale Bumpers National Rice Research Center is to explore the basic knowledge of rice natural defense for accelerating breeding for disease resistance. First, a major blast resistance gene, *Pi-ta*, was determined to be responsible for preventing the infections of the most common blast races in the southern United States, and functional characterization of *Pi-ta* interacting genes will eventually lead to novel knowledge for sustained blast control. Second, robust pathogenicity assays for blast and sheath blight were developed to facilitate resistance gene identification and incorporation. Third, molecular interactions of rice with the necrotrophic pathogen *R. solani* have been studied and several candidate genes were identified as an initial step to reach complete resistance to sheath blight. Fourth, a lesion mimic mutant of the U.S. rice cultivar Katy with enhanced resistance was recovered and a single recessive gene is responsible for this enhanced resistance to both *M. grisea* and *R. solani*. Fifth, putative mutant populations of 20,000 M_2 rice lines were developed for identifying resistance genes and resistance related genes using methods of both forward and reverse genetics. Finally, molecular mechanisms of the instability of rice blast fungus are better understood for predicting the stability of resistance in rice cultivars that are currently grown in the southern United States.

In summary, new knowledge derived from this program has not only facilitated the development of end-user-friendly DNA markers for improved resistance but also generated useful genetic stocks that can be used for both basic and applied research for the rice community. In the future, public databases will be explored to develop molecular strategies for developing disease resistant rice cultivars. Increased use of resistant cultivars and decreased use of pesticides can facilitate the creation of an environmentally friendly rice production system.

Historical Utilization of Blast Field Resistant Cultivars in U.S.A. Rice Production

Lee, F.N., Singh, M.P., and Counce, P.A.

The rice blast disease, caused by *Pyricularia grisea* Cav., has been identified in 85 rice-producing countries and often causes devastating yield loss in upland, intermittent, and shallow flood irrigated agronomic systems of these countries. Cultivar resistance, either major gene or partial ('field'), is the preferred rice blast management strategy. However, major gene resistance is frequently compromised by rapid pathogen adaptation, at times with severe yield loss, which then forces an increased use of fungicides and the subsequent release of new resistant varieties to repeat the cycle. The more desirable field resistance does not facilitate rapid pathogen adaptation but is difficult to develop and utilize.

In Arkansas and other U.S. production areas, there is long history of pathogen adaptation to 'resistant' cultivars. Rice growers, forced to rely upon residual resistance masked by the failed gene, have adapted to this boom or burst cycle. They now manage rice blast by growing field tolerant cultivars in combination with proper cultural practices, including field selection (open, well ventilated), avoiding excessive use of nitrogenous fertilizers, and effective crop management techniques. Correctly establishing and maintaining the irrigation flood during the growing season is a key cultural practice known to enhance field resistance to rice blast.

Historically, highly field resistant rice cultivars such as Starbonnet, Cypress, and Mars were utilized several years before being replaced with higher yielding cultivars. In Arkansas, record and near record rough rice yields have been achieved while growing very high yielding but blast susceptible or moderately susceptible cultivars, such as LaGrue, Wells, and Cocodrie. Although subject to significant yield loss under disease conductive conditions, these cultivars were planted to approximately 75% of the 2003 rice acreage. The primary blast control measure was a deep continuous flood which enhanced cultivar field resistance. This blast control strategy is hindered by the lack of implementation information and the inability to effectively select for field resistance in cultivar breeding programs.

Molecular Characterization of *Magnaporthe grisea* Avirulence Alleles *(AVR-Pita)* in U.S. Pathotypes

Winston, E., Singh, P., Jia, Y., and Correll, J.

The rice blast fungus, *Magnaporthe grisea* Herbert (Barr), causes severe limitations in rice producing regions throughout the world. There are over 20 major genes for blast resistance *(R)* that have been identified in rice. Maintaining durable *Pi-ta*-mediated resistance is challenging due to the high degree of pathogenic variability and genetic instability of *M. grisea* avirulence alleles. Genetic mapping demonstrated that the *M. grisea AVR-Pita* gene is closely linked to the telometric region residing on chromosome 3. In addition, evidence suggests that races of the rice blast pathogen have the ability to mutate, thereby affecting host specificity. Isolates such as these are referred to as "race shift" isolates. The objective of this study was to determine the functionality of *AVR-Pita* alleles in isolates of *M. grisea* races found in the southern United States.

Utilizing gene specific primers, native promoter, and coding regions of the *AVR-Pita* gene are being amplified from cDNA and genomic clones of the *M. grisea* wild-type isolates 0-137 and ZN61 (race IB-49), respectively. These fragments were directionally cloned into the fungal transformation vector pCB1004. Clones are being analyzed by ClaI and BamHI restriction digestion and PCR amplification using *AVR-Pita* gene specific primers. Clones exhibiting the predicted fragment size are being sequenced using the ABI-PRISM BigDyeTM Terminator cycle sequencing system. Positive clones will be homologous to *AVR-Pita* genomic sequence. Clones will be transformed into a race-shifted isolate to test the functionality of the *AVR-Pita* allele from ZN61. Complementation studies will be subsequently performed by inoculating the recombinant pathogen onto resistant rice cultivars, which contain *Pi-ta* to determine if the virulent isolate is converted to an avirulent isolate by the addition of *AVR-Pita*.

These studies will provide direct evidence that *AVR-Pita* alleles can undergo spontaneous mutation and are deleted from the *M. grisea* genome. The data obtained from these experiments will enhance our knowledge in understanding the evolution of the rice blast fungus and the molecular mechanisms that are involved in *Pi-ta*-mediated resistance.

Development of the Rice Stinkbug Monitoring Program in Rice

Rashid, T., Johnson, D.T., and Bernhardt, J.L.

The rice stinkbug, *Oebalus pugnax* (F.), is one of the major pests of rice in the southern United States. Two sampling methods are recommended for monitoring rice stinkbug populations in a rice field, direct observation and sweep net samples. Most fields are sampled by sweep net to estimate field densities. Initiation of sampling is usually recommended after 75% of the panicles have emerged. A sample unit consists of 10 consecutive 180 degree sweeps with a sweep net. One sweep is made with each of 10 forward steps. A series of sample units randomly taken throughout the field are recommended. The present economic threshold is five or more rice stinkbugs per 10 sweeps during the first 2 weeks after heading. Direct counts of rice stinkbugs on rice panicles is another possible sampling method but it requires more time than sweep net sampling and has no economic threshold developed for it. An alternative sampling method is needed that is less time-consuming and physically less taxing than either sweep net sampling or direct counting of rice stinkbugs on rice panicles. It may be possible to determine a relationship between the rice stinkbug density on its alternate grass hosts in areas adjacent to rice fields prior to heading and the subsequent population increase in rice fields during heading. The objective of this study was to record and compare weekly or biweekly changes in rice stinkbug counts from yellow pyramid traps and visual inspections of wild grass hosts and sweep net samples made in the grassy margins adjacent to rice fields and sweep net samples taken in rice fields.

In 2002, rice stinkbug counts were recorded from 10 yellow pyramid traps along one margin of a rice field. Rice stinkbug counts were also made from 40 sweep net samples and 40 visual inspections of panicles of alternate grass hosts on each of four field margins. In 2003, three rice fields were sampled with five yellow pyramid traps, each along one margin of a rice field. At each trap location, a 10-sweep net sample was made of the grassy margin and three 30-sweep net samples were made inside the rice field and averaged. For both years, these rice stinkbug counts were recorded weekly before and during panicle development and biweekly from late August to after rice harvest.

From 4 June to 1 November 2002, pyramid traps captured more than 13 rice stinkbugs/trap between 5 June (no rice heading) and 12 July (75% rice heading). Trap counts dropped below 1 bug/trap during the rice heading period from 12 July to 22 August. From 12 to 18 July 2002, rice stinkbugs were dispersing into the heading rice field as noted by sweep net counts in the rice field. Rice lines/varieties ‘RU0101093’ and ‘Wells’ were harvested on 29 August and ‘Francis’ on 6 September. After harvest, pyramid trap catches increased in late September to > 20 bugs/trap, dropped to below 1 bug/trap after 3 October and to zero by 1 November. Appearance of rice stinkbugs in sweep net samples in rice (3 bugs/10 sweeps) on 12 and 18 July corresponded to a drop in pyramid trap counts. Significantly higher numbers of rice stinkbugs were visually counted or swept from grassy hosts from 28 June to 12 July (> 10 bugs/sample) than recorded from 18 July to 9 August (< 1 bug/sample). These numbers decreased the week prior to the insecticide application on 18 July. A similar trend in rice stinkbug counts was observed for all three sampling methods repeated in a replicated study in 2003. Pest sampling and management options are discussed.

Rice Stinkbug Control in the Mississippi Delta

Robbins, J.T.

The rice stinkbug [*Oebalus pugnax* (F.)] is one of the most damaging pests of rice in the Mississippi Delta. Losses due to stinkbug injury in tests conducted at the Delta Research and Extension Center varied from 224 kg/ha to over 336 kg/ha on untreated plots. Yields from test plots treated with Karate Z at 0.03 kg/ha applied at early heading showed an increase of over 336 kg/ha. Also an increase in rice yields was recorded from test plots treated with Dimilin, Mustang Max, and Methyl Parathion. Damage to rice occurred from rice stinkbug adults and nymphs. Thresholds for application of insecticides were three stinkbugs of any stage per 10 sweeps taken at early heading.

Rice Water Weevil Control in Arkansas Using Different Management Approaches

Studebaker, G.E., Johnson, D.R., and Robertson, W.H.

The rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, is a major pest in Arkansas rice. Longitudinal scars parallel to the rice-leaf midrib are characteristic of feeding by rice water weevil adults. However, the economical damage is caused by the larvae feeding on rice roots. The current University of Arkansas recommendation for rice water weevil larvae control is fipronil (Icon)-treated seed and foliar treatments. Researchers have found that fipronil-treated seed provided better control of rice water weevil larvae and higher rice yield than lambda-cyhalothrin and diflubenzuron. However, other insecticides may provide adequate control. Evaluation of these insecticides is necessary to prevent dependence on limited control options. This study was conducted to evaluate several new and current insecticides, as well as a novel application method for control of rice water weevil larvae in drilled rice.

Various seed and post-emergence treatments were evaluated for the control of rice water weevil larvae in drilled rice at the University of Arkansas Pine Tree Branch Agricultural Research Center located in St. Francis County. Eleven treatments in 2002 and 13 treatments in 2003 were evaluated with a randomized complete block design with four replications. All postemergence treatments were applied with a CO_2-pressurized hand boom or hand sown. The treated-seed-carrier broadcast treatment consisted of fipronil-treated seed broadcast postflood. Each plot was evaluated by collecting two 10-cm diameters by 7.5-cm deep soil cores. The soil cores were washed through a 0.64-cm mesh followed by a 40-mesh screen sieve, and rice water weevil larvae populations determined.

In 2002, the fipronil-treated seed, lambda-cyhalothrin, and both rates of thiamethoxam-treated seed gave significant control of the rice water weevil. Fipronil-treated seed, fipronil-treated-seed-carrier broadcast, both rates of thiamethoxam-treated seed, and gamma-cyhalothrin (0.017 kg/ha) had significantly lower rice water weevil larvae populations at 26 DAT. By 33 DAT, no treatment had significantly lower rice water weevil larvae counts than the untreated check. Some postemergence treatments, particularly lambda-cyhalothrin, had significantly higher larvae counts than the untreated check, indicating a need for a sequential application. Based on the seasonal average, fipronil-treated seed and both rates of the thiamethoxam-treated seed provided significantly lower rice water weevil larvae counts than the untreated check. Lambda-cyhalothrin had the lowest yield of all treatments and was significantly lower than untreated check. Fipronil-treated-seed-carrier broadcast achieved the highest yield, which was significantly greater than lambda-cyhalothrin.

In 2003, fipronil-treated seed, lambda-cyhalothrin, thiamethoxam-treated seed, cypermethrin, and gamma-cyhalothin all had significantly less rice water weevil than than the untreated check. Most treatments were not significantly different, but the gamma-cyhalothrin (0.017 kg/ha) was different from fipronil- and thiomethoxam-treated seed with higher larval counts 19 DAT. Overall, fipronil and thiomethoxam seed treatments gave numerically best control with 93 to 99% control. Foliar treatment of lambda-cyhalothrin, gamma-cyhalothrin, and cypermethrin gave from 64 to 83% control.

Yield Components and Quality of Rice in Response to Graminaceous Seed Density and Rice Stinkbug Populations

Tindall, K.V., Williams, B.J., Stout, M.J., and Webster, E.P.

The rice stinkbug (RSB) (*Oebalus pugnax*) is an important pest of rice. RSB damage rice by piercing the flower, resulting in a sterile flower (non-filled seed) or feeding on the developing seed, reducing the quality of the grains (pecky rice and broken kernels). Recent work has shown that graminaceous weeds near rice can serve as a source of stinkbug infestation. In 2002 and 2003, experiments were conducted at Macon Ridge Research Station near Winnsboro, Louisiana, to examine how RSB populations responded to a range of weed densities when rice was treated with insecticide or left untreated. Rice (var. 'Cocodrie') was drill seeded at 112 kg seed/ha. Plots were 2.03 x 4.57 m. Treatments consisted of weed density and insecticide treatment and were factorially arranged in a completely randomized design. Weed densities were achieved by applying different rates of herbicide at different timings. Herbicide treatments were: 0.22 kg ai/ha Command (clomazone) applied preemergence (PRE), 0.44 kg ai/ha Command applied PRE, 0.67 kg ai/ha Command applied PRE, 0.44 kg ai/ha Command applied PRE followed by 0.21 kg ai/ha Clincher (cyhalofop) at the 4- to 5-leaf rice stage, 0.67 kg ai/ha Command applied PRE followed by 0.21 kg ai/ha Clincher at the 4- to 5-leaf rice stage, and no herbicide applied. Insecticide applications were 0.056 kg ai/ha Karate-Z (lambda-cyhalothrin) or no insecticide; applications were made weekly to exclude RSB from treated plots. Vegetation was removed from two .09-m^2 areas of each plot 1 to 2 days prior to flooding. Plants were grouped by plant species and counted. Weeds in this study had seed heads present for approximately 3 weeks before rice panicles emerged. Sampling for RSB began approximately 1.5 weeks prior to rice panicle emergence. Samples were taken every 5 to 7 days for 3 weeks using a sweep net (15 cm in diameter). Prior to harvest, 10 rice plants were removed from each plot. Each plant was used to determine percent filled seed and pecky rice, seed weight, and milling quality. Data gathered from these treatments were analyzed in SAS using analysis of covariance with weed density being the continuous variable and insecticide application as the categorical.

Weed density ranged from 0 to 49.5 weeds/ 0.1 m^2. Weed composition consisted of 46% barnyardgrass, 28% Amazon sprangletop, 18% broadleaf signalgrass, and 8% large crabgrass. When rice was not treated with insecticide, RSB populations increased as weed density increased. Despite weekly insecticide applications, RSB were not totally excluded from treated plots. Although RSB were present in treated plots, there was no increase in number of RSB as weed density increased. As weed density increased in the non-treated rice, percentage of filled seeds was reduced at a significantly greater rate than in treated rice. Rice stinkbugs had 3 weeks to feed on weeds before panicles emerged in the non-treated plots. Therefore, RSB were present to feed on flowers as flowers emerged, reducing the percentage of filled seeds. Additionally, percent pecky rice increased and milling quality declined as weed density increased, and non-treated plots had more pecky rice and lower milling quality than in non-treated rice. Although RSB reduced percentage of filled seeds, yield reductions were seen only in response to weed density. This suggests that when weeds and RSB are present, weeds are the primary contributor to yield losses.

It is well established that weeds are important pests because of competitive interactions with crop plants. In rice production systems, many grass weeds have been shown to interfere with rice early in rice development. Data suggest that grass weeds can also indirectly interfere with late season rice by attracting RSB to rice and reducing the amount of filled seed. Therefore, it is important to control grass weeds early and monitor populations of RSB if grass weeds are not properly controlled.

Management of Rice Stinkbugs Using Various Insecticides in Arkansas

Johnson, D.R., Robertson, W.H., and Studebaker, G.E.

The rice stinkbug, *Oebalus pugnax* (Fabricius), is a major pest of rice production in Arkansas. Rice stinkbugs damage rice by feeding on the flowering rice and on kernels as they develop. Economic injury to rice results from yield reduction and the discoloration of rice kernels as a result of feeding. Discoloration is commonly related to rice stinkbug feeding activity. Discolored, or 'pecky,' rice kernels reduce the commercial value of rice. Riceland estimates that Arkansas rice producers lost $30 million due to rice stinkbug damage in 2001. Damage occurs when the insect inserts its mouth parts into the developing rice kernel and extracts some or all of the contents, resulting in a discolored area due to fungi introduced at the time of feeding. Insecticides are the main control agents utilized against the rice stinkbug. Some new insecticides are being developed that may aid in the control of the rice stinkbug. Evaluation of these and current products remains necessary for maintaining control procedures.

This study was conducted in 2003 at the University of Arkansas Northeast Research and Extension Center, located in Mississippi County, and the University of Arkansas Pine Tree Branch Station, located in St. Francis County. At both locations, a single spray application of selected insecticides was applied to each test followed by three individual rating evaluations. Eleven replicated treatments were applied at each location using a two-man CO_2 hand boom. Each evaluation consisted of 10 sweeps with a stinkbug net through each of the treatment areas. These sweeps were taken at the tops of the plants after the plant population had achieved full heading.

At the Mississippi County location, the test consisted of both single chemical applications and tank mixes of selected insecticides. The single chemical applications were low and reduced rates for Mustang Max 0.8 EC (zeta cypermethrin) at 0.017 and 0.020 kg ai/ha, Karate Z 2.08 CS (lambda-cyhalthrin) at 0.024 and 0.029 kg ai/ha, Malathion 5 EC (malathion) at 1.681 kg ai/ha, and Methyl Parathion 4 EC (methyl parathion) at 0.420 and 0.560 kg ai/ha. The tank mix application consisted of Mustang Max 0.8 EC (0.017 kg ai/ha) with Methyl Parathion 4 EC (0.420 kg ai/ha), Mustang Max 0.8 EC (0.017 kg ai/ha) with Methyl Parathion 4 EC (0.560 kg ai/ha), Karate Z 2.08 CS (0.024 kg ai/ha) with Methyl Parathion 4 EC (0.420 kg ai/ha), and Karate Z 2.08 CS (0.024 kg ai/ha) with Methyl Parathion 4 EC (0.560 kg ai/ha). This spray application took place on Sept. 5, 2003. Evaluations for each of these treatments were conducted at 4, 6, and 11 days after treatment (DAT). With the exception of Malathion 5 EC (1.681 kg ai/ha), all of the treatments significantly reduced the stinkbug population. The tank mix of Mustang Max 0.8 EC (0.017 kg ai/ha) with Methyl Parathion 4 EC (0.560 kg ai/ha) was the most efficient, providing 94% control on average when compared with the untreated check. The most efficient single chemical spray was the lower rate of Methyl Parathion 4 EC (0.375 kg ai/ha) providing 89% control.

The St. Francis County test consisted of only single chemical applications of selected insecticides. These applications were of low and reduced rates of Mustang Max 0.8 EC at 0.017, 0.020, and 0.028 kg ai/ha; Karate Z 2.08 CS at 0.026, 0.029, and 0.034 kg ai/ha; Malathion 5 EC at 1.681 kg ai/ha; and XDE-225 1.25 CS (gamma-cyhalothrin) at 0.017, 0.022, and 0.034 kg ai/ha. Methyl Parathion 4 EC was applied at the recommended rate of 0.560 kg ai/ha. Spray applications took place on Sept. 2, 2003. Evaluations for each of these treatments conducted taken at 6, 9, and 16 DAT. Again, with the exception of Malathion 5 EC (1.681 kg ai/ha), all of the treatments significantly reduced the stinkbug population. The highest applied rate of Karate Z 2.08 CS (0.034 kg ai/ha) was the most efficient, providing 97% control on average when compared with the untreated check.

A similar study conducted in 2002 at the St. Francis County location showed that Karate Z 2.08 CS (0.029 kg ai/ha) was the most efficient, providing 91% control on average when compared with the untreated check. Karate Z 2.08 CS provided the highest percentage of control for 2 years at this location; however, due to increasing adult stinkbug resistance to Karate Z 2.08 CS in Arkansas, tank mixes were tested at the Mississippi County location.

The Development of Rice Sheath Blight Resistance Using Transformation of Pathogenesis-Related Protein Genes

Zhang, S.L., Shi, Y.L., Zhang, Y.H., Shao, Q.M., Shih, D., and Rush, M.C.

The introduction and expression of pathogenesis-related (PR) protein genes have significantly reduced the development of fungal pathogens in several crops. In this research, we co-transferred two plasmids containing the β-1, 3 glucanase and chitinase genes, along with the hygromycin B resistance selection gene into rice in an attempt to increase the resistance of rice to the sheath blight disease. Embryogenic calli were induced from rice-seed scutella of the variety Taipei 309. Calli were co-transformed with the β-1, 3 glucanase and chitinase genes using microprojectile bombardment. Bombarded calli were selected on media containing hygromycin and plants were regenerated. Seventy-nine regenerated plants were transferred first to the greenhouse and then to the field in 2003. Plants were inoculated with *Rhizoctonia solani* at the maximum tillering stage, and some plants showed high levels of partial resistance to rice sheath blight when compared with non-transgenic plants. Rice leaves were sampled from both transgenic plants and non-transgenic plants. Genomic DNA was isolated from these samples and PCR and southern blot analysis showed the transgenes were present in resistant transgenic plants. The probes used in southern blot analysis were fragments of the transgenes.

Cloning and Characterization of Induced Genes by the Sheath Blight Pathogen *Rhizoctonia solani*

Singh, P., Jia, Y., Eizenga, G.C., and Lee, F.N.

Sheath blight, caused by *Rhizoctonia solani* Kühn, is a serious disease in rice growing areas worldwide. No complete genetic source of resistance is known among rice cultivars. A rice cultivar, Jasmine 85, has shown considerable resistance to sheath blight that appears to be controlled by several minor resistance genes. The objective of the present study is to clone these minor resistance genes for stacking them into improved rice cultivars.

To clone these candidate resistance gene(s), a subtractive cDNA library was constructed using Jasmine 85 inoculated with a virulent field isolate of *R. solani.* For this purpose, inoculation experiments were conducted using detached leaf inoculation method and 16 hours after inoculation was selected for isolating differentially expressed genes. Total RNAs from inoculated and control leaf samples were isolated by RNeasy Plant Mini protocol. A PCR-based method was used for producing high-quality cDNA from the total RNA by Super SMART PCR cDNA synthesis kit. These cDNAs obtained from inoculated and control samples were used for PCR-Select cDNA subtraction protocol according to the manufacturer's recommendations. The PCR mixture enriched for differentially expressed cDNAs was cloned in TOPO TA cloning vector and sequenced using ABI-PRISM BigDye Terminator Cycle Sequencing.

So far, 133 expressed sequence tags have been identified. Most of the genes are unrelated with the disease resistance but a few of them are potential candidates for sheath blight control. These promising candidate genes are a putative protein kinase, a putative wall-associated kinase, a putative K^+/H^+ antiporter, PDR-and MDR-like ABC transporters. Research to confirm the expression of these genes is in progress. These genes will eventually be used to develop user-friendly DNA markers for developing a complete resistance to sheath blight.

Identification of Disease Resistance in the *Oryza* spp. and Following Its Introgression into Cultivated Rice with DNA Markers

Eizenga, G.C., Xiang, G., Jia, Y., and Lee, F.N.

Rice wild relatives (*Oryza* spp.) are an important source of novel genes for rice improvement. Previous studies of 21 *Oryza* spp. accessions identified resistance to rice sheath blight (*Rhizoctonia solani* Kuhn) and rice blast (*Pyricularia grisea* [(Cooke) Sacc.] via greenhouse screening methods. Subsequently, selected *Oryza* spp. accessions were backcrossed to the U.S. long-grain 'Ahrent' and U.S. medium-grain 'Bengal.' Recently, DNA markers were developed to determine the presence of *Pi-ta* and *Pi-b*; two major blast resistance genes in U.S. cultivated rice. *Pi-ta* is a major blast resistance gene introduced into 'Katy' from the Vietnamese landrace 'Tetep' and *Pi-b* is another major gene introduced into 'Saber' from Chinese cultivar 'TeQing.' In a different study, a set of 180 microsatellite markers was used to genotype 550 rice (*O. sativa*) accessions with about one half representing germplasm used in U.S. rice breeding programs and one half representing international rice germplasm. The objectives of this study were to 1) determine the resistance of the remaining *Oryza* spp. using greenhouse methods, 2) identify *Pi-ta* and *Pi-b* in the *Oryza* spp. accessions and selected progeny, 3) genotype the *Oryza* spp. accessions, and 4) use selected polymorphic microsatellite markers to follow the introgression of *Oryza* spp. DNA into Ahrent and/or Bengal.

The 56 accessions included in this study represented the following *Oryza* spp.: *O. alta*, *O. australiensis*, *O. barthii*, *O. glumaepatula*, *O. latifolia*, *O. meridionalis*, *O. nivara*, *O. officinalis*, *O. rufipogon,* and the *O. sativa* cultivated parents for crossing. The blast and sheath blight inoculations were done in the greenhouse and rated using standard protocols. The blast races (isolates) used were IB-1 (ZN15), IB-33, IB-49 (ZN51), IB-54, IC-17 (ZN48), IE-1 (ZN5), IE-1K (ZN19), IG-1 (ZN39), and IH-1 (74L2) and the sheath blight isolate 95KBNT collected near Stuttgart, Arkansas, in 1995.

Genomic DNA was extracted from leaf tissue using a CTAB method or the DNeasy Plant Mini Kit per the manufacturer's instructions. Three pairs of *Pi-ta* dominant primers, one pair of *pi-ta* recessive primers, and one pair of *Pi-b* dominant primers were used to determine the presence of *Pi-ta*, *pi-ta* and *Pi-b*, respectively. The presence or absence of these PCR products was visualized on a 1% agarose gel. The 180 microsatellite markers used to genotype the *Oryza* spp. accessions were visualized by fluorescent-labeled products, processed by an ABI 3700, and analyzed to detect polymorphisms in the PCR product. Once genotyped, approximately 30 polymorphic markers will be selected to follow the introgression of the *Oryza* spp. chromatin into the cultivated parent. At least one marker will be located on each of the 24 rice chromosome arms. Other polymorphic markers will be selected based on their proximity to known resistance genes.

Sheath blight tolerance was identified in the initial *Oryza* spp. confirming an IRRI report of sheath blight tolerance in these accessions. This tolerance was diluted when initial backcrosses were made to the cultivated rice parent. Resistance to all U.S. blast races was not identified in any of these accessions. As a result of backcrossing with selected *Oryza* spp. there are small populations of 1) Ahrent by five different *O. nivara*, one *O. nivara/O. sativa*, one *O. barthii* and one *O. rufipogon* accession(s) in the BC_3 or BC_4 and 2) Bengal by two different *O. nivara* and one *O. nivara/O. sativa* accession(s) in the BC_4 that have been developed.

Results from screening the *Oryza* spp. accessions with the four PCR-based markers for *Pi-ta* indicate the *Pi-ta* gene is present in an *O. barthii*, O. *rufipogon,* and *O. nivara/O. sativa* accession(s). The screening of the remaining *Oryza* spp. for *Pi-ta* and all accessions with the PCR-based *Pi-b* marker for the *Pi-b* gene is still being completed.

Data analysis is in progress that will give the genotype of each *Oryza* spp. accession included in this study based on the 180 microsatellite markers used in the earlier study of *O. sativa* germplasm. Once the genotyping analysis is complete, approximately 30 microsatellite markers will be selected from the aforementioned 180 markers to follow the introgression of selected *O. barthii*, *O. nivara,* and *O. rufipogon* accessions into the cultivated rice parent of either Ahrent or Bengal. Since recombination occurs more frequently in the distal region and most introgression involves distal rather than proximal chromatin, polymorphic markers located in distal regions will be given preference.

Bakanae-Like Symptoms Produced by Gibberellic Acid in Louisiana

Groth, D.E., Dunand, R.T., Hollier, C.A., Rush, M.C., and Shao, Q.

In 2003, rice seedlings showing bakanae disease symptoms were detected in several Louisiana fields. Typical symptoms included elongated, slender, pale seedlings that appeared around 2 to 4 weeks after planting. Symptoms appeared in both drill- and water-seeded rice fields. Fields were monitored throughout the season for further plant symptom development but none was detected. One to 2 weeks after detection, symptomatic plants were unidentifiable in the fields. In one field, both symptomatic and asymptomatic individual plants were flagged and observed for several weeks. Approximately 10% of both the symptomatic and asymptomatic plants died within 2 weeks. Symptomatic plants that did survive returned to normal growth habits and were indistinguishable from asymptomatic plants within 2 to 3 weeks. No additional symptoms of bakanae developed in any of the affected fields.

Seed and seedlings were collected from affected fields, surface sterilized, and plated on *Fusarium* selective media. Numerous *Fusarium* and other fungi were isolated from these plants, transferred to fresh media, and purified by hyphal tipping. Inoculum was produced by growing these fungi on a moist sterile rice hull:rice grain medium. Profuse mycelium and spore production were detected. A small quantity (1 to 2 ml) of this inoculum was placed in 10 ml of sterile water, along with 10 to 20 surface sterilized rice seeds, and incubated for 2 to 4 hours. These seeds were then either water seeded into shallow (~10 to 20 mm) water over soil or planted 10 to 20 mm deep into commercial potting soil in the greenhouse. No typical bakanae symptoms developed on any of the inoculated seedlings but *Fusarium* infections were detected on numerous seed and seedlings. No significant damage was done to the seedlings, and seedling heights and appearances were similar to the uninoculated checks.

Residual seed from the affected fields were obtained and planted in the greenhouse. Several samples of the same seed lots treated and untreated with gibberellic acid were obtained. All of the seedlings showing symptoms in the greenhouse had been treated with gibberellic acid, and the proportion of affected seedlings was very similar to affected fields. None of the untreated seedlings had symptoms in the greenhouse. Only one field was planted with gibberellic acid untreated seed.

Apparently, the bakanae symptoms were due to gibberellic acid seed treatment. Potentially higher than normal temperatures during late spring and uneven distribution of gibberellic acid on the seeds caused this situation. Although one field was planted with untreated seed, gibberellic acid contamination could not be ruled out. Similar symptoms had been detected in previous years but not reported. Disease surveys of commercial fields and inspections of certified rice seed fields did not detect any further bakanae symptoms in Louisiana in 2003.

Functional Analysis of the Rice Blast Resistance Locus *Pi-CO39(t)* and Its Corresponding *AVR1-CO39* Gene from *Magnaporthe grisea*

Leong, S.A., Chauhan, R.S., and Lazaro, D.

A new rice blast resistance locus, *Pi-CO39(t),* corresponding to avirulence locus, *AVR1-CO39* of *Magnaporthe grisea* was located on the short arm of rice chromosome 11. Comparative sequence analysis of blast resistant (CO39-indicia) and susceptible (Nipponbare-japonic*a*) rice genotypes at genomic regions co-segregating with *Pi-CO39 (t)* showed that two haplotypes are substantially diverged with respect to relative number, size, orientation, and location of NBS-LRR genes. A cluster of 18 NBS-LRR disease resistance-like genes in Nipponbare haplotype (500 kb) and a cluster of 8 NBS-LRR genes in the CO39 haplotype (230 kb) have been identified at the *Pi-CO39 (t)* locus. Both the NBS-LRR gene clusters are flanked by clusters of Serpin genes (serine/cysteine proteinase-inhibitors), which have been implicated as negative regulators of Toll-mediated antifungal defense pathway in *Drosophila*. Expression analysis of predicted disease resistance, as well as serpin genes was performed on RNA templates isolated from rice leaves. All the NBS-LRR genes were constitutively expressed in both the haplotypes, except the *RPR1* (NBR16) gene in Nipponbare, which showed induced expression in response to *M. grisea* infection. Two serpin genes in CO39 and one in Nipponbare showed induced expression in response to *M. grisea* infection. Functional analysis of these genes by complementation and gene silencing is underway and has identified one NBS-LRR gene as a probable receptor for *AVR1-CO39*. Orf3 of *AVR1-CO39* was demonstrated to produce the active function of this avirulence gene by direct expression in resistant plant cells.

Abstracts of Posters on Plant Protection
Panel Chair: M. Stout

Development of Improved Methods for Sheath Blight Evaluation

Shank, A.R., McClung, A.M., and Fjellstrom, R.G.

Sheath blight (SB) (caused by *Rhizoctonia solani*) is one of the most destructive diseases of rice in the world. Although screening nurseries are used by breeders to select for SB tolerant breeding lines, this requires a fair amount of seed and is usually performed only in advanced breeding generations. Development of molecular markers that are linked to SB resistance genes would allow marker assisted selection to be performed during earlier generations using a trivial amount of leaf material, as has been demonstrated with other disease resistance and cereal quality characters. For this technology to be developed, clear and repeatable screening methods are needed to accurately associate phenotypic resistant/susceptible ratings with marker polymorphisms. Previous research has shown that expression of SB disease symptoms is influenced by plant height and maturity. In order to circumvent interactions between adult-plant characters and the expression of sheath blight resistance under field conditions, alternative methods using greenhouse and laboratory evaluations of seedlings and detached plant parts were tested.

Rice varieties that had been categorized based upon their field reaction to SB were evaluated: Susceptible - Dixiebelle, Lemont, and Rosemont; Intermediate - Saber, Priscilla, and Dragon Eyeball 100; and Resistant - TeQing, Jasmine 85, Pecos, and BR10 (PI 574667). SB inoculum was grown on PDA plates from which plugs or strips of mycelia were cut and placed at the base of the seedlings. Two-, 4-, and 6-week old seedlings that had been grown in flats in rows 5 cm apart were evaluated in a mist chamber after inoculation with the PDA strips. In addition, small clusters of 2-, 4- and 6-week old seedlings were evaluated in 10 cm pots that were covered by 1) 2-l clear plastic soda bottles with the cap removed and the bottom cut off, 2) soda bottles with top and bottom cut off, and 3) tubular mylar cylinders.

Detached plant parts were evaluated using Nunc bioassay and the mycelia-PDA plugs. Plant parts included 1) detached 2^{nd}, 4^{th}, and 6^{th} greenhouse-grown seedling leaves; 2) flag-2, flag-1, and flag field-grown leaves; and 3) detached stems from greenhouse-grown plants at the 6^{th} leaf stage and from field-grown plants at the flowering stage.

The most definitive results were obtained using seedlings grown under soda bottle containers that were evaluated 7 days after inoculation for amount of necrotic lesions. Testing multiple cultivars from different disease classes under the same bottle covering resulted in confounded results due to leaf contact among the resistant and susceptible cultivars. However, differentiation was sufficient to discriminate levels of resistance/susceptibility among disease classes, which suggests that this method could be valuable for scoring segregating populations.

Development of a Detached Leaf Inoculation Method for Rapid Evaluation of Rice Cultivar Response to Sheath Blight Pathogen

Singh, P., Jia, Y., Eizenga, G.C., and Lee, F.N.

Sheath blight, caused by *Rhizoctonia solani* Kühn*,* is one of the most destructive fungal diseases of rice worldwide. To date, no complete genetic resistance to the disease is available among cultivated rice. A better understanding of mechanisms of host defense responses to different field isolates would enhance development of sheath blight-resistant cultivars. However, a reliable and reproducible inoculation technique in the laboratory is not available to accurately determine virulence of isolates. In the present study, differential rice cultivar responses to *R. solani* were detected by an *in vitro* detached leaf inoculation method using 14 field isolates from Arkansas, the major rice-growing state in the United States. The second youngest leaves of greenhouse-grown rice plants were detached and inoculated with potato dextrose agar plugs containing mycelia and incubated in Petri dishes. The total length of disease lesion was measured. Six rice cultivars, Cypress, Jasmine 85, Labelle, Lemont, Katy, and M-202, were used to evaluate their responses.

Jasmine 85 was significantly more resistant to *R. solani* when compared with the other cultivars tested. Katy and Lemont were moderately tolerant, whereas Cypress, M202, and Labelle were susceptible. The minor resistance responses to *R. solani* and minor pathogenicity differences of different isolates were determined by this method. Successful application of this assay should accelerate the identification and incorporation of minor sheath blight resistance genes into improved rice cultivars.

Exploration of Ethylene Mediated Partial Resistance for the Rice Blast Disease

Singh, M.P., Lee, F.N., and Counce, P.A.

Rice blast is a major yield limiting disease of rice throughout the world. Rice growers and researchers have long observed but poorly understood the phenomenon of field resistant cultivars being more prone to blast when growing upland than when growing irrigated. We investigated the role of root zone hypoxia activated perception of ethylene as an activation signal for the blast defense response observed with flooded rice.

The interaction of ethylene regulating compounds with upland or flood growth regimes on rice blast disease development was evaluated. Regulators utilized were the ethylene generator/promoter 2-chloroethylphosphonic acid, ethephon, formulated as Prep (55.4% ethephon), Bayer CropSciences, U.S.A., and the ethylene synthesis inhibitor aminoethoxyvinylglycine hydrochloride, AVG, formulated as Retain 15SP (15% AVG), Valent U.S.A. Corporation. Upland conditions were established with test plants growing in 12.5-cm pots filled with 7.5 cm field soil and maintained with daily irrigation without any surplus water. Flood treatments were a continuous 15-cm flood, relative to the soil surface, established by positioning pots of previously upland test plants inside a 22.5-cm deep plastic pot filled with water. Hormone treatments were applied to 4-week-old plants as foliar and/or soil drench applications. Treatments were segregated on widely separated greenhouse benches to limit interactions. Untreated control plants were established using comparable amounts of distilled water applied in a like manner. Plants were inoculated 2 days following hormone treatments. Immediately following inoculation, plants were moved into a dew chamber at 20 ± 1°C air temperature and 100% RH in dark for 18 hours then returned to their original test positions. Treatments were evaluated according to leaf lesion type using the standard 0-9 visual rating systems. The top two fully expanded inoculated leaves were selected from five plants of each replication for evaluation and a blast index was calculated.

Single 50-ppm ethephon foliar-drench treatments lowered the BI of susceptible cultivars growing upland to levels comparable with the BI of untreated flooded plants. Single 50 ppm AVG drench treatments increased the BI of susceptible flooded cultivars to levels comparable with the BI of untreated upland plants. Regardless of application method, flooded plants of susceptible cultivars Newbonnet, LaGrue, Mars, and Cypress were resistant to rice blast following two treatments with 50 ppm ethephon. The BI of untreated upland plants, untreated flood plants, and flood plants treated with ethephon were not significantly different within major R gene cultivars Drew, Katy, Kaybonnet, Saber, and Oryzica Llanos 5. When treated with AVG, however, the BI of these cultivars were statistically greater than untreated plants.

Rice plants respond to submergence stress with a series of physiological, biochemical, and morphological changes. Flood-induced blast resistance varies with cultivar and is apparently related to the initial degree of inherent blast resistance. Under upland conditions, cultivars having major R gene resistance are resistant while cultivars known to exhibit field resistance are susceptible. However, flood responsive cultivars, such as Newbonnet, LaGrue, Mars, and Cypress, exhibit substantial field resistance when growing under continuous flood. When growing upland, artificially induced ethylene production in these cultivars with ethephon treatment restores previously observed field resistance. Interestingly, blocking ethylene synthesis reversed the flood-induced resistance in the flood responsive cultivars. AVG treatment also increases susceptibility of blast resistant cultivars containing major R genes. Taken together, our results strongly suggest that ethylene is an essential component of a resistance-signaling pathway, which confers resistance to the rice blast pathogen *Pyricularia grisea*. Identifying and developing cultivars that express high levels of ethylene-induced blast resistance should be researched as means to develop durable, farmer friendly, sustainable alternative approaches in integrated rice blast management programs.

Impact of Preventative Fungicide Application on Rice Yield and Milling Quality in Arkansas

Thiesse, B., Chaney, H.M., Griffin, B., Gipson, R., Sutton, E.A., and Cartwright, R.D.

The use of fungicides in Arkansas rice production has increased during the late 1990s, with the introduction of more effective compounds and the release of higher yielding but less resistant rice cultivars. Currently, between 30 and 40% of Arkansas rice hectarage is routinely treated with a foliar fungicide. Principally, fungicide treatments target sheath blight but treatments to prevent kernel smut or help prevent neck blast are also made.

Among many growers and within the fungicide industry, there is a widely held belief that fungicide applications always pay for themselves, if not directly in yield protection then at least in increased milling quality (typically increased head rice). Several years ago, this was clearly not the case and research showed that fungicides provided an economic benefit or "broke even" only when there was substantial foliar disease present that the fungicide was effective against. However, the cultivars tested were somewhat more resistant to diseases than the present ones and their yield potential was lower. Also, new and more effective fungicides are now available and these factors argue for updated testing of the idea that preventative fungicide applications are always beneficial in rice.

Field plots were established on cooperating farms in Craighead and Prairie counties during April 2003. Cultivars ‘Bengal,’ ‘CL161,’ ‘Francis,’ and RiceTec hybrid ‘XL8’ were included to provide diversity in disease resistance and yield potential. These were planted in paired plots in a randomized complete block design with one plot in each rep receiving preventative fungicide treatment while the other did not. Fungicide treatments included trifloxystrobin plus propiconazole in Craighead County and azoxystrobin plus propiconazole in Prairie County and were applied at labeled rates and timings. Plots were harvested with a modified plot combine to preserve milling quality samples and yield was adjusted to 12% grain moisture.

Sheath blight was present at the Craighead County location. Fungicide treatment at this site resulted in a significant yield increase of 1213 kg/ha for CL161. Yield was not significantly different between treated and untreated plots for Bengal, Francis, or XL8. Based on numerical yield values alone, actual return per hectare varied from $135.36 to $192.17/ha for the fungicide treatment on CL161, depending on the assumptions used. For the other cultivars, return varied from a loss of $113.62/ha to a gain of $78.05/ha for Francis; loss of $113.62 to a gain of $5.34 for Bengal; and loss of $113.62 to a loss of $4.94/ha for XL8 – again, depending on an array of assumptions. Milling quality could change these results substantially but have not been finalized.

No significant diseases were noted at the Prairie County location. Numerically, all treated plot yields averaged 202 to 354 kg/ha more than the untreated plots by cultivar, however, statistical significance was marginal at best for the differences in cultivar Francis and XL8. Using a range of assumptions, net return for the fungicide application ranged from a loss of $91.40 to a gain of $4.94/ha for Francis and XL8 based on numerical yield results. Net return for the fungicide application to CL161 and Bengal ranged from a loss of $121.03 to a loss of $14.82/ha based on yield alone. Again, milling results may change these values when completed.

Based on these two experiments, it does not appear that preventative fungicide treatments always result in a measurable positive outcome based on yield alone. However, it was true that treated plots always had a slightly higher numerical average yield than untreated plots. The outcome of milling quality results will likely determine the final economic result, as expected. These experiments plan to be repeated at more locations in Arkansas during 2004 and 2005.

Application of Variable Rate Fungicides with the Use of Multispectral Imagery

Jayroe, C., Baker, B., Greenwalt, A., Cartwright, R., Stiles, S., and Hamilton, M.

In Arkansas over 30% of the 600,000 ha of rice planted are susceptible to sheath blight and other fungi. Treatments for these inputs typically cost in excess of $49/ha, making fungicides the most expensive input in rice production. In the past, multispectral imagery has shown significant results for identifying areas of plant stress. This study examines the possibility of using multispectral aerial imagery as a tool in identifying signs of fungus infestation. The imagery was acquired during the vegetative stages of growth and terminated at panicle initiation. The fields were observed weekly for any instances of stress, disease, or infestations identified by the multispectral imagery. The objective of this project was to refine the use of multispectral imagery and determine its usefulness in making variable rate prescriptions and/or midseason decisions. The economic impact on rice production was considered from a variable rate perspective and, in this study, yielded a 63% savings.

The Agents Causing Bacterial Panicle Blight Disease on Rice in Louisiana: A Complex of *Burkholderia* spp.

Yuan, X.L., Shahjahan, A.K.M., and Rush, M.C.

Blighted panicles and diseased sheaths were collected from fields in Louisiana, Arkansas, and Texas. Diseased grains and sheath tissues were plated on S-PG medium, which is semi-selective for *Burkholderia,* and bacteria growing on the medium with colony characteristics of *Burkholderia* and *Pseudomonas* were transferred to King's B agar (KBA) medium. These isolates typically produced yellow-green pigment on the KBA medium. A total of 402 isolates were obtained, which after purification by serial dilution in sterile water, gave 420 bacterial isolates. Pathogenicity tests were conducted with all of the isolates on rice seedlings and emerging panicles of the variety Cypress. A total of 361 isolates, which were all gram negative and rod shaped bacteria, were identified to species level by the Biolog GN2 system. The identified bacteria belonged to 39 species in 16 genera. *Burkholderia* was the most common genus with 261 isolates. One hundred and three isolates were identified as *B. gladioli*, 68 isolates were *B. glumae*, 25 isolates were *B.* plantarii, 60 isolates were *B.* multivorans, 3 isolates were ***B.** cepacea***,** 52 isolates were in the genus *Pseudomonas*; and 26 isolates included 14 other genera. Pathogenicity tests confirmed that 234 or 65% of these isolates were pathogenic on rice. The four most common species, *B. glumae*, *B. gladioli*, *B. multivorans*, and B. *plantarii,* comprised 90% of the pathogenic bacteria, suggesting that a complex of *Burkholderia* species may be the agents causing the bacterial panicle blight disease of rice recently found in Louisiana. Of the strains identified as *B. glumae*, 91% were pathogenic on Cypress, suggesting widespread pathogenicity among the strains of this species.

P. fuscovaginae, which was reported as a causal agent of grain discoloration and grain rot in Latin America, Japan, and Africa, was not detected among these isolates. Three of 15 *Pseudomonas* species isolated were pathogenic to rice seedlings. Two strains of *P. syringae* pv *zizanize* were pathogenic on both rice seedlings and panicles. Three strains each of *P. pyrrocinia* and *P. fluorescens* were also pathogenic. In addition, an isolate identified as *Vibrio tubiashii* by the Biolog system, appeared to be weakly pathogenic on rice seedlings.

Transformation of Rice with the Thionin Gene for Bacterial Panicle Blight Resistance

Zhang, S., Shi, Y.L., Zhang, Y.H., Shao, Q.M., Shih, D., and Rush, M.C.

The development of fungal pathogens can be significantly reduced by the introduction and expression of pathogenesis-related protein genes. In our research, a plasmid containing the thionin gene along with the gene for hygromycin B resistance, used for *in vitro* selection, was transferred into rice in an attempt to increase the resistance of transgenic plants to bacterial panicle blight (BPB). Rice callus from the cultivar Lafitte was used for transformation using the Biorad particle gun. The thionin gene was detected in regenerated plants (R_0) using the PCR method and Northern blot testing showed that the transgene was expressed. Following generations of progeny were further tested by inoculation with the pathogen *Burkholderia glumae* in the field at the LSU AgCenter's Rice Research Station in Crowley, LA. Emerging panicles were inoculated by spraying panicles in glycine bags. The disease was rated at maturity on inoculated transformed and non-transformed rice plants. Some transformed plants showed a high level of resistance to BPB. These plants had the thionin gene. After harvest, panicles were dried for 2 days in an oven at 42°C then weighed, and the number of filled kernels in each panicle was determined. Statistical analysis was used to compare the differences among transgenic plants and non-transgenic plants. Significant loss of panicle weight and numbers of filled kernels were observed between transgenic resistant plants and non-transgenic plants.

Screening Rice Varieties and Lines for Reaction to Bacterial Panicle Blight Caused by *Burkholderia glumae*

Rush, M.C., Shao, Q.M., Shahjahan, A.K.M., and Groth, D.E.

A nursery to screen for bacterial panicle blight (BPB) was established at the LSU AgCenter's Rice Research Station (Crowley, Louisiana) in 2003. This nursery included the 2003 URRN entries and five previously identified resistant check lines and cultivars. The nursery was planted with a Hege Tray Planter in rows with a 18-cm spacing between rows. Three 1.8 m-row plots were planted for each entry with three replications in a completely randomized design. The plots received 24-69-69 kg/ha (N-P-K) preplant and 134 kg N/ha preflood. Herbicides included Arrosolo + Londax followed by Clincher. Preplant Icon and Karate Z were used for insect control later in the season. The center row of each plot was inoculated with a 24-hr culture of *Burkholderia glumae* (951886-4-1c) applied with a hand sprayer when 50% of the panicles emerged from the boot stage of growth. A 0-9 rating scale was used to rate entries for BPB resistance at maturity. Thirty entries (15%) were resistant using the 0-9 rating, 108 entries (53%) were intermediate in reaction, and 67 entries (33%) were susceptible or very susceptible. Three entries previously tested and found resistant (AB647, Nipponbare, and LM-1) were resistant in the 2003 nursery. LR2065 was moderately resistance (3.7). Resistant 2003 URRN entries included 005, 007, 013, 015, 031, 032, 042, 060 (DREW), 075, 076, 079 (KBNT), 101, 136, 142, 153, 155, 158 (DLRS), 162, 182, 189, 198, and 200 (XL8). Crosses were made in 2003 between four resistance sources and Cocodrie to study stability and inheritance of resistance to BPB. F_2 populations from these crosses will be grown and tested for resistance in 2004. We will continue to make crosses among germplasms identified as resistant and the susceptible cultivars Cocodrie and Bengal.

Bacterial Panicle Blight Disease of Rice in Arkansas

Parsons, C.E., Sutton, E.A., Carpenter, C., Runsick, S., Thompson, R., Chlapecka, R., Taylor, S., Clark, S.D., and Cartwright, R.D.

Bacterial panicle blight, caused by *Burkholderia glumae*, has caused substantial yield and quality losses in Arkansas since 1993, primarily to the medium grain cultivar 'Bengal.' The pathogen has historically been known in Asia as the cause of bacterial grain rot. The disease has likely been present for many years in the United States but has been misidentified or too minor and erratic to study in the past.

With the introduction of Bengal in 1992, the disease has increased in Arkansas until it is important each year in the medium-grain production area. While weather moderates severity somewhat, Bengal growers no longer expect the extremely high yields and quality the cultivar delivered when first released. While research on basic aspects of the disease and the seed borne nature of the pathogen continue in Louisiana and elsewhere, we have also conducted various applied research projects on the disease for several years.

Given the seed borne nature of the pathogen, several seed treatment trials have been conducted in Arkansas using Bengal seed harvested from fields with severe bacterial panicle blight disease. Seed was treated with a laboratory seed treater using a number of conventional and experimental fungicides and bactericides, including oxolinic acid. Seed was planted in April and May with conventional plot drill equipment and inspected for seedling death and stand counts. Plots were harvested and yield adjusted to 12% grain moisture. To date, results from the seed treatment trials in Arkansas for control of bacterial panicle blight have been disappointing at best. While significant stand count differences have been noted for a few fungicides and bactericides, no effect on the later season disease, bacterial panicle blight, has been noted. This may be due to ineffective coverage and penetration of the materials, lack of basic efficacy against the pathogen, or the ability of surviving pathogen cells to rapidly multiply during the growing season.

Foliar treatments have also been tested using conventional backpack sprayer methodology. Plots were inoculated with a suspension of cells grown in nutrient broth overnight and diluted to 10^7 cells per ml with distilled water. Cell suspensions were sprayed on plots at late boot and early heading to encourage uniform disease development. In some tests, additional inoculations were made to increase severity. Results from multiple test plots in Arkansas showed commercial formulations of the experimental compound, oxolinic acid, reduced bacterial panicle blight symptoms by 95%, and resulted in a 35% yield increase over untreated plots. Unexpectedly, applications of azoxystrobin fungicide in some trials resulted in significant yield increases of up to 20% with no notice of major fungal diseases. It was hypothesized that azoxystrobin could be interfering with secondary fungal invasion of panicles damaged by bacterial panicle blight. This effect was also noted in commercial field demonstrations with azoxystrobin applied to Bengal rice. However, this fungicide approach did not always work and azoxystrobin did not appear to directly affect *B. glumae* or bacterial panicle blight. Regardless, without registration of oxolinic acid, reliable control of bacterial panicle blight with a foliar treatment does not appear likely.

Evaluation of the Uniform Rice Regional Nursery for reaction to bacterial panicle blight in Arkansas began in 2001 using the inoculation method previously described. Due to the variation in maturity of the 200 rice lines in the nursery, all plots were inoculated six times starting at the booting stage for the earliest lines. While variation in susceptibility among the lines to bacterial panicle blight was noted, it was still apparent that late maturing lines were escaping infection either due to more poorly timed inoculations or the moderation in temperature later in the growing season. In general, medium-grain lines, including Bengal and RU0001151, were consistently among the most susceptible. Among long grains, various experimental lines, and the newly released 'Francis' long-grain cultivar were highly susceptible under inoculated conditions.

Seed Transmission of the Bacterial Panicle Blight Pathogen *Burkholderia glumae*

Groth, D. E. and Frey, M. J.

Panicle blight was recently identified as being caused by the bacterium *Burkholderia glumae* in the United States. Yield and quality loss estimates vary from a trace to 50%. The bacterium has been reported to be seed borne and can cause a seedling blight that thins stands. The pathogen was initially identified as a leaf epiphyte for use as a sheath blight biocontrol agent. The bacterium appears to survive on the plant as an epiphytic population on the leaf and leaf sheath and follows the canopy up. This population infects the grain at flowering and causes grain abortion and rotting during grain filling. Sheath rot symptoms have been reported. Seed treatments have shown some activity in reducing seed borne pathogen populations and subsequent head disease. The objective of this study was to determine if *B. glumae* is seed transmitted and if epiphytic populations play a part in seed transmission.

An antibiotic resistant mutant (Bgrif) of *B. glumae* was selected by exposure to the antibiotic rifampin. The isolate was inoculated onto rice heads of Cypress and Lemont in the field during the fall of 2002. This seed was assayed for the presence of the bacteria by soaking seeds in a buffered solution with a wetting agent and plating onto a selective medium made of PDA with 100 ppm rifampicin and 200 ppm cycloheximide incorporated in to it. Infested seed lots were planted in the greenhouse during the winter 2002-2003 and in the field in 2003. Epiphytic populations were evaluated by leaf prints and leaf washing and plating onto the selective media. Grain was assayed at plant maturity as described above.

Seeds inoculated with Bgrif had high levels of bacteria. The bacteria survived over winter on the seeds. Seedlings in the greenhouse and field developed epiphytic populations of Bgrif from inoculated seed. The bacterium was able to continue to establish new epiphytic populations on later developing leaves. Infected seeds were produced on scattered heads and not all seeds were infected. Epiphytic populations were erratic and had low populations. Spread of the bacterium on and between plants appeared very limited.

A Decade of On-Farm Rice Cultivar Testing and Disease Monitoring in Arkansas

Cartwright, R.D., Parsons, C.E., Thiesse, B., Gipson, R., Chlapecka, R., Chaney, H.M., and Thompson, R.

Rice diseases continue to be a major constraint to higher yield and quality in southern U.S. rice production. Numerous diseases occur in the South, including Arkansas, and both incidence and severity change both within each season and over longer periods of time. The continual introduction of new cultivars and new fertilizer or other management options influence both the type and severity of the diseases farmers contend with.

In 1993, Dr. George Templeton (deceased) and the lead author initiated a statewide disease-monitoring project to catalog both the kinds of rice diseases present and their severity on different cultivars of rice. It had been almost 20 years since the last attempt at monitoring in the state and many changes in rice and rice production had occurred. Also, rice exporters and rice importers in other countries were requesting updated information on rice diseases present in Arkansas. With funding from the Arkansas Rice Research and Promotion Board, the project began by planting replicated sets of specific rice cultivars in seven rice fields in widely different parts of the state in 1993. The cooperating growers managed the plots with the rest of the field along with guidance from the local county extension agent. Plots were inspected periodically for diseases and other problems and harvested for yield at the end of the season. On inspection trips to and from the plot locations, an extensive network of cooperation developed between rice county agents, growers, consultants, and the lead author.

This network resulted in the establishment of a widely circulated Rice Disease Newsletter and a comprehensive field survey project between 1993 and 1995 in addition to the on-farm plots. The newsletter was circulated to Arkansas growers and consultants by the County Extension System and to various recipients in other states that requested it. Over 10 years, the newsletter reached at least 5000 interested parties per year by email, fax, or post.

Between the on-farm plots and the 3-year field survey, the following diseases were cataloged and categorized in Arkansas: sheath blight, blast, kernel smut, false smut, seedling disease complex, narrow brown leaf spot, brown spot, scald, sheath rot, crown sheath rot, head scab, bacterial panicle blight, leaf smut, autumn decline or hydrogen sulfide toxicity, potassium deficiency, straighthead, glyphosate injury (mimics straighthead), stem rot (regular and irregular forms), white tip nematode, and ear blight (*Curvularia*). The following have caused major problems in the state each year: sheath blight, blast, kernel smut, seedling disease complex, straighthead, glyphosate injury, and bacterial panicle blight (on 'Bengal'). Others have caused localized problems in different years including false smut, stem rot x brown spot x potassium deficiency complex, crown sheath rot, and autumn decline. Others have been only minor curiosities during the monitoring period. Other diseases that were reported but not confirmed included sheath blotch (one observation in one field in 1995) and Fusarium sheath rot (misidentified and later shown to be bacterial panicle blight).

Benefits of the monitoring program have been numerous. On-farm cultivar performance and reaction to several diseases in different environments have been used to upgrade information for growers and provide feedback to rice breeding programs. More than 200 cultivars, hybrids, and advanced lines have been evaluated in virtually every growing environment in the state over the past decade. Presence of the plots in local areas has provided county extension agents the opportunity to host numerous local field days and training clinics in their locale. The network of cooperators established by the program has provided early warning to the state of developing epidemics (e.g. blast) and early detection (e.g. false smut was first detected in Arkansas in 1997). And updated information on diseases present has allowed us to provide needed information to APHIS and the U.S. rice industry when export questions arise from other countries.

Management of False Smut for Rice in Arkansas

Clark, S.D., Parsons, C.E., Sutton, E.A., Carpenter, C., Thiesse, B., Eason, R.L., and Cartwright, R.D.

False smut, caused by *Ustilaginoidea virens*, was first noted in Arkansas during 1997 in 17 rice fields in northeast Arkansas, primarily on the cultivar 'Drew.' Since that time, the disease has been reported in virtually every rice county of the state but remains most severe in the northeast counties. The factors leading to the increased severity of false smut in Arkansas are not known but most popular rice cultivars now grown are susceptible.

In response to the increasing severity and distribution of the disease, various research projects were initiated to develop or improve control options. Numerous fungicide trials have been conducted to identify short-term chemical control options. In the past 3 years, more intensive screening of rice germplasm has been conducted to help rice breeding programs incorporate resistance into current and future high yielding rice lines.

In order to conduct both fungicide trials and germplasm evaluations, a reliable inoculation method had to be devised. Attempts to culture the pathogen, while successful, did not result in isolates useful in the production of inoculum. Therefore, in 1998, field trials were planted in late May to early June based on the late-season appearance of the disease. In order to encourage uniform disease, fresh false smut balls from earlier planted commercial rice fields were hand harvested, placed in plastic bags, and transported on ice to trial locations. False smut balls were removed from panicles, placed in distilled water, and hand-agitated to release the orange conidia into the water. The conidial suspension was filtered through two to four layers of cheesecloth, diluted to a minimum of 10^6 conidia/ml, and sprayed on emerging panicles within the test plots. Typically, plots were inoculated two to four times in this manner during early heading, approximately 2 days between inoculations. Within 1 to 2 weeks, new smut balls formed in the inoculated panicles and increased until harvest. Fungicide test plots were harvested with a modified plot combine. Grain from each plot was weighed and tested for moisture and the false smut balls counted by hand. Grain yield was converted to 12% moisture, and false smut levels reported as number of false smut balls/kg of dry rice.

Fungicide results varied from year to year. In general, fungicides containing propiconazole or copper were the most effective at reducing false smut. However, copper-containing fungicides were phytotoxic and reduced rice yields more than the disease. Propiconazole was found to be moderately effective from 126 to 351 g/ha (or higher), reducing the number of false smut balls/kg dry rice by 50 to 80%, depending on the trial. Timing of the lower rate propiconazole applications was found to be critical with applications during the swollen to boot splitting stages of development most effective. Applications after heads began to emerge resulted in approximately 50% reduction in control. Azoxystrobin was erratic in suppression of false smut with lower rates being ineffective. Azoxystrobin rates of 224 g/ha and above were somewhat effective. Azoxystrobin and propiconazole combination treatments were as effective as propiconazole alone, with no antagonism or synergism noted. Based on these trials, guidelines for the proper rate and timing of propiconazole in fields with consistent false smut have been developed.

Evaluation of the Uniform Regional Rice Nursery for reaction to false smut began in 2001 using the inoculation method developed for the fungicide trials. Reaction was measured by visual estimate and by counting false smut balls per panicle in some instances. Approximately 200 lines were evaluated each year and included certain hybrid rice cultivars. While true susceptibility was easily noted, consistent resistant reactions were more difficult to observe. Partially, this was due to the variability in maturity among the lines with very early ones escaping infection while very late lines being overwhelmed in certain years, depending on weather and timing of inoculation. In general, long-grain rice from the Arkansas and Louisiana breeding programs, including LaGrue, Drew, Francis, Cocodrie, Cypress, and Wells, were among the more susceptible while certain long grains from Texas were among the least susceptible. Hybrid rice appeared to be less susceptible than conventional rice as did medium- and short-grain rice.

False smut continues to be a sporadic and aggravating rice disease, especially for northeast Arkansas producers. While research to date has provided some management options, better ones are needed. In that light, research on the basic aspects of false smut epidemiology have been initiated as having studies on the impact of nitrogen rate and timing on disease severity. Hopefully, future developments will reduce the disease to its former minor rank.

Pathogenic and Genetic Diversity among *Bipolaris, Drechslera, and Exserohilum* Species on Rice

Ouedraogo, I., Correll, J.C., Boza, E.J., Cartwright, R.D., and Lee, F.N.

There is a number of leaf spot diseases of grasses caused by species of *Bipolaris, Drechslera*, and *Exserohilum*. Brown leaf spot, caused by *Bipolaris oryzae,* is an important disease greatly affecting yields in many areas of Africa. However, the impact of this disease in the United States has not been carefully evaluated. In Arkansas, brown leaf spot typically is more severe in fields with poor overall fertility, but the impact of fertility, the disease, and the interaction of the two have not been evaluated. Also, eye spot disease of rice, caused by *Drechslera gigantean*, has been reported in a number of rice growing areas but has not been reported from rice in the United States. In an effort to examine pathogenic and genetic diversity of these leaf spot pathogens, isolations from symptomatic rice and grass weed tissue were made in Arkansas and North Carolina.

A collection of monoconidial isolates was made from symptomatic rice leaves and panicles from rice fields in Arkansas and North Carolina, as well as from several grass weeds. The collections included *B. oryzae*, *B. maydis, B. zeae*, and several unknown *Bipolaris* species, *D. gigantea*, and *E. rostratum*. Pathogenicity tests with the various species were conducted in the greenhouse on the rice cultivar Bengal. A considerable degree of variation in virulence was observed among the isolates examined. Both *B. oryzae* and *D. gigantea* caused lesions similar to those observed in the field.

Molecular and genetic variation among multiple isolates within each of the species was examined using mitochondrial DNA RFLPs. In addition, molecular comparisons between isolates of *B. oryzae* from the United States and Burkina Faso also were made. A test is being developed to examine isolates of *B. oryzae* for vegetative compatibility.

Increase in Incidence of Sugarcane Borer, *Diatraea saccharalis*, Damage in the Presence of Amazon Sprangletop, *Leptochloa panicoides*

Tindall, K.V., Castro, B.A., Williams, B.J., and Stout, M.J.

The sugarcane borer, *Diatraea saccharalis* (F.), has a broad host range that includes several crops, including rice, *Oryza sativa* L. Sugarcane borers are becoming an increasingly important pest of rice. However, there is little recent research on this pest in rice. In the summer of 2003, a field experiment was conducted to determine if the presence of Amazon sprangletop, *Leptochloa panicoides* (Presl) Hitchc influences sugarcane borer damage to rice. Experiments were conducted at the Macon Ridge Research Station near Winnsboro. Rice was planted into a Gigger silt loam at a rate of 112 kg/ha. Experimental design was a randomized block design with three treatments replicated three times. Plots measured 4 x 3 m and consisted of 20 rows of plants. Treatments consisted of three spatial arrangements of rice and sprangletop. In the first treatment, rice was grown in the absence of sprangletop. The remaining two treatments were mixed plots that differed in placement of sprangletop relative to rice. Mixed plots of sprangletop and rice were grown such that either rice was surrounded by sprangletop or sprangletop was surrounded by rice. Sprangletop plants produced seedheads approximately 4 weeks prior to rice; many seedheads were white. Sprangletop plants with whiteheads were removed and examined for larvae. After rice panicles emerged, borer damage was recorded on 19 Sept by walking through each plot and removing plants that had signs of borer damage. Panicles were taken to the laboratory, examined for larvae, and grouped into categories of damage. Borer damage was characterized as dead hearts, complete whiteheads, and partial whiteheads. A panicle with three or more non-filled, white rice seeds with evidence of borer feeding was considered a partial whitehead. All larvae collected were identified to verify that the larva was sugarcane borer and not rice stalk borer or European corn borer. Numbers of whiteheads and partial whiteheads were analyzed using contrast statements to compare damage to rice from interior portion of whole plots of rice and damage to rice collected from the interior portion of mixed plots. Likewise, comparisons were made between damage to rice from outer margins of whole plots of rice and damage to rice collected from outer margins of mixed plots.

Greater than 95% of the larvae collected from both rice and sprangletop plants were sugarcane borers. A few European corn borers were collected from sprangletop plants. When rice was in the exterior portions of mixed plots, there was 12 times more dead hearts, 1.5 times more partial whiteheads, and 2 times more total damage (dead hearts, whiteheads, and partial whiteheads) present than in the exterior of whole plots of rice. When rice was in the interior of mixed plots, the total damage was 1.6 times greater than in the interior of whole plots of rice.

Use of the Aquatic Barrier Traps to Monitor Rice Water Weevils in Fields Enrolled in the Rice Research Verification Program

Bernhardt, J., Richards, T., and Branson, J.

Most of the currently registered insecticides for the rice water weevil, *Lissorhoptrus oryzophilus* Kuschel, control require some type of estimate of the density of adults for proper timing of application. For that purpose, the floating aquatic barrier trap was developed to directly monitor adults in rice fields. The trap depends solely on the semi-aquatic behavior of adults and the fact that the majority of adults swim in the top 10 cm of the water column. The applicability of the traps needed to be tested in 'real world' conditions, such as that in grower fields. The Rice Research Verification Program (RRVP) was the appropriate test arena. The RRVP is an interdisciplinary educational program that stresses university recommendations for intensive crop management and integrated pest management. The goal is to maximize profitability while verifying recommendations and elucidating research needs.

In 2003, aquatic barrier traps were used to monitor rice water weevil adults in nine RRVP fields. The fields were in Arkansas, Chicot, Clay, Crittenden, Cross, Jackson, Poinsett, Woodruff, and St. Francis counties in Arkansas. As the growers began flooding fields, six or eight traps were placed in bar ditches where water is normally at least 10 cm deep. Traps were anchored with a tall wire flag and equally spaced along two opposite field margins at a minimum distance of 8 m from the margin. County agents checked the traps daily or every other day. When traps were checked, adult rice water weevils were separated from other invertebrates and counted. Traps were then repositioned to within 6 to 8 m of the previous position. Traps were monitored a minimum of 3 days and a maximum of 7 days. Two fields had the cultivar 'Francis' and the hybrid 'XL8' that did not yet have defined thresholds for insecticide application for weevil control. A threshold for Francis was used that was based on preliminary data from 2002. Threshold data on 'XL6' from small plots tests in 2000 were used for XL8. Between 21 and 28 days after onset of permanent flood 20 to 30 standard soil core samples per field were taken to estimate the density of rice water weevil immatures. Core samples were taken at random along transect lines that divided the fields into four sections for small fields (≤ 20 ha) and five sections for the larger fields (≥ 24 ha). Five, six, or seven core samples were taken along each transect.

County agents reported no problems with the traps but complained slightly about the daily checks and the time spent on monitoring the fields. Most reported between 30 to 45 min. to check the traps. In general, the traps performed as expected but the number of traps in relation to field size was a concern in three fields larger than 32 ha.

The maximum field average for the number of adults per trap ranged from 2.5 to 41.5 in the nine fields. This value was used to predict the average number of larvae per core sample by using the ratio of 1 adult:0.6 larvae. In two fields, the predicted number of larvae equaled or surpassed the treatment threshold. In Woodruff County, the field of XL8 had a maximum average of 11/trap 4 days after the onset of flood. Previous data with XL6 had indicated an average loss of 50 kg/ha for each larva present in a core sample. In St. Francis County, the east half of the field of 'Wells' rice had a maximum average of 41.5/trap 5 days after the onset of flood. The east edge was bordered by a ditch bank of unmanaged weeds that probably served as an excellent over-wintering site for adults. Both fields were treated with Karate Z at 0.034 kg ai/ha. The Jackson County field was drained and dried for straighthead and resulted in 70% control of larvae. Comparisons of the predicted number of larvae to the number of larvae found in core samples in the remaining six fields had the following results: two fields were overestimated by 16% of the threshold; two fields were underestimated by 16% of threshold; and two fields were on target. For the fields that were over- or underestimated, none were close enough to the threshold to cause concern for excessive yield losses or near enough to treating a field that did not need treatment.

We were encouraged that the aquatic barrier trap performed well in these growers' fields. The traps provided a quick method to sample adults, timely data on population density, and accurate data on which to base a decision to apply control measures for rice water weevil adults. We will continue to place traps in the RRVP fields and further refine factors such as trap placement, number of traps needed, and accuracy of predictions.

The Influence of Grain Maturity on the Susceptibility of Rice to Rice Stinkbug Damage

Patel, D. and Stout, M.J.

A greenhouse experiment was conducted to evaluate the effects of panicle age and grain maturity on quantitative and qualitative losses caused by feeding of the rice stinkbug, *Oebalus pugnax*, on rice panicles. Stinkbugs were caged on rice panicles (one bug per panicle) at 1, 5, 9, 13, and 17 days after anthesis (DAA). Stinkbugs were allowed to feed for 4 days then removed. Proportion of filled grains, grain weight, and grain peckiness were evaluated at grain maturity. The results show that rice grains are most susceptible to rice stinkbug damage during the first 2 weeks after anthesis.

The proportion of filled kernels was lowest in panicles infested one DAA. The proportion of filled grains was greatest in the untreated control, and the 13, 17, and 21 DAA treatments and intermediate in the 5 and 9 DAA treatments. A similar pattern was observed for average grain weight. Kernel weights were lowest in the 1 DAA treatment, intermediate in the 5 and 9 DAA treatments, and highest in the treatments infested later.

Pecky rice (qualitative damage) was greatest at 9 DAA followed by 5, 13, and 1 DAA. Percent peckiness in the 9, 5, and 13 DAA treatments were not significantly different from each other, whereas peckiness in the 1 DAA treatment was significantly lower than in the 9 and 5 DAA treatments but not the 13 DAA treatment. The untreated control treatment and the 21 and 17 DAA treatments had the lowest peckiness.

The above results confirm that the susceptibility of rice grains to qualitative and quantitative damage from rice stinkbug feeding decreases as grains mature. Rice is most vulnerable to rice stinkbug damage during the first 2 weeks after anthesis.

Abstracts of Papers on Processing, Storage, and Quality
Panel Chair: E. Champagne

Effect of Drain Time and Meteorological Conditions at Harvest on Medium-Grain Rice Quality

Mutters, R.G., Thompson, J.F., Hair, M., and Knutson, J.

Commercial records show a general relationship between rice moisture at harvest (HMC) and head rice quality (HRY), but there is a wide variation in quality at any given HMC. California growers believe that keeping soil moisture high at harvest fosters high HRY and that periods of dry north winds reduce HRY. The goal of this experiment was to determine the effects of drain timing and meteorological conditions on HRY.

A field of M202 medium-grain rice was divided into three plots and the plots were drained on September 12, 18, or 26 and harvested on September 30 and October 6, 13, and 16. Each plot was hand harvested at six to eight locations and threshed with a small plot thresher. Rice moisture for each location was determined with a single grain moisture meter (Kett) and HRY determined by the California Department of Food and Agriculture Grain Quality Inspection Lab using USDA-FGIS procedures.

The early drained plot had lower HRY than the other two plots. The differences were greatest at the last two harvest times where HRY was almost 10 lb/cwt lower for the early drained plots compared with the normal and late-drain plots. The differences were associated with higher HMC for the normal and late drained plots. When HRY is graphed against HMC, there is no difference in the drain time treatments except that the later drained plots have higher HMC and generally higher HRY.

Before October 9, the weather was calm and the paddy was exposed to dew for 10 to 15 hours per day. From October 9 through Oct 14, there were two periods of north wind and significant dew was present for only one night. The typical pattern of calm conditions and dew resumed after Oct 14. The paddy harvested on Oct 13 showed a straight line decrease in HRY as HMC decreased and the regression line fell in a region of generally HRY compared with commercial data. Even samples with HMC near 15% had HRY greater than 50 lb/cwt, resulting in grower return in the range of $4.75 to $5.25/cwt. After the dew returned, the HRY was also linearly correlated with HMC, but the relationship was clearly different from the previous harvest. HRY dropped by 10 to 15 percentage points and grower return dropped by about $0.50/cwt. The dry north wind conditions allowed the rice to dry with relatively little quality loss. The calm conditions and dew after the wind caused a HMC increase and a significant reduction in HRY. The HRY loss appeared to be associated with rehydration of rice after it had dried below a threshold moisture content of about 16%.

The results of these observations imply that harvest should proceed at maximum possible rates during dry weather conditions. Growers receive the greatest value for their crop under these conditions because they allow high quality rice to be harvested at low moisture. HRY loss after the return of dew forming conditions can be minimized by keeping rice moisture high with practices, such as late draining of fields.

Individual Rice Kernel Moisture Content Variability Trends at Harvest

Bautista, R.C. and Siebenmorgen, T.J.

Moisture content (MC) distributions of individual rice kernels on panicles were measured for cultivars Bengal, Cypress, and Drew. The samples were harvested at different stages of maturity from foundation seed fields at two locations in Arkansas (Stuttgart and Keiser) with widely varying soils during 1998, 1999, and 2000. The objective was to assess the variability and trends in individual rice kernel MC distributions as affected by maturity, planting location, and year. Individual kernel MC distributions were multi-modal until the average harvest MC (HMC) reached about 16%, at which point the distributions tended to be primarily single-modal. For all varieties, HMC significantly affected kernel MC standard deviation. For Cypress and Drew, individual kernel MC standard deviation was significantly affected also by year, location, and interactions of HMC*year and HMC*location. Regression equations that accounted for the variation in individual kernel MC at varying kernel HMCs were generated for each cultivar.

Effects of Rough Rice Harvest Moisture Content on Peak Viscosity

Wang, L., Siebenmorgen, T.J., Matsler, A.D., and Bautista, R.C.

The effects of rice harvest moisture content on pasting properties of milled rice were investigated. One medium-grain and nine long-grain rice varieties were plot combine harvested at different intervals from three locations in 2002. Rough rice samples were dried and milled under controlled conditions, the head rice yield was recorded, and the rice flour was analyzed for pasting properties. The optimum harvest moisture content for maximizing head rice yield varied with locations and ranged from 15 to 23%. The peak viscosity of rice flour within a given variety was generally inversely correlated with harvest moisture content. The rate of increase in peak viscosity as the harvest moisture content decreased depended on variety and location, which is speculated to be due to varying distributions of kernel moisture contents and resultant overall kernel maturity.

Laboratory Study and Computer Simulation of In-Bin Rice Drying

Jia, C. and Siebenmorgen, T.J.

One of the concerns when using in-bin rice drying systems is the variation in moisture content (MC) between the bottom and top layers of the drying bed. These differences can have ramifications in subsequent management of stored rice and in subsequent milling and end-use quality. The objective of this study was to measure the MC profiles incurred within a lab-scale bin dryer in which rice depths were varied and drying air conditions were controlled. The data collected from these tests were also used to validate a recently developed simulation model that predicts drying behavior in on-farm, in-bin systems.

The lab-scale drying system comprised a drying bin (transparent Plexiglas, with a 31.3 cm inner diameter and 61 cm height), a centrifugal fan, and an air relative humidity (RH) and temperature control unit for generating desired air conditions. Six 1.3 cm holes were drilled along the bin wall height for sampling at 8, 16, 24, 32, 40, and 48 cm from the bottom of the perforated floor. Long-grain rice variety Francis and medium-grain rice variety Bengal were used. A grain probe was used to collect 25-g samples for oven MC analysis at each sampling elevation at specified times during drying.

Two drying conditions, an ambient air condition of 24°C/61% RH and a heated air condition of 32°C/65% RH, were used to simulate possible on-farm drying conditions. The rice equilibrium MC for both air conditions was approximately 12.5 % (w.b.). Experimental results showed that ambient air drying produced a slightly more uniform MC profile inside the bin, even though the equilibrium MC of both air conditions was equal. The difference in MC from the bottom to the top of the bin under ambient air drying with a 20-cm rice depth was 0.3 percentage points (w.b.) when the average MC of rice reached 13.0 % (w.b.); however, the difference in MC under the heated air condition with the same rice depth and conditions was 0.6 percentage points (w.b.). Decreasing rice depths, which were accompanied by increasing airflow rates, significantly reduced the MC difference inside the bin during drying. Simulation results also showed that there was good agreement between the predicted and experimental data; the average difference in predicted and measured MCs was less than 0.3 percentage points (w.b.).

Investigation of IRRI Test Tube Mill Operating Parameters

Bautista, R.C., Siebenmorgen, T.J., and Burgos, R.M.

The International Rice Research Institute (IRRI) Test Tube Mill was developed for milling small quantities of rice typically produced from breeding test plots for quality analyses. The objective of this study was to optimize the operating parameters of the IRRI Test Tube Mill. The goal was to minimize the milling duration required to attain a milling degree equivalent to a 12% brown rice kernel mass loss. Operating parameters, including brown rice mass, milling duration, tube oscillation frequency, and test tube size, were investigated with the brown rice kernel mass loss as the response parameter. Two rice cultivars: Bengal (medium-grain) and Cypress (long-grain) at 12.5 and 12.1% moisture content, respectively, were used for the tests. Results indicated that milling with the IRRI Test Tube Mill was significantly affected by brown rice mass, milling duration, tube oscillation frequency, and the tube head space. A strategy to select parameters to attain a 12% brown rice mass loss percentage, given a certain amount of brown rice, is proposed. The results provide a guide to users, particularly rice breeders and physiologists, in the selection of proper parameters for removing the bran from limited brown rice sample masses.

A Timed Milling Study of Several Rice Varieties and Hybrids and Evaluation of Their Quality Characteristics

Earp, C.F., Matsler, A.L., and Siebenmorgen, T.J.

In 2001, observations were made that RiceTec hybrids XL8 and XL7 were whiter than standard U.S. long-grain rice varieties when milled to the same length of time. The degree of milling studies reported here were conducted to investigate the cause of the increased whiteness of the hybrids. The first year samples were XL8, XL7, Cypress, Cocodrie, Lemont, and a RiceTec line. During the second year, samples included five U.S. varieties, XL7, XL8, and five experimental hybrids. Four of the Year 1 samples were from the same strip trial and two samples were from other locations. The second year samples were all grown in the same strip trial in Alvin, TX, in 2002. Dehulled rice samples were milled with a McGill No. 2 at times varying from 0 to 70 s.

Satake milling meter and Hunter color meter data were used to determine whiteness. At 60 s milling time, Satake milling degrees (SMD) of XL7 and XL8 were between 135 and 140. In year one, the SMD of the varieties ranged from 95 to 105, and in Year 2, they ranged from 117 to 129. SMD of experimental long-grain hybrids ranged from 128 to 139. SMD of two experimental medium-grain hybrids were 107 and 110.

Surface and total lipids were determined for all samples from both years using a Soxtec Avanti extraction method with petroleum ether and 5-g sample size. Extraction conditions were 1 h pre-extraction drying at 100^{o}C, a 20-min boiling duration at 135^{o}C, rinsing for 30 min at 135^{o}C, and drying for 30 min at 100^{o}C. Surface and total lipids of XL7 and XL8 were lower both years than the U.S. long-grain varieties. Total lipids in brown rice ranged from 1.77 to 2.77% in Year 1 and from 1.79 to 2.39% in Year 2. Cocodrie was highest in Year 1 and an experimental hybrid was highest in Year 2. Surface lipids at 60s milling time ranged from 0.13 to 0.61% in Year 1 and from 0.04 to 0.10% in Year 2. Hybrids had 7 to 17% lower lipids than varieties for 2 years. Total lipids were 5 to 20% lower in the Year 2 samples than in Year 1.

SMD and surface lipids had a linear relationship with R-squared values of 0.98 and above. The two medium-grain hybrids had lower SMD values than the long-grain samples and higher surface lipids. When the SMD is plotted versus surface lipids, the slope is less in the medium grains than in the long grains. This may be due to the thickness of the medium-grain kernels and whether the extraction method is pulling out less of the lipids (i.e. is the surface lipid measurement really just surface lipids in the long grains?). This needs to be investigated further.

Protein levels were measured with a Leco analyzer. Protein ranged from 7.32 to 11.06% in brown rice for Year 1 and from 6.5 to 11.06% at 60 s milling in Year 1. Year 2 levels were 7.48 to 9.64% protein in brown rice and 7.27 to 8.76% in 60 s milled samples. The high protein level in Year 1 was the RiceTec line grown in Puerto Rico. XL8 had the lowest protein in Year 1. The Year 2 samples had very similar protein levels. Protein levels were approximately 0.7 to 1.1% higher in brown rice than in milled samples.

Percent bran removal was calculated at the varying milling times. In Year 2 samples, the % bran removed at 20s for the varieties ranged from 5.4 to 8.9% and for long-grain hybrids from 7.2 to 12.3%. At 60 s milling time, the % bran removal for the varieties was 15.4 to 17.5% and 12.2 to 18.6% in the long-grain hybrids. The two medium-grain hybrids had 7.3 and 9.2% bran removal at 20 s and 12.2 to 13.9% at 60 s milling time. The long-grain hybrids exhibit greater initial bran loss, indicating an ease of milling where less milling time is required to achieve a particular level of bran loss and degree of milling. The medium grains remove less bran at each milling time than the long-grain hybrids.

Scanning electron (SEM) and fluorescence microscopies were used to observe structural differences in the six samples in Year 1. No major structural differences were observed with SEM. The RiceTec line appeared to have greater protein matrix in the peripheral endosperm than the other samples, and this was confirmed with the higher measured protein level. Using fluorescence microscopy, there appeared to be greater amounts of protein matrix and protein bodies in the peripheral endosperm of varieties compared with hybrids. Cocodrie appeared to have the most protein bodies and greater protein matrix extending throughout the endosperm, possibly accounting for increased milling time required to produce a well-milled sample. The dense protein matrix in the RiceTec line was easily seen with fluorescence produced by the protein-specific fluorochrome, acid fuchsin.

Rice Kernel Breaking Force Distributions and the Relationship to Milling Quality

Siebenmorgen, T.J. and Qin, G.

Three-point bending tests were conducted to determine the mechanical strength distributions of brown rice kernels. Three long-grain rice cultivars, Cypress, Drew, and XL6, were initially studied. Fracture energy (the total energy required to break a kernel) was found to represent the mechanical strength of brown rice kernels. The breaking force (the force required to break a brown rice kernel in three-point bending) was not significantly related to kernel width or length. However, there was a significant correlation between breaking force and kernel thickness. Thicker kernels tended to have higher breaking forces, but the presence of fissures and chalkiness deteriorated the integrity of some thick rice kernels and, thus, lowered the breaking force of these kernels.

For all three cultivars, kernel-to-kernel breaking force distributions were bimodal: one dominant peak existed around 30 N and a smaller peak around 15 N. Even though the three rice cultivars had similar average kernel breaking forces, their breaking force distributions were quite different. In turn, head rice yield was not related to the average breaking force of rice kernels in a sample; however, head rice yield was closely related to the percentage of "weak" kernels, defined as kernels that did not sustain approximately 20 N force in bending. Based on this apparent finding, the breaking force distributions and head rice yields for seven additional rice lots were measured. A linear relationship was observed between a sample head rice yield and the percentage of weak kernels in the sample.

Effects of Steaming, Drying Air Temperature, and Tempering on the Compressive Strength of Parboiled Rice

Saif, S.M.H. and Lan, Y.

It is necessary to control the breakage of kernel during milling of parboiled rice for improving milling yield. The process of such breakage is a result of complex mechanical stress situations involving tensile, compressive, and combined stresses. Again, such breakage in parboiled rice is often attributed to the degree of parboiling, rate of drying, moisture content after drying, and pressure used during milling. Besides milling yield, a desirable flavor and taste qualities of parboiled rice could also be obtained by controlling the processing parameters, such as keeping the steam treatment to a minimal level and slow drying followed by tempering.

Two varieties of rice, Lemont (a long grain with 23% amylose) and Rico-1 (a medium grain with 17.3% amylose), were tested for its compressive strength. Rough rice was soaked in warm water of 55ºC in a water bath for 240 minutes. Saturated steam at 103.5 kPa was applied to soaked grain for two steaming duration treatments of 5 and 10 minutes. Steamed samples were dried by means of a laboratory dryer with air at 21, 40, and 60ºC, to final moisture content of 10.5% w.b. After the single pass drying, the kernels were tempered at room temperature of 21ºC. During the tempering period, hand shelled kernels of parboiled brown rice were tested for Ultimate Compressive Strength (UCS) at the intervals of 0, 1, 2, 3, 9, and 24 hrs. An INSTRON Universal testing machine, Model 4501, Automated Material Testing System operated by Series IX software version 4.14 through a personal computer.

The results indicated that both steaming duration and drying temperature affected the UCS in both varieties. Five-min steamed rice dried with 21ºC air slightly decreased in UCS due to increase in steaming duration. Drying at a low temperature of 21ºC leaves the kernel with very low moisture gradient in it. On the other hand, a greater degree of parboiling enhances such moisture distribution than the low degree of parboiling. The latter leaves the core region of the kernel with ungelatinized (crystalline) or partially gelatinized (partially crystalline) starch granules that are expected to behave differently than the gelatinized regions. The drying temperatures of 40 and 60ºC significantly decreased the UCS under both the steaming regimes and varieties. Such a strength behavior indicated the role of moisture gradient inside the kernel at end of drying in developing the strength pattern. When the steaming duration was increased from 5 to 10 min, the UCS values increased with the increase in drying temperature to 40 and 60ºC. This was possible due to the presence of a large portion of dry gelatinized starch in the kernel periphery that imparted greater UCS. Such changes in UCS values were more in Lemont than in Rico-1 as the steaming effect in the former was more than the latter. Mean UCS values obtaining for Lemont steamed for 5 min and dried at 21, 40, and 60ºC were 116, 76, and 75 MPa, respectively. The values for 10-min steamed samples were 109, 94, and 75 MPa, respectively. For Rico-1, corresponding UCS values were 88, 76, and 75 MPa for 5-min steamed sample, whereas for 10-min steamed samples the values were 87, 85, and 82 MPa, respectively.

Tempering effect was positive on the UCS value of parboiled rice kernels. Tempering after drying increased the UCS more in the 5-min steamed Lemont and 10-min steamed Rico-1. Both the kernels had a similar degree of parboiling, Lemont having slightly higher than Rico-1. Gains in UCS increased with the increase in drying temperature. Five-min steamed Lemont gained UCS by about 0.58, 2.0, and 0.83% per hour, respectively, for 21, 40, and 60ºC drying temperatures. Ten-min steamed Rico-1 gained UCS by about 0.34, 1.54, and 1.37% per hr for samples dried at 21, 40, and 60ºC, respectively. It is apparent that samples dried with 40ºC temperature gained in UCS the most. The UCS values of 10-min steamed Lemont were increased by 0.12, 0.5, and 1.8% per hr, respectively, for 21, 40, and 60ºC drying temperatures. Five-min steamed Rico-1 gained UCS by about 0.08, 0.5, and 0.58% per hr for the respective drying air temperatures.

Stackburn in a Test Tube

Belefant-Miller, H. and Ledbetter, C.

Stackburn, also known as burnt rice, rice yellowing, or amber grain, is a commercial storage problem of rice wherein the endosperm becomes yellow in conjunction with high temperatures and moisture. We have developed a technique to induce stackburn on a small scale by rinsing milled rice kernels with water and incubating them in test tubes or microfuge tubes at 70°C. This allows the visualization of the process and direct measurement of the color change using a Minolta Color Reader CR-10 colorimeter. Stackburn increased with temperature, tested through 80°C. Water distribution affected the pattern of color formation. Every rice cultivar tested, which included long and medium grains, as well as japonicas and indicas, showed some level of stackburn. Despite reports of correlations of fungal presence with stackburn, no indications of fungal involvement were found using sterilization and culturing.

Effects of Steaming, Drying Temperature, and Tempering on the Tensile Strength of Parboiled Rice

Saif, S.M.H. and Lan, Y.

Tensile strength failure is known to be the major source of breakage in kernels during milling. Parboiled rice also behaves the similar way as raw rice in milling. Kernels pre-stressed during the drying process due to residual moisture gradient are likely to break later in milling. However, if the stress is allowed to relax over time by tempering the kernels, perhaps the strength could be recovered to a level according to treatment. Again, steaming intensity influences the degree of parboiling. The drying behavior of the kernel would depend upon the degree of parboiling. This study evaluated the effects of steaming, drying, and tempering on the ultimate tensile strength of the parboiled rice kernels.

Tensile strength of two varieties of rice, Lemont (a long grain with 23% amylose) and Rico-1 (a medium grain with 17.3% amylose), were measured. Rough rice was soaked in warm water (55ºC) in a water bath for 240 minutes. Saturated steam at 103.5 kPa was applied to soaked grain for two steaming duration treatments of 5 and 10 minutes. Steamed samples were dried by means of a laboratory dryer with air at 21, 40, and 60ºC, to final moisture content of 10.5% w.b. After the single pass drying, the kernels were tempered at room temperature of 21ºC. During the tempering period, hand shelled kernels of parboiled brown rice were tested for ultimate tensile strength (UTS) at the intervals of 0, 1, 2, 3, 9, and 24 hrs. An INSTRON Universal testing machine, Model 4501, Automated Material Testing System operated by Series IX software version 4.14 through a personal computer was used.

The parboiling process generally increased the UTS by about four to five times that of raw rice, depending on the variety and parboiling treatments. The UTS of Lemont was higher than Rico-1 by about 25 to 50% in the range of 5- to 10-min steaming duration and 10 to 60ºC drying temperature. Increasing the steaming duration generally increased the tensile strength. Slow drying at 21ºC drying temperature gave higher tensile strength than higher drying rates at 40 and 60ºC. Drying temperature greater than 40ºC decreased the tensile strength. Average UTSs for Lemont dried at 21ºC were found to be 50 and 61 MPa, respectively, for steaming treatments of 5 and 10 min. when the drying temperature was increased to 40ºC the UTS, values measured were 42 and 50 MPa, respectively. The UTS values corresponding to 60ºC were and 37 and 47 MPa for the respective steaming durations. The UTS values for Rico-1 dried at 21ºC were 38 and 40MPa, respectively, for 5- and 10-min steaming. The values slightly decreased to 35 and 39 MPa when dried at 40°C that further decreased to 32 and 37 MPa when drying temperature increased to 60ºC.

Effects of tempering for 24 h at 21ºC (room temperature) were significant in 5-min steamed Lemont and 10-min steamed Rico-1. Degree of parboiling of these two kernel types was similar. However, degree of parboiling was the highest in 10-min steamed Lemont while it was the lowest in 5-min steamed Rico-1. Gains in UTS due to tempering increased as the drying temperature increased in Lemont. The gains ranged from 11.0 to 16.8% for 5-min steamed kernels in the drying temperature range of 21 to 60ºC. In Rico-1, however, UTC was about 16.0% only in the case of kernels steamed for 10 min and dried at 21ºC. At higher drying temperatures the gains were 13.3 and 9.9%, respectively, for 40 and 60ºC. In 10-min steamed Lemont kernels, the UTS increased by 3.0 to 7.7%. But, Rico-1 steamed for 5 min gained 11.0 and 11.7% corresponding by drying temperatures of 21 and 40ºC. At 60ºC drying temperature, the gain was limited to only 8.8%.

From the pattern of gain in strength, it is apparent that the degree of parboiling was a significant determinant in the strength gaining process during the tempering period. Also, the fact that was most important in defining the strength in the kernel was the right combination of degree of parboiling and the moisture in the gelatinized region. Portion gelatinized in the kernel, thus, played an important role.

Industry Quality Improvements of Rice Grading Characteristics Employing a New Vision Image Analysis System

Sliffe, T.M.

Evaluation of grain appearance has historically been done using the only tool available, the human eye. Accurate and consistent visual inspection requires long experience, as well as deep knowledge. Principals underlying this innovative equipment will be discussed.

It was developed in close cooperation with the grain industry to perform reliable, accurate, and repeatable quality inspection in a manner that is as objective as it is fast. Typical analysis time is about 1000 kernels per minute. This automated grain inspection system includes two cameras that record two images of each kernel while kernels are separated and transported by a rotating disk. One image is recorded for transmission analysis and one for reflectance analysis. Rice breeding programs may use the instrument for evaluating length, width, cracks, and damaged grain.

Each kernel is classified by the calibration model according to pre-set kernel specifications. The result can be presented as number of kernels, number percentage, or weight percentage. The Cervitec uses a unique crack detection function for rice kernels. The system utilizes Artificial Neural Network (ANN), the most advanced and capable calibration technique today. ANN can be trained to recognize different types of damages, such as broken or colored kernels. Transferable ANN calibrations ensure that the accurate classification results are the same on all instruments.

Relationship between Milling Conditions and Rice Quality Assessment Results

Pan, Z. and Thompson, J.F.

Rice is sold on the basis of its milling quality, which is determined based on the quality appraisal results of a small rice sample. The FGIS's standard procedures and equipment used for the milling quality appraisal were originally developed over 50 years ago and have not been changed substantially since that time. One of the major concerns of rice producers about the standard milling equipment was the heat accumulation during milling, which results in high milling temperature and low milling quality or yield, directly causing the economic loss of rice producers. The objective of this study was to determine the relationship between rice sample milling conditions (pressure and time) and quality assessment results.

Rice samples of medium grain M202 with a moisture content of 12.1% (w.b.) were milled with McGill No. 3 rice mill to study the effects of milling conditions (variables), including the weights and time periods of milling and polishing, on the quality of milled rice. A central composite experimental design was used in this study to determine experimental conditions. The tested weights of milling and polishing were in the range of 6 to 14 lb and 0 to 4 lb, respectively. The time periods of milling and polishing were in the range of 10 to 50 sec. The rice samples were also milled under both Western and Southern standard FGIS's procedures. The Western procedure used a 10-lb weight and 30 sec for milling and a 2-lb weight and 30 sec for polishing. The Southern procedure used a 7-lb weight and 30 sec for milling and a 0-lb weight and 30 sec for polishing. The evaluated quality characteristics of milled rice include total rice yield, head rice yield, whiteness index, and fat content. The temperature of milled rice at the end of milling was also measured. The relationships among these quality characteristics were determined. It was found that the milled rice temperature increased, but total and head rice yields decreased with the increase of whiteness index. The contributions of milling variables to the quality of milled rice were determined with a response surface method. The research results showed that different milling conditions resulted in significant differences in the quality appraisal results of milled rice. It is important to standardize and optimize the rice sample milling conditions to achieve representative and uniform quality appraisal results.

Evaluating a Soxtec Extraction System for Measuring Surface Lipid Content of Milled Rice

Matsler, A.L. and Siebenmorgen, T.J.

The degree of milling (DOM) is an indicator of how well rice was milled and is critical in determining milling quality, functional properties, and sensory attributes of rice. The rice industry is currently using many different methods for measuring the DOM of rice. The goal of this work is to provide basic information on DOM measurement to aid in the selection of a more widely accepted DOM method.

The first objective in this overall effort was to establish a wet chemistry technique for use as a reference in calibrating other, more rapid methods of determining DOM. Measuring the surface lipid content of rice after milling is one way to quantify the DOM of rice. While there are several methods to measure DOM, there is not an established "standard" method for determining the surface lipid content of milled rice. The specific objective of this study was to determine how the operating parameters of a Soxtec extraction procedure affect surface lipid concentration values for milled rice. This was accomplished by varying the pre-extraction drying, boiling, rinsing, and post-extraction drying durations, as well as the extraction solvent. Experiments were performed on stored *Oryza sativa* L. 'Cypress' and 'Bengal' rice milled for 10, 30, and 60 s in a McGill No. 2 mill. Results showed that a 1 h pre-extraction drying duration, 20-min boiling duration, 30-min rinsing duration, and 30-min post-extraction drying duration provided the maximum amount of surface lipid extraction from milled head rice utilizing petroleum ether as the solvent. With a method established for determining surface lipid content of milled rice, the Soxtec will now be used as a reference for calibrating more rapid methods of determining the DOM of milled rice.

A Gas Chromatographic Procedure for Determining Rice Degree of Milling

Bergman, C.J. and Goffman, F.D.

Rice degree of milling is a quantification of the amount of bran that has been removed from kernels during the milling process. All things being equal, under-milled rice will weigh more than well-milled rice and thus influence its value. Kernels that have been milled to a different degree reportedly have varying functional and sensory properties. Also, degree of milling has an affect on the levels of phytochemicals in rice bran. Consequently, degree of milling is an important end-use quality characteristic to the rice industry. It is also important to the research community because of its affect on rice quality, that is, only samples that have been milled to the same degree should be compared in end-use quality related studies. This, however, is seldom documented in published research.

The numerous methods that have been developed to determine degree of milling can be categorized into two groups; those that assess the amount of bran remaining on milled rice and those that measure (or predict) chemical components in the outer layers of rice kernels. These methods all have shortcomings such as a large quantity of sample is required, lengthy analysis time, and the predictive methods have not been validated with cultivars of differing genetic backgrounds. In the last few decades, however, extracting the amount of lipid in the outer layers of 5 to 10 g of milled rice using a Goldfish apparatus (i.e., surface lipids) has become the most commonly used degree of milling research tool. The objective of this research was to develop and test a rapid GC procedure for milled rice surface lipid content.

Long-, medium- and short-grain rice milling standards were obtained from the USDA GIPSA Federal Grain Inspection Service. Another group of samples included conventional U.S. long-grain cultivars, conventional U.S. medium-grain cultivars, a Japanese premium quality-type cultivar, a waxy cultivar, and other quality types. The samples were divided into two groups for milling, the long grains and the medium grains. Broken, diseased, and immature kernels were removed from the samples and then milled using standard protocols designed to mill rice of various length width ratios to a similar degree of milling. The milled rice surface lipid content of 6 g of each sample was determined with petroleum ether in a Goldfish extraction apparatus. The fatty acid content of rice surface lipids was also determined by gas chromatography of fatty acid methyl esters (FAMEs). FAMEs were prepared using extracts obtained from 50 mg of each milled rice sample. An internal standard, tricaprylin, was added to each sample along with isooctane. Two µL of the isooctane phase was then injected into a gas chromatograph equipped with a flame ionization detector. The oven temperature was programmed as follows: the initial temperature (160˚C) was linearly increased to 167˚C at a 2˚C/min rate, then to 210˚C at a 15˚C/min rate, then to 250˚C at a 10˚C/min rate, and the final temperature was held for 14 min. The samples were injected at a split rate of 1:8.8. GC fatty acid peaks were identified by comparing retention times to those found for a set of reference standards. Response factors were determined for all of the fatty acids found in milled rice using tricaprylin. These factors were used to determine individual fatty acid levels that were summed and reported as total surface lipids.

The Goldfish surface lipid content of the samples ranged from 0.16 to 0.58%. Approximately 0.3% surface lipid content is considered well milled by the U.S. rice industry. These results indicate that some of the samples studied were what is considered to be over-milled and some were under-milled. This is in spite of the fact that standard procedures were used to mill these samples. These results are not surprising, since slight variations in length width kernel ratios between cultivars and within samples have been reported to result in degree of milling differences. This provides further evidence of the importance of reporting sample degree of milling in rice end-use quality research. Without doing so, scientists can not be sure differences are due to treatments and not variation in degree of milling between samples. A high correlation was found between the Goldfish and GC surface lipid procedure when analyzed across the FGIS standard samples, U.S. cultivars, and international accessions. The mean Goldfish surface lipid content (0.46%) was greater than that found using the GC method (0.39%). The reproducibility of the GC degree of milling procedure was superior to the Goldfish method. This indicates that the rapid GC method described here can be used to determine rice degree of milling using a small quantity of sample and solvent, and the results obtained are comparable with the more time consuming Goldfish procedure.

Silicon Deposition in Rice Grains During Reproduction Development

Bryant, R.B., Counce, P.A., and Rutger, J.N.

Rice plants accumulate silicon (Si) in their tissue and seeds. Research has shown that increasing Si in the plant significantly decreased the severity of diseases such as blast, brown spot, and stem rot. Si has also been shown to increase yield (4-48%), reduce grain discoloration, control pests, and reduce the need for fertilization. Analyses of rice, including Si, have been conducted using days after planting, days after emergence, or days after heading (DAH). The problem with the above time lines is that the seeds on a panicle of the main stem, as well as those on tillers, will be in different stages of development. Also, the grains on the panicle do not progress at the same rate. Consequently, measuring grains at days after anthesis has serious drawbacks – in particular, knowing which grains were at different stages of development. The rice growth staging system was developed to provide an objective, uniform system for expressing rice development. During reproductive development of R3 through R8 growth stages, if one grain on the main stem panicle is at a particular stage of development, the plant is at that stage of development. The objectives of this project were to determine rice grain Si content by developmental stage.

Seeds of 'Wells Brittle' and 'Wells' were planted in window trays in the greenhouse, and at growth stage V2, 20 plants were transplanted one each into vented 2-liter pots. The soil was kept moist and the plants were fertilized once a week with a complete soluble fertilizer solution. Plants were flooded at growth stage V8. Pots were arranged in a randomized complete block, split plot design and rotated twice weekly. Cultivar was the main plot treatment and growth stage for sampling was the subplot treatment. Beginning at growth stage $V_{F\text{-}2}$, each plant was monitored daily for growth stage. When sufficient seeds of a growth stage were present on the plant, the panicles were harvested and the grains were separated according to their reproductive growth stage (R3 through R8). Care was taken to prevent desiccation during the separation.

Crude silica was determined by weighing approximately 2 g of dried seeds (R3 to R8) to the nearest 0.1 mg. The seeds were counted, moisture content determined, and the dried seeds were digested in 20 ml of acid (62.5% conc. HNO_3, 12.5% conc. H_2SO_4 and 25% of 60-62% $HClO_4$) over night. The acid digest was heated until clear, and after cooling, the digest was filtered through a Whatman #44 ashless filter paper, washed several times with deionized water, and dried at 80^{o}C overnight. The filter paper containing the silica was added to a preheated clean crucible and charred. The crucible was placed in a muffle furnace at 550^{o}C until it came to a constant weight. Percent crude silica was determined on a dry weight basis.

When the grains were taken off the plants using DAH without separating them into developmental stages, the moisture contents of Wells Brittle and Wells were 53.1 and 49.3%, respectively, for 14 DAH. The Si content for the above mixture was 11.4% for Wells Brittle and 9.1% for Wells. When the rice grains were separated into development stages and then analyzed, R4, R5, and R6 for Wells Brittles contained 0.42, 0.59, and 0.92mg and Wells contained 0.34, 0.48, and 0.59 mg of Si, respectively. The moisture contents of each stage for Wells Brittles and Wells were 46.9, 56.8, and 54.9% and 45.1, 58.9, and 53.1%, respectively. The above data show that each developmental stage has a different moisture content and the average will depend on the mixture of the grains. Thus, using a time line such as DAH will give an error because it will be an average of the seeds present, therefore, the age of the plant would determine the ratio of developing seeds.

The average moisture content of the seeds in each developmental stage was 51.9, 46.9, 59.4, 55.7, 35.3, and 20.0% for R3, R4, R5, R6, R7, and R8, respectively, for Wells Brittle. For Wells, the moisture content was 51.5, 46.5, 59.7, 53.3, 31.2, and 20.0%, respectively. The average Si content for Wells Brittle was 70, 180, 220, 210, 350, and 380 μg/grain for R3, R4, R5, R6, R7, and R8, respectively. For Wells, the Si content was 70, 150, 190, 220, 170, and 240 μg/grain, respectively. Si accumulation in both cultivars was similar until R6 then the accumulation of Si in Wells Brittle was greater than that of Wells.

This research showed that Si accumulation is not constant in the seed during reproductive development. How the accumulation of Si affects yield, grain discoloration, or the severity of diseases need to be investigated and the Si profile of other varieties needs to be examined. Also, the developmental staging system can be used to look at other analyses that may be affected by plant development.

Volatile Marker Compounds for Microbial Infection in Rice

Grimm, C.C., Champagne, E.T., and Greene-McDowelle, D.M.

Contamination of grain with microbial infestations is a common problem. Current detection techniques require several days for analysis. Rapid detection of microbial contamination would ensure safety and aid in the assessment of overall crop quality. In addition to normal metabolic products, such as water and carbon dioxide, microbial organisms produce other volatile compounds, some of which can impart high flavor impact on foods. Rice, characteristically lacking in a definitively unique flavor, is highly susceptible to the adsorption of off-flavor odors, subsequently decreasing crop quality and safety. Our objective was to compare the volatile profiles of rice and selected common fungi to develop a rapid, instrumental method to detect and identify damaged rice as a result of fungal contamination.

Aliquots of selected rice were infected with *Aspergillus flavus*, *Fusarium grameanerum*, or *Penicillium Roqueforti*, common fungi found on rice. The resultant headspace was compared with a control rice sample and fungi grown on potato dextrose agar. Samples were analyzed at selected periods over a 2-week period. For headspace analysis, the enclosed headspace above the rice sample was sealed and analyzed for volatile compounds by solid phase microextraction - gas chromatography (GC) mass spectrometry.

A carboxen/divinylbenzene/polydimethylsiloxane fiber was employed to collect the volatiles from a heated sample held at 65ºC. Volatiles were desorbed into a heated injection port held at 270ºC. The GC was held at an initial temperature of 50ºC for 1 minute during desorption then increased to 300ºC at a rate of 5ºC minute. A 5% diphenyl/95%dimethylpolysiloxane capillary column was employed for separation of volatiles. Compounds were initially identified using a Wiley mass spectral library with subsequent confirmation by the use of authentic standards to confirm retention time and mass spectra. Peak areas were integrated based upon a single ion, which was generally the base peak, as long as no interference was observed from co-eluting compounds.

Lipid oxidation products dominated the GC traces of the non-infected rice as was true of infected rice, with the oxidation products occurring in greater quantities in the infected rice samples. In previous studies of fungal volatiles, 1-octen-3-ol and 3-octanone have been identified as good indicators of fungal contamination. These compounds were also detected in our control rice samples. For instance, 1-octen-3-ol was observed in the control and the infected rice and increased with time. Other key marker compounds found include 2-methylbutanol, 3-methylbutanol, 1-octen-3-one, and limonene. In a typical sample, a 25-fold increase of 1-octen-3-ol was observed for the infected rice while 3-octanone was exclusive to the infected samples.

A series of terpenes were detected in infected rice samples. A correlation between the production of sesquiterpenes and the initiation of the biosynthesis of certain mycotoxins, such as aflatoxin and deoxynivalenol (vomitoxin), has been reported. Additionally, in previous investigations, it has been shown that terpenes are the most suitable compounds for differentiation between fungal species. However, none of the terpenes were consistently present to serve as marker compounds, indicating the presence of a particular fungal species. Of interest was the detection of trace levels of geosmin and 2-methylisoborneol in some of the infected rice samples. Even present at levels below 1 ppb, these compounds can add a musty aroma, making the rice undesirable for human consumption.

In summary, gross fungal infections of rice can be detected successfully by a rapid GC/MS analysis of the volatile compounds. Volatile metabolite production is significantly influenced by duration of fungal growth. Species identification employing this method will require additional research.

Starch Structure and Pasting Characteristics of Rice Varieties Grown in Different Locations

Bryant, R.J. and Gibbons, J.

Environmental conditions such as temperature affect rice grain quality. This change causes an increase or decrease in the market value. It is not known if some varieties are affected less than others. Therefore, the objective of this research was to examine rice varieties grown in different locations and analyze them for their starch structure and pasting characteristics. The algorithm used weather data from the nearest NOAA weather station to each site. The algorithm began calculating DD50 units beginning at the R3 growth stage (taken as 50% heading). From an archive of the DD50 interval between R3 and R8, the R6 growth stage period was predicted and the actual temperature during that growth stage was read.

The seven varieties, one medium-grain Japonica (Bengal), two long-grain indicas (4484 and Zhe 733), and four long-grain Japonicas (Cocodrie, Cypress, Francis, and Wells), were grown in Arkansas (Ar), Cross (Cr), and Jackson (Ja) counties, AR, and Dunklin (Du) County, MO. Each variety was milled and analyzed for moisture, apparent amylose content, gelatinization temperature, viscosity profile, and amylopectin chain length. The temperature during the R6 growth stage was also determined from a predictive program.

Du had the lowest temperature, both high and low, during the R6 growth stage, except for the low temperature of Cocodrie and Zhe 733 grown in Ar. The difference in apparent amylose content ranged from 0.8% for Francis to 2.4% for Bengal with the varieties grown in Cr having the lowest and Ja, Ar, and Du having the highest, respectively. RVA profile showed that setback 2, final viscosity minus the peak viscosity, for Cypress, Francis, 4484, and Wells grown in Du, which is the farthest north, were much greater than the others, which were closer to each other. Setback 1, final viscosity minus the trough viscosity, for all varieties other than Cocodrie were highest for the ones grown in Du. Setback 2 for Cocodrie, Zhe 733, and Bengal for the different locations were closer. Except for Cypress, setback 2 of the varieties grown in Ar, which is the farthest south, were lower than those grown in the other locations. Varieties grown in Du, which had the lowest average temperature during R6, had the lowest gelatinization temperature with Cr producing the highest, except for Cypress and Zhe733 grown in Ja. Starch profile and the amylopectin chain length differed over locations and the correlation between the starch profile, amylopectin chain length ratios, temperature, and amylose content is still being examined.

This research shows that environment affects rice varieties differently, and some varieties are more stable than others. The data can be of use to rice breeders in selecting future varieties.

Effect of Rice-to-Water Ratios on Cooked Rice Flavor and Texture Attributes

Bett-Garber, K.L., Champagne, E.T., Ingram, D.A., and McClung, A.M.

It is general knowledge that rice to water ratio for cooking has an effect on texture. Its effect on flavor is not known. Furthermore, its effect on specific texture attributes is not well documented. Three rice-to-water ratios consisted of ideal, slightly less, and slightly in excess of the ideal. The ideal rice-to-water ratio was determined by amylose content and cook type. Four diverse cultivars were compared: Dellmont, Saber, Neches, and Bengal. The amount of water used to cook the rice did not significantly affect the flavor attributes. Although within cultivar, rice to water ratio had a marked effect on water-like/metallic in Dellmont, sweet taste in Saber, and alfalfa/grassy/greenbean flavor in Neches. The amount of water affected 11 texture attributes. Of these 11, initial starchy coating, slickness, stickiness between grains, uniformity of bite, and moisture absorption increased in intensity with greater amounts of water at cooking. Roughness, springiness, hardness, and chewiness decreased in intensity. Cultivar differences significantly affected eight flavor attributes and 11 texture attributes.

Evaluation of Rice Taste Value after Drying

Zheng, X. and Lan, Y.

At present, research on the rice quality of post-drying is focused on fissure, head rice yield, etc. Researchers pay less attention to rice taste, although it is an important index to evaluate rice quality. Rice taste is subject to the major constituents, which include moisture (M), protein (P), amylose (A), fat acid (F), and drying temperature (T). In this paper, rice taste value of post-drying rice was evaluated and analyzed based on the artificial neural network (ANN) method and near infrared spectrum technology.

Rice samples of DONGNONG 420, DONGNONG9316, V10, with initial moisture contents (MC) 21.6, 18.5, and 14.5% (w.b.), respectively, were used to conduct thin-layer drying experiments. The parameters used in this study included drying temperatures (30~60, step 5℃) and air velocity (0.5m/s). The final MC of the rice samples was 14.3, 15.2, and 16.3%, respectively.

First, major constituents of the rice sample A, P, M, and F were measured in a near-infrared grain analyzer (ZX-888). Second, the taste index (S) of each sample was determined by the panel sensory evaluation method, in terms of appearance, flavor, stickiness, hardness, and elasticity of the cooked rice. Third, a mathematical model was developed involving 36 index groups (A, P, M, F, T) with ANN method using Matlab 6.5. A trained suitable model whose verified results were obtained: mean square error: 0.9982, correlation coefficient: 0.9733, and error percent within 5%: 100% was determined. The six verifying samples were used to validate the ANN model.

The most remarkable factor affecting the taste value of post-drying was drying temperature. When drying temperature exceeded 45℃, rice taste index was greatly decreased. When it was lower than 45℃, rice had a better taste quality.

The correlation coefficient between amylose content and taste value was 0.48. The variable rate of amylose content within rice is related to the initial MC of the rice, drying temperature, and drying duration, which increases the amylose content deteriorating cooked rice taste. The correlation coefficient between fatty acid content and taste index was -0.56. The fatty acid content increased with drying temperature, and also the gelatinizing temperature increased. Therefore, high fatty acid content was the main factor that decreased rice taste index. High temperature post-drying rice was aged easily and produced unusual aroma.

The correlation coefficient between moisture content and taste index was 0.68. When the moisture content range was 14 to 16%, the rice taste was excellent. The correlation coefficient between protein content and taste index was –0.33. No remarkable change in protein content was observed. The analysis of results led to a conclusion that neural network model can evaluate rice taste value of post-drying rice.

Quality Characterization of California Public Rice Varieties

Noble, A.E., McKenzie, K.S., Bergman, C.J., and Shoemaker, C.F.

A set of 17 rice varieties were grown at the Rice Experiment Station (RES) over a 3-year period and analyzed under a battery of physicochemical tests. Environmental conditions during the growing season can impact such characteristics as apparent amylose content. Measurements taken over different years help establish a range for these environmentally sensitive characteristics, and provide a more conclusive quality profile for each variety. The tests, indicators of cooking and processing characteristics, were conducted by the Rice End-Use Quality Research Laboratory at the USDA-ARS-Rice Research Unit (Beaumont, TX), RES, and Department of Food Science and Technology, UC Davis. Data collected include grain length and width, apparent amylose content, protein content, alkali spreading value, cooking time, gelatinization temperature, RVA profiles, and Controlled Stress Rheometer profiles. Aroma and grain elongation were also measured for some varieties. Results, including photos and data, were compiled in single page summaries for each variety. This project was supported in part by a grant from the California Rice Commission. The 3-year results are available through the California Rice Commission.

Effect of Flour-Blasting Brown Rice on the Reduction of Cooking Time

Guraya, H.S., James, C., and Champagne, E.T.

Long-grain non-parboiled, long-grain parboiled, and American Basmati-type brown rice were bombarded with parboiled rice flour sufficient to create microperforations in the water-resistant outer coat of the seed. These microperforations in the treated rice significantly increased the rate of hydration. Air pressure was kept at a constant 60 p.s.i. and the particle size of the flour was around 120 mesh, which was optimum to produce the microperforations without removal of bran. The optimum blasting time varied with the type of rice and ranged from 40 to 60 sec. Hardness of the fully cooked, flour-blasted rice was the same at half the cooking time of the untreated brown rice, but percent absorption was lower because it requires less time to cook. This produced fluffier, firm, and non-sticky cooked flour-blasted brown rice compared with freshly cooked control brown rice.

Antioxidant Properties of Milled-Rice Co-Products and Their Effects on Lipid Oxidation in Ground Beef

Shih, F.F. and Daigle, K.W.

Rancidity of food due to lipid oxidation is a serious problem that results in off-flavors but also decreases nutritional quality and safety of food. Benefits of antioxidants in food storage have been studied extensively in recent years. Synthetic antioxidants, such as butylated hydroxylanisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG), and tert-butylhydroquinone (TBHQ), have been commonly used to suppress the formation of free radicals, preventing lipids from oxidating causing food spoilage. Although these synthetic reagents are efficient and relatively cheap, special attention has been given to natural antioxidants because of a worldwide trend to avoid and minimize the use of synthetic food additives. Plant seeds contain phytochemicals that are natural antioxidants. These natural antioxidants are attracting further interest because of their clear benefits as anticarcinogenic agents and as inhibitors of biologically harmful oxidation reactions in the body.

Rice is one of the major staple foods in the world, and the processing, characterization, and utilization of rice has been investigated extensively. Rice ingredients are recognized to be nutritious, hypoallergenic, and healthy for human consumption. However, only limited information is available on their capacity as antioxidant materials. Pigments in rice have been found to be associated with antioxidant components. Rice bran and rice oil are known to be rich in potent antioxidants such as oryzanol and tocopherol. Methanolic extracts of wild rice or wild rice hulls have been reported to contain phytic acid and showed appreciable antioxidant activities when added to ground beef. Rice hull and rice bran are particularly attractive as sources of antioxidants because these milled-rice co-products are plentiful and cheap. Rice ingredients such as rice flour and rice bran have been used in foods to provide texture and body. It is desirable to investigate whether they also play a role in inhibiting lipid oxidation and enhancing stability of the product.

In this report, we compared the antioxidant properties of methanolic extracts of rice seeds, milled-rice co-products, and other selected plants seeds, including cottonseed, soybean, and corn. The conventional methods were used for analysis of the antioxidant activity, including the beta-carotene method and the thiobarbituric acid-reactive substances (TBARS) method. Results indicated that values of antioxidant effectiveness ranged from 45 to 86%, based on 100% activity at no change in color during the beta-carotene bleaching test. A correlation existed between the antioxidant activity and the total phenolic content of the rice ingredient extracts (R^2 = 0.81). When selected extracts were applied to ground beef, the lipid oxidation was inhibited by, in relative effectiveness, rice hull > rice bran > brown rice. When applied directly to beef, both defatted brown rice flour and rice bran strongly retarded the lipid oxidation.

In conclusion, methanolic extracts of milled rice co-products, including rice bran and rice hull, were found to be effective antioxidants. A good correlation was also noticed between antioxidant activities and phenolic content of the rice ingredient extracts. When incorporated into ground beef, the extracts of brown rice, rice bran, and rice hull, or the flours of brown rice and rice bran, inhibited lipid oxidation effectively and thus prolonged storage stability of the product.

Performance of Rice Bran Based Adhesive

Cathcart, A.K. and Pan, Z.

Rice bran, an abundant and underutilized byproduct of the rice milling industry, is obtained by abrasive milling of brown rice. Due to its composition, it may have a significant adhesive potential. Typically commercial rice bran in the United States contains 15 to 20% protein and a significant amount of starch which can vary from 10 to 20%. Since the adhesive properties of starch and protein have long been recognized, rice bran may develop important adhesive properties under certain conditions and be applied in a number of applications that include the fabrication of particle panels. The effects of thermal and chemical treatments on the adhesive properties of defatted rice bran were investigated. Results showed that modifying rice bran with heat and alkali produced a bio-based adhesive with better adhesive properties than the unmodified bran counterpart.

To evaluate the quality of particleboard bound with the developed rice bran adhesive (RBA), a portion of the currently used synthetic adhesive, PMDI (polymeric diphenylmethane diisocyanate) was replaced with RBA. Results showed that up to 30% PMDI may be replaced with RBA to obtain quality products with performance characteristics similar to those of PMDI bound particleboard. A preliminary economic analysis showed that despite additional processing steps in the particleboard manufacturing process due to RBA preparation requirements, using RBA to replace up to 30% PMDI is feasible. The use of the developed bio-based adhesive is an environmentally friendly alternative to synthetic particleboard adhesives that may reduce dependency on petroleum and its derivatives.

Abstracts of Posters on Processing, Storage, and Quality
Panel Chair: E. Champagne

Development of Whole Rice Bread

Kadan, R.S.

Rice flour is an ideal ingredient to make bread for people suffering from Celiac and other chronic allergic diseases because its proteins are devoid of gliadin and rice is known for its ease of digestion, bland taste, and hypoallergenic properties. However, the absence of gliadin creates a special challenge to make baked products since gliadin is an essential component of gluten. For the past thirty years, scientists have developed rice bread using methyl cellulose and other food gums as a substitute for gluten in rice baked foods. To improve rice bread further, they add tapioca, potato, eggs, milk, and soy proteins. The rice bread is still considered dry, crumbly, and hence, unacceptable by the consumers. Perhaps one of the reasons is that the rice starch retrogrades faster than wheat starch. These ingredients not only increase the cost but also unnecessarily expose the consumers to potential allergy as nearly 50% of Celiacs also suffer from various food allergies.

Our objective was to see if an acceptable rice bread (RB) could be made from all rice ingredients by using a commonly available bread machine. Our exploratory research has shown that a RB, which is comparable to white wheat bread and whole wheat bread, can be made by using a bread machine at a fraction of the cost of commercial rice breads. The making of whole rice bread by the consumer from a bread mix with a commonly available bread machine provides an ideal approach to enjoy a fresh gluten-free bread. Research is continuing to optimize the WRB process.

Effects of Rice Flours in Wheat-Based Fried Snack Food

Kadan, R.S.

Rice grain, because of its unique attributes such as ease of digestion, bland taste, and hypoallergenic properties, is becoming a popular food in the U.S. diet. During milling, 15 to 20% of the kernels break and these sell at a much lower price than whole kernels. We have an active research program to develop value added food products from flour made from broken rice. In order to determine their potential use in new foods, broken kernels from two rice cultivars, a long grain (Cypress) and a waxy (glutinous, NFD 108) were extruded at various temperatures and their functional properties characterized. The two flours were also added into a popular southern fried wheat flour based snack food (Café Du Monde mix) and the directions followed to make the snack. The results showed that a substitution of either 25% unextruded long grain rice flour or 70°C extruded long grain- rice flour into the wheat-based fried snack decreased its fat absorption by 35 to 50 % without affecting the overall texture. Further research is needed to evaluate the addition of long grain flours in other wheat-based fried foods and batters to lower their fat absorption ability and hence the impact on endemic obesity.

Effect of Drying Temperature and Loading Rate on the Stress Relaxation Behavior of Parboiled Rice

Saif, S.M.H. and Lan, Y.

The processing conditions for optimal cooking and eating quality with minimal broken losses in milling are of prime importance for economic production of milled parboiled rice. Since parboiling process changes the very structure of the rice kernel, an expected change also takes place in its stress relaxation pattern by the process parameters like steaming, drying, and milling. In the milling process, kernels are subjected to all sorts of mechanical forces that influence the breakage of the kernel. In order to understand the development and transmission of externally induced stress in the kernel, the knowledge of relaxation behavior is important.

'Lemont,' a popular long-grain rice, was tested for the compressive stress relaxation behavior. Rough rice sample was soaked in 55ºC constant temperature water bath for 240 min. Soaked sample was then treated with two steaming durations, 5 and 10 min, using saturated steam at 103.5 kPa. Steamed sample was then dried with 21 and 40ºC air. Dried kernels were hand shelled and the brown rice kernels were tested for compressive stress relaxation.

Compressive stress relaxation tests were conducted on dried kernels at the intervals of 0, 3, 9, and 24 hr after drying. At each interval, 10 kernels, randomly selected from a batch of 50 kernels, were evaluated. The experiments were replicated four times. Entire loading process and data acquisition operation were carried out by INSTRON Universal Testing Machine, Model 450, Series IX Automated Material Testing System run by Series IX software, version 4.14, through a personal computer. Crosshead speed was set at 2.5 mm/min. Preset initial loading rates of 40 and 60N were used. The test kernel was loaded to the preset level of initial loading and the load stayed that way until the stress decayed to the magnitude of e^{-1} of initial loading level. Stress relaxation data was then analyzed using successive residual method to determine the stress relaxation parameters. A FORTRAN program was written for the successive residual method of solution.

The results indicated that generally a four element Maxwell Model perfectly described the compressive stress relaxation behavior in Lemont parboiled rice. The steaming duration, drying temperature, and loading rate significantly ($p<0.05$) affected the stress relaxation time constant in the kernel. Also, the tempering duration up to 9 hr significantly ($p<0.05$) reduced the relaxation time constant value. Increasing the steaming duration from 5 to 10 min decreased the relaxation time in kernels at all drying temperatures and initial loading rates. Conversely, increasing the drying temperature from 21 to 40ºC increased the relaxation time, at all initial loading rates. Increasing the drying temperature for 10 min steamed rice from 21 to 40ºC caused an increase in relaxation time by about 17 and 20% for 40 and 60 N loading rates, respectively. Increases in 5-min steamed kernels were approximately 7 and 13% only. Also, increasing the initial loading rate from 40 to 60 N decreased the relaxation time constant value, in general. The parboiling variables, however, did not have any significant effect on the intercept values, nor on second, third and fourth element parameters. For initial loading of 40N, average relaxation time obtained for kernels dried at 21ºC were 309.9 and 259.8 s, respectively, for 5- and 10-min steamed kernels. The values for kernels dried at 40ºC were 323.8 and 316.2 s. For initial loading of 60N, the relaxation time constant values were 299.3 and 257.2 s (for 21ºC), and 304.3 and 301.8 s (for 40ºC), respectively, for 5- and 10-min steamed kernels.

It was evident that the moisture gradient, a residual effect of drying, inside the kernel played an important role in determining the stress relaxation time. As the moisture gradient minimized in the kernel during the tempering period the stress relaxation time gradually reduced and attained the lowest magnitude in the range at the end of tempering period. Also degree of parboiling (or degree of gelatinization) of the kernel mattered much. Therefore, moisture profile inside the kernel together with the degree of parboiling very likely governs the relaxation time values. Low moisture in the gelatinized peripheral region would produce increased relaxation time. So would be the case in the regions with crystalline starch granules and low moisture, as evident from comparison of 5 and 10 min steamed kernels. When the gelatinized region is increased with increased moisture in it, the relaxation time is expected to decrease.

Effect of Milling Temperature on Consistency and Accuracy of Rice Sample Milling Procedures

Pan, Z., Thompson, J.F., Wei, L., and Amaratunga, K.S.P.

One of the major concerns of the current standard rice sample milling procedures of Federal Grain Inspection Service is the temperature rise of milling equipment (McGill No. 3) during milling, which could cause significant reduction of total rice yield (TRY) and head rice yield (HRY) resulting in inconsistent and inaccurate milling results. The objectives of this study were to determine the relationships among milling conditions, milling temperature, and quality appraisal results of milled rice and effect of cooling methods on the accuracy and consistency of rice sample milling procedures.

In this study, the effect of temperature rise on milling quality of milled rice was studied. The quality of milled rice, including TRY, HRY, whiteness, and fissures, was measured when the samples were milled continuously without cooling between samples. The temperatures of cutting bar and milled rice were also recorded. It was found that the temperatures of the cutting bar and the milled rice increased and reached 73°C and 83.6°C, respectively, after milling six samples. Temperatures adversely related to HRY and resulted in reductions of HRY as high as 3.8%.

Rice samples with different qualities were also milled under low ambient temperature and two cooling devices (heat exchangers) developed at UC Davis. The two heat exchangers could be used to remove the heat from outside and inside of milling chamber during the milling process. When a exterior heat exchanger was used to cool the mill and the rice, the milled rice temperature was reduced and HRY were improved up to 3.6% comparing without a heat exchanger after milling six samples. It was surprisingly found that the cooling not only improved the HRY, but also whiteness of milled rice. The low ambient temperature and interior cooling also improved the HRY. Based on the research results, controlling the temperatures of milling equipment and milled rice during milling are very important for ensuring consistent and accurate milling results.

Modeling of Rice Taste Value

Zheng, X. and Lan, Y.

It is necessary to dry rice after harvesting. However, drying condition may affect grain quality, producing fissures, inferior taste, etc., and thereby greatly reducing market value, particularly in high temperature sensitive varieties. The effect of drying conditions of rice on rice taste quality was studied to determine a reasonable process of drying and drying parameters.

A series of thin-layer drying experiments of rice (variety: DONGNONG 9316) was conducted in an agricultural drying lab, Northeast Agriculture University, China. The drying experiment conditions were as follows: the initial moisture content of the rice: 16 to 25%, step 3%; drying temperature: 30 to 60°C, step 5°C； air velocity 0.5m/s. The rice sample (100 g) was dried to the final moisture content of 14%. Dried samples were milled and stored.

Correlations among the major ingredients including amylose, protein, moisture, and fatty acid that determine rice taste were obtained. According to the principle of the taste analyzer, rice taste value may be directly calculated with the measured values of above experiments using the following equations:

$$S = \frac{34121}{A^{1.33} P^{0.81} (15 + |15 - M|)^{0.06} F^{0.28}} - 2$$

where S=taste index of rice, A=rice amylose content, P=rice protein content, M=rice moisture content, and F=rice fatty acid content. The above equation was obtained using SPS (V3.11) software.

The correlation between the critical drying temperature that maintains the best rice taste and the initial moisture content was investigated. The taste variable ratio of the rice was defined as ratio of the taste value of the rice grain dried at a given temperature to the one dried in shade. The regression equation of drying temperature was obtained under different initial rice grain moistures. The correct temperature can guarantee that the taste index is higher than 98%. The following equation is fit to the initial rice moisture 16 to 25 % (w.b.)

$$T = \exp(5.021 - 0.058M)$$

T - critical drying temperature, ^{0}C; M - initial moisture (% w.b.).

It showed that the higher initial moisture content of the rice the lower initial temperature that reduced the rice taste value. The rice of the low moisture content can dry in high temperature and maintain its original taste.

Effects of Drying Conditions on Rice Taste and Quality

Zheng, X. and Lan, Y.

Drying is an important process in post-harvest operation for rice. However, rice that is high temperature-sensitive is susceptible to stress cracks with high temperature drying. It is important to properly evaluate and analyze changes in post-drying quality for rice dryer design. Much research on post-drying rice quality on stress crack has been done. However, even when stress cracks didn't appear, rice taste may degrade. Therefore, it is necessary to study rice drying for protecting rice taste quality. In this paper, the change of post-drying taste of rice was studied and the factor of rice taste degradation was analyzed.

Fresh rice (Dongnong 420) was stored at 4ºC in a refrigerator. The moisture content was 21.4% (w.b). Drying temperatures were 40, 45, 50, 55, and 60ºC; relative humidity was 40%; and air velocity was 0.4 m/s. Each rice sample was put on a thin-layer drying tray and weighed every 5 min. When its moisture content reached 14.5%, rice was removed from the dryer and cooled. The rice sample was then sealed in plastics bags.

Rice gelatinization temperature increased with drying temperature. Higher rice drying temperature increased fatty acid. Fatty acid combines with amylose and affects gelatinizing.

The conclusions of our study were: 1) Higher rice drying temperature increased drying rate. If the drying temperature exceeded 45ºC, the rice taste index decreased. If it was lower than 45ºC, quality of rice was improved. 2) Post-drying rice microstructure was observed under electronic microscope. High temperature destroyed rice internal crystalline structure as starch granules gelatinized. It made paste decrease inside cooked rice, which is less sticky and hard. It is one of the reasons why high temperature post-drying rice tastes bad. 3) Rice fatty acid content increased during storage with high drying temperature. Fatty acid easily combined with amylose and restricted starch gelatinization and led to low rice taste quality.

Freshness of Vacuum Packaged Rice

Zheng, X. and Lan, Y

Due to lack of an effective method to store rice, a large quantity of high quality rice is affected by mold, insects, and aging, which causes huge losses every year in China. Therefore, it is imperative to develop an effective method to store rice, which can maintain the good rice taste quality. "Vacuum packaging" is a feasible method to store rice. Vacuum packaging limits oxygen availability and restrains grain respiration, as well as mold and insect growth. Therefore, the vacuum method may reduce breakdown of nutrition ingredients, prevent mold growth, kill insects, slow down the aging process of rice, and maintain rice taste quality.

Keeping rice quality under vacuum packaged conditions and consequent degradation retardation mechanism of the rice quality were studied. Comparative experiments under the convention storage condition (CSC) and vacuum packaged condition (VPC) were conducted in the drying lab of the North-East Agricultural University (NEAU), China. The rice (Variety: DONGNONG 9316) was supplied by the rice processing center at NEAU. Vacuum package bags (PA/PE membrane) and a vacuum package machine (DZD-500/2sc) were used. Experimental conditions of rice stored were as follows: initial moisture content, 13.2 to 17.5%; the vacuum degree, 2%; stored temperature, 10 to 12ºC； stored relative humidity, 50 to 70%; and rice storing duration, 180 days. The stored rice sample was picked out every 30 days.

The $A_{heptanol}$ and $A_{acetaldehyde}$ were measured by a gas chromatography (GC meter HP-5973). The ratio of the $R=A_{heptanol}/A_{acetaldehyde}$ between vacuum and conventional stored conditions were calculated. The R value showed that the larger the value, the more aged the rice. The critical value of R was 1.7. If the $R>1.7$, the sample of stored rice began to age. If $R<1.7$, the stored rice are in a safe condition. The safe stored durations of different initial moisture contents were obtained under conventional and vacuum packaged conditions. It showed that vacuum condition may constrain fatty acid formation and decomposition and slow down rice aging, which prolong rice freshness.

The content of the physicochemical components including fatty acid, moisture and amylose was in subtle change under VPC. However, there was big change for those components under CSC. Therefore, rice taste is better kept under VPC. The higher the rice moisture content, the greater its taste change. There were less yellow kernels under VPC than in CSC, which almost controlled insect pests and fungal invasion that are associated with quality deterioration during storage. The reasonable storage parameters involving various moisture contents were developed that were applied in actual stores and were proved to be feasible.

Recovery Efficiency of Nitrogen in Fresh and Pelletized Poultry Litter in Rice

Golden, B.R., Slaton, N.A., Brye, K.R., Norman, R.J., and Delong, R.E.

Arkansas is one of the leading poultry producing states in the United States with the majority of broiler production located in northwest Arkansas. The long-term application of high poultry litter rates to pastures near the point of its production has sustained excellent forage yields, but phosphorus (P) has accumulated in some soils to excessive levels and is considered a non-point source of nutrient pollution to surface waters. Recent legislation prohibits the application of poultry litter in regions designated as 'Nutrient Surplus Areas' requiring that alternative uses for excess poultry litter be developed. One alternative use is to transport and apply the excess litter to row-crop producing areas in eastern Arkansas. Poultry litter has previously been shown to increase rice (*Oryza sativa* L.) yields on leveled fields, but its value as a nitrogen (N) source for flood-irrigated rice grown on undisturbed fields has not been determined. The feasibility of transporting the excess litter from northwest to eastern Arkansas is partially dependent on its value as a fertilizer source. The objective of this research project was to determine the N-fertilizer values of fresh and pelletized poultry litter applied preplant to soils used for the direct-seeded, delayed flood rice production system.

Studies were conducted at the Northeast Research and Extension Center (NEREC) on Sharkey clay at the Pine Tree Branch Station (PTBS) on a Calhoun silt loam and at the Rice Research and Extension Center (RREC) on a Dewitt silt loam in 2003. Fresh (4.2% total N at 21% moisture) and pelletized (4.1% total N at 11% moisture) litter were applied at five total N rates, ranging from 34 to 269 kg N/ha and mechanically incorporated within 3 hours of application. 'Wells' rice was drill seeded at 112 kg/ha at the PTBS and RREC and 135 kg/ha at the NEREC. At the 5-leaf stage, prior to establishing a permanent flood, urea was applied at six N rates, ranging from 0 to 168 kg N/ha at the PTBS and RREC and 0 to 280 kg N/ha at the NEREC to plots receiving no litter. Total aboveground N uptake was determined near the panicle differentiation (PD) stage and at early heading (HDG) by harvesting whole plants in a 0.9-m section from the first inside row of each plot. Plants were dried, weighed, ground to pass a 1-mm sieve, and whole plant N concentration was determined by combustion. Total N uptake was calculated by multiplying % N concentration by dry matter and expressed as kg N/ha. Grain yield, adjusted to 12% moisture content, was determined by harvesting the middle five rows of each plot with a small-plot combine. Each experiment was arranged as a randomized complete block, 3 (N source) x 5 (total N rate) factorial design and was compared with an untreated control. Each treatment was replicated four times. Each location was analyzed separately. The Fishers Protected Least Significant Difference (LSD) procedure ($p = 0.05$) was used to compare treatment means when appropriate. All statistical analyses were performed using SAS version 8.2.

The N source x N rate interaction significantly affected total N uptake at both sampling times at all three locations. For each location when samples were taken at PD, total N uptake increased numerically as total N rate increased within each source, but significantly different total N uptakes generally occurred only within N rates for urea. Although total N uptakes from all litter rates tended to be numerically greater than the unfertilized control, they were statistically similar. In contrast, total N uptakes from the lowest N application rate as urea tended to be greater than the unfertilized control. By HDG, the general trend for N uptake among N sources remained consistent with the description for PD. However, total N uptakes from fresh and pelletized litter applied at the two highest total N rates were generally greater than the unfertilized control and similar to the lowest one or two rates of N applied as urea. Rice grain yields tended to parallel total N uptake at HDG for each location. The N source x N rate interaction significantly affected rice grain yields at the NEREC and the RREC, but only the main effects of N source and application rate were significant at the PTBS. Maximum grain yields (8136 to 10,462 kg/ha) were produced only by the application of 100 kg N/ha at the PTBS and RREC and 280 kg N/ha at the NEREC. At the NEREC and RREC, application of the highest rate of fresh or pelletized litter produced yields that were greater than the unfertilized control and similar to the lowest rate of N applied as urea.

Litter source did not influence total N uptake by rice, suggesting the mineralization of organic N is similar between pelletized and fresh litter. Organic N mineralized from poultry litter between application and flooding enhanced seedling growth before flooding, but much of this N was probably denitrified when the permanent flood was established. Nitrogen released from the two litter sources after flooding increased N availability compared with the untreated control and the lower preflood urea N rates between PD and HDG, which resulted in grain yields equal to the lowest urea N rates (34 to 56 kg N/ha). On average, preplant incorporated poultry litter applied at rates of 5,000 to 6,000 kg/ha resulted in similar rice N uptake and grain yield as about 112 kg urea/ha applied preflood.

Impaired Cycling of Soil Nitrogen under Continuous Rice Rotations in the Arkansas Grand Prairie Area

Olk, D.C., Anders, M.M., Boeckmann, J.M., Grantham, J., and Holzhauer, J.

Continuous rice (*Oryza sativa* L.) is currently grown on a small area in the Delta. In the future, it may become more common in fields near waterways as decreasing availability of groundwater threatens rice production elsewhere and enhances market opportunities. In a 4-year field experiment at the University of Arkansas Rice Research and Extension Center in Stuttgart, however, rice yield has been 12 to 23% less in a continuous rice rotation than in the conventional rice soybean (*Glycine max*. (L.) Merr.) rotation. Field observations attribute the yield gap to a late season nutrient disorder.

Previous work in tropical irrigated lowland rice indicated a late season decrease in crop uptake of soil organic nitrogen (N) under relatively anaerobic soil conditions, i.e. in fields supporting two and three lowland crops annually. The anaerobic conditions slowed decomposition of woody tissues from roots and straw, resulting in accumulation of phenolic compounds in the soil organic matter. The phenols chemically stabilized soil organic N into molecular forms that are not readily mineralizable. These changes were simultaneous with a long-term yield decline in fields that (i) were managed initially near the yield potential ceiling and (ii) received most of their N fertilizer early in the growing season, making crop N uptake at later growth stages dependent on the mineralization of soil organic N.

In the 2002 season, we measured the cycling of ^{15}N-labeled urea N under rice cultivation in the continuous rice and rice-soybean rotations experiment at Stuttgart. Labeled fertilizer was applied to microplot rings at the same rate (168 kg/ha) as unlabelled N fertilizer was applied to the surrounding main plots. All labeled and unlabeled N fertilizer was applied at the 4-leaf stage just prior to soil flooding. Plants were harvested from separate microplots at the green ring growth stage (83 days after emergence, DAE), the 50% heading growth stage (103 DAE), and harvest (133 DAE). Soil samples were also taken at these times for determination of their ^{15}N content and phenols content. The ^{15}N concentrations of soil and plant samples were determined by continuous flow isotope ratio mass spectrometry, and the phenol content of soil at harvest was determined through cupric oxide oxidation. Nitrogen concentration of the Y leaf was estimated through visible light spectrophotometry.

Between the green ring and 50% heading growth stages, N concentration of the Y leaf decreased more in the continuous rice rotation than in rice-soybean, indicating decreased N availability in continuous rice. Crop uptake of labeled fertilizer N occurred largely during early growth stages, and it was greater in the rice-soybean rotation than in continuous rice, the difference increasing from 7 kg N/ha at green ring to 9 kg N/ha at 50% heading and 14 kg N/ha at harvest. Crop uptake of soil N, i.e. unlabeled N, continued throughout the crop season and was comparable in magnitude with crop uptake of fertilizer N between green ring and 50% heading. At green ring and 50% heading, crop uptake of soil N was 6 kg/ha greater in rice-soybean than in continuous rice, and at harvest, the difference was 24 kg/ha. Phenolic compounds were more abundant in the continuous rice soils than in the rice-soybean soils. Ferulic acid and *p*-hydroxycinnamic acid, common phenols in rice plants, were on average 46% more abundant in continuous rice soils than in rice-soybean soils. Syringyl phenols were 16 to 25% more abundant in the continuous rice soils than in rice-soybean soils. Similar to phenols, ^{15}N also accumulated in the continuous rice soils. From the green ring growth stage through 50% heading to harvest, the enrichment of soil ^{15}N under continuous rice cropping compared with rice-soybean increased from less than 1 kg/ha in the plow layer to 7 kg/ha to 14 kg/ha.

Consistent with previous work in tropical lowland rice, these preliminary results suggest that the accumulation of phenolic compounds under relatively anaerobic soil conditions was accompanied by (i) an N accumulation in soil, i.e. slowed mineralization of both organic N and immobilized fertilizer N into plant-available forms, (ii) visible symptoms of a late-season N deficiency in the rice crop, and (iii) a rice yield loss. The key factor may not be the annual duration of anaerobic conditions but instead the soil aeration status during decomposition of crop residues, when the chemical composition of newly forming organic matter and its binding of nutrients are determined. To better establish a causal effect of anaerobic decomposition on N cycling, the ^{15}N field study will be repeated during the 2003 and 2004 seasons and newly developed techniques of nuclear magnetic resonance spectroscopy will be used to directly observe the binding of organic N by phenolic compounds.

Rice Response to 5% Heading Applications of Fertilizer Nitrogen

Bollich, P.K., Leonards, J.P., Regan, R.P., Romero, G.R., and Walker, D.M.

Rice is highly responsive to and requires fertilizer nitrogen (N) for proper growth and optimum grain yield. In Louisiana, N is applied in a range of 67 to 202 kg/ha depending on cultivar, soil type, and environment. A standard approach to fertilizer N management in drill-seeded rice has included an application of 60 to 70% of the total just before permanent flood establishment and the remainder at midseason. Midseason application timing is usually identified with the period of panicle initiation through panicle differentiation. Questions have arisen regarding the application of N later than the traditional midseason timing. Applying N once rice begins to head has the potential to increase rough rice grain yield but also to improve whole grain milling yield. In southwest Louisiana where ratoon cropping is practiced, there is also potential for a heading application to affect the resulting ratoon crop by improving regrowth and increasing grain yield.

A drill-seeded study was conducted in 2003 at two locations in Louisiana to determine the effectiveness of fertilizer N applied at 5% heading. At East Carroll Parish in north Louisiana and at the Rice Research Station in southwest Louisiana, the study was conducted on Sharkey clay and Crowley silt loam soils, respectively. The study was designed as a randomized complete block with a factorial arrangement of five cultivars (Francis, Cocodrie, Cheniere, Cypress, and Wells), two levels of preflood N (84 and 168 kg/ha), and three levels of 5% heading N (0, 33, and 67 kg/ha). Plot dimensions were 2.1 x 7.6 m (12 drill rows with 18-cm row spacing). Agronomic practices utilized in this study followed current recommendations. Days to 50% heading, plant height, main crop grain yield, ratoon crop grain yield (Rice Research Station only), and milling yield were determined.

Days to 50% heading and plant height were increased as preflood N increased at the Rice Research Station. Nitrogen applied at 5% heading had no effect. An interaction between variety and preflood N occurred for main crop grain yield. Grain yields of all cultivars increased as preflood N increased, but the differences in yield between the two levels of N were much greater with Cocodrie. Nitrogen application at 5% heading had no effect on grain yields. Ratoon crop yields were also unaffected by preflood N level and heading N. Total grain yields were significantly increased with heading N and were due to the additive but nonsignificant effects observed with the main and ratoon crop yields individually. Milling yield was not affected by preflood or heading N.

Days to 50% heading and plant height were increased as preflood N increased at the East Carroll Parish location. Heading N had no effect. An interaction between variety and preflood N occurred for main crop grain yield. Grain yields of all cultivars increased as preflood N increased, but the differences in yield between the two levels of N were quite different, depending on variety. Heading N had no effect on grain yield. Whole grain milling yield was significantly increased with heading N applied at 33 kg/ha. Interactions occurred between variety and preflood N and variety and 5% heading N for total milling yield but were not considered to be important.

Heading N did not affect rice growth since plant height, days to 50% heading, and grain yield were not influenced at either location. Ratoon yield at the Rice Research Station was also unaffected by heading N. Whole grain milling yield did not respond to heading N at the Rice Research Station, but at the East Carroll location, whole grain milling was significantly increased with an application of 33 kg/ha. Although this increase was significant, it was less than one percentage point, which makes the economic return from this application questionable. Applications of heading

N do not appear to be economically feasible based on the results on one year of research at two locations. Additional research needs to be conducted to determine the consistency of response of rice to heading N over time and environment.

Evaluation of Several Nitrogen Fertilizers for Use at Preflood in Delayed Flood Rice

Norman, R.J., Wilson, Jr., C.E., Slaton, N.A., Boothe, D.L., Griggs, B.R., and Bushong, J.T.

Urea is the primary nitrogen (N) source used in the delayed flood rice cultural system practiced in the southern United States. This is because of its high N analysis and low cost relative to other N sources. Urea has many fine qualities, but it also has an undesirable characteristic in that its initial reaction when applied to soil is alkaline, and thus, it is prone to ammonia volatilization losses if not soil incorporated within a couple of days after surface application. In the delayed flood system, the flood water is used to incorporate the large, preflood N fertilizer application. Many farmers cannot get the flood water across their fields within a few days following the preflood N fertilizer application. Most take 5 to 10 days to get the flood water across the field. In a situation where a farmer cannot flood timely after N application, might it be better to use an N source that is not so easily prone to ammonia volatilization losses? Ammonium sulfate is slightly acid in its initial reaction when applied to soil so it is much less prone to ammonia volatilization losses compared with urea. Urease inhibitors have been promoted as a means to significantly slow ammonia volatilization losses from urea fertilizer. Agrotain is a urea fertilizer that contains the urease inhibitor NBPT. Unity is a N fertilizer source made from municipal waste and ammonium sulfate and should have some of the desirable characteristics of ammonium sulfate. In addition, Unity contains some organic N that by its very nature is slow release. High NRG-N is a liquid N source that is being sold as a preemergence and preflood N source for delayed flood rice. Because of the need to find a less volatile preflood N fertilizer source for delayed flood rice coupled with advent of several new N fertilizers on the market, the objectives of this study were to evaluate the aforementioned N fertilizer as to their ammonia volatility and influence on the grain yield of drill-seeded, delayed flood rice.

The studies were conducted from 2001 to 2003 at the University of Arkansas Pine Tree Branch Experiment Station on a Calloway silt loam (Glossaquic fragiudalfs) having a soil pH between 7.0 to 7.5 and at the University of Arkansas Rice Research and Extension Center on a DeWitt silt loam (Typic Alabaqualfs) having a soil pH between 5.8 and 6.3 at the time of measurement. The cultivar 'Wells' or 'Cocodrie' was used in all studies and seeded at 100 kg/ha in nine row plots of 4.6 m in length. The rice was grown upland until the 4- to 5-leaf growth stage and then a permanent flood was applied and maintained until maturity. The experimental designs utilized varied from a split-split plot to a randomized complete block with a factorial arrangement, all with four replications. Fertilizer N sources were: i) urea, ii) Agrotain, iii) ammonium sulfate, iv) Unity, and v) high NRG-N. Fertilizer N rates ranged from 67 to 202 kg N/ ha. The N fertilizers were applied to a dry soil surface with no incorporation from several days up to 2 weeks prior to application of the permanent flood. At maturity, the plots were harvested with a small plot combine. Ammonia volatilization of the different N sources applied to the soil was conducted using static chambers. Statistical analyses were conducted on grain yield and ammonia volatilization data with SAS, and mean separations were based upon protected LSD where appropriate.

Agrotain and ammonium sulfate lost, via ammonia volatilization, only 2 to 5% of the applied N within 5 days after application and only 3 to 10% of the applied N within 10 days after application. Conversely, urea lost 15 to 20% of the applied N within 5 days and 17 to 25% of the applied N within 10 days of application. Application of Agrotain and ammonium sulfate produced the highest grain yields, which were quite similar and were significantly higher than those produced with urea when flooding was delayed for 5 and 10 days. Rice grain yields did not decline or declined only slightly as application time before flooding increased to 5 and 10 days when Agrotain or ammonium sulfate were applied. Unity was applied preplant and preflood in 2001 and resulted in lower grain yields compared with urea applied preflood. Unity applied preplant resulted in poor yields compared with urea applied preflood due to Unity not possessing the slow release properties required of a preplant N source in delayed flood rice. Unity applied preflood resulted in lower grain yields compared with urea applied preflood in 2001 because the Unity had a tendency to float with the flood water. Unity was made denser and less buoyant and studied again in 2003. Unity was compared with ammonium sulfate applied at several times (1 to 10 days) prior to flooding. Unity produced rice grain yields equivalent to ammonium sulfate at all application times in 2003. High NRG-N was studied when applied at preemergence and preflood according to Agro-Culture protocol. High NRG-N applied in split applications at preemergence and preflood or in a single application at preemergence or preflood produced significantly lower grain yields compared with urea applied preflood. Agro-Culture also had us test a new liquid N source, XN. XN was superior to High NRG-N, however, XN applied in a single preemergence application or in a split application at preemergence and preflood produced lower grain yields compared with urea applied preflood.

Regional Evaluation of HM9310 and HM0108 as a Midseason N Source for Rice

Walker, T., Bollich, P.K., Dunn, D., Kenty, M., Norman, R.J., Street, J., and Turner, F.

The dynamic nature of nitrogen (N) coupled with the flooded soil environment makes N management for optimum rice yields and quality challenging. Agronomists continue to evaluate methods and products to increase the efficiency of fertilizer N. A regional study was conducted in Arkansas, Louisiana, Missouri, Mississippi, and Texas to evaluate the effectiveness of two foliar N products, HM9310 (0.3 kg N/l) and HM0108 (0.14 kg N/l and 0.14 kg K_2O/l), on rice grain yield and quality.

'Cocodrie' was drill-seeded at each location, and all production practices were conducted according to the recommended practices of the individual states. At each location, a factorial study that included two preflood (PF) N rates (67 and 134 kg N/ha) and eight midseason (MS) N treatments was arranged in a randomized complete block design. The N source for three of the MS N treatments was urea, and the rates were 11, 22, and 44 kg N/ha. HM9310 and HM0108 were both applied at rates of 11 and 22 kg N/ha. Each of the MS N treatments was compared with an untreated control. The MS urea N treatments were applied by hand at 1.3-cm internode elongation (IE) except for Arkansas where urea N was sprayed on as a solution. All foliar N treatments were split into two applications, which were 1.3-cm IE and 7 days after 1.3-cm IE, and broadcasted with CO_2-pressurized backpack sprayers at a volume of 94 l/ha. Yield data were adjusted to 120 g/kg moisture. Milling quality was determined at one location according to standard milling procedures. All data were pooled across locations using PROC MIXED.

A significant interaction among the PF N rate and location was significant for rice grain yield. This interaction appeared to be due to less N response to increased PF N at the Arkansas and Missouri locations. Differences in MS N treatments were also detected. When the data were averaged across both PF N rates, the MS N treatments of urea at the rates of 11 and 44 kg N/ha were the only treatments that increased yield when compared with the untreated control.

An interaction among location and PF N rate was significant for total milled rice. As the PF N rate increased, total milled rice decreased in Louisiana and Mississippi; however, the PF N rate did not affect total milled rice in the other states. Though there were differences among individual MS N treatments when averaged across the PF N treatments, no treatment increased total milled rice compared with the untreated control; however, when urea was applied at the 11 and 44 kg N/ha MS N rates, total milled rice was less than the untreated control.

An interaction occurred among location and PF N rate for whole milled rice. Whole milled rice decreased as the PF N rate increased in Louisiana and Texas; however, no differences were detected in the other states. Though there were differences among individual MS N treatments when averaged across the PF N treatments, no MS N treatment increased whole milled rice above the untreated control; however, when urea was applied at the 11 and 44 kg N/ha, whole milled rice was less than the untreated control.

These data indicate that when HM9310 and HM0108 are split-applied at 1.3-cm IE and 1.3-cm IE + 7 days, at the rates of 11 and 22 kg N/ha, Cocodrie rice yields are not increased compared with the untreated control. In addition, neither urea nor the two foliar N sources increased milling quality. These data also indicate that Cocodrie is not highly responsive to N when applied at MS.

Prediction of Rice Phosphorus Concentration at the Midtillering Stage using Soil pH and Mehlich-3 Phosphorus

Slaton, N.A., Wilson, Jr., C.E., Norman, R.J., DeLong, R.E., Boothe, D.L., and Clark, S.D.

A United States Department of Agriculture (USDA) survey reported that rice, *Oryza sativa* L., acreage receiving phosphorus (P) fertilizer applications was 44% for Arkansas, 88% for California, and 84% for Louisiana with an average application rate of about 25 kg P/ha (49 to 54 lb P_2O_5/A). Previous research in Arkansas has shown that significant rice yield increases from P fertilization seldom occur on undisturbed silt loam soils, even when the soil test P level is very low or low. Although growers are encouraged to fertilize crops, including rice, according to soil test recommendations, numerous research has shown that soil test P extracted by most soil test methods is poorly correlated with rice yield response to P fertilization. The flooded soil environment compromises the ability of routine soil test methods to accurately predict the need for P fertilization of rice. Therefore, P fertilizer recommendations for rice based on soil test P are prone to recommend P fertilizer application to soils that are not P deficient. Alternative approaches are needed to improve the accuracy of P fertilizer recommendations. The objective of this research was to correlate the routine soil test measurements of soil pH and Mehlich-3 extractable P (M3P) with whole plant P concentrations at the midtillering growth stage of rice grown on silt loam soils. Our hypothesis was that midtillering P concentration may be better correlated with soil test parameters than rice grain yield. If so, use of this relationship would improve the accuracy of P fertilizer recommendations by identifying soils that have limited P availability shortly after flooding when P deficiencies are usually observed in commercial rice fields.

Studies were conducted on silt loam soils following soybean, *Glycine max* (Merr.) L., in several growers' fields located in Cross County, AR; at the Pine Tree Branch Station, near Pine Tree, AR; and the Rice Research Extension Center, near Stuttgart, AR. Data, including soil pH, Mehlich-3 P, and whole plant rice P concentrations, from the unfertilized controls in a number of replicated P fertilization trials were assimilated into a database. In each study, composite soil samples were collected from the 0- to 10-cm depth from each unfertilized control plot. Soil pH (water pH, measured in 1:2 soil: water ratio) and M3P, determined by inductively coupled plasma (ICP) spectrophotometry, were measured on each composite sample. Data from each replicate, rather than replicate means, were used for a total of 61 data points from eight different trials. In all trials, rice was drill seeded and managed according to guidelines for the direct-seeded, delayed-flood rice production system recommended by the University of Arkansas Cooperative Extension Service. Nitrogen fertilizer was applied near the 5-leaf stage and flooded immediately. Whole, aboveground plant samples were taken 10 to 14 d after flooding (midtillering stage) from a 0.9 m section in the first inside row from each plot. Plant samples were dried, ground to pass a 1-mm sieve, digested with HNO_3 and 30% H_2O_2, and analyzed for nutrient concentrations by ICP. Whole plant P concentrations were regressed against soil pH, M3P, and combinations of these two parameters. A multiple regression model using the linear and quadratic terms of soil pH and M3P and the interaction between soil pH and M3P was used to establish the relationship between these parameters and whole plant P concentration. Linear and quadratic models using soil pH or M3P alone were also evaluated. A significance level of 0.10 was used to include (< 0.10) or exclude (> 0.10) the initial terms of each model. The simplest, significant model that described the relationship was selected. All statistical procedures were performed using SAS version 8.2.

The 61 data points ranged in pH from 5.7 to 8.4, M3P from 5 to 71 mg P/kg, and tissue P concentrations from 0.10 to 0.37 %P, which represents the majority of silt loam soils used for rice production in Arkansas. The linear relationships between rice P concentration and soil pH (P = 0.0404) and rice P concentration and M3P (P <0.0001) were significant. Rice P concentration tended to increase as M3P increased and decreased as soil pH increased. Non-linear models showed the quadratic terms for soil pH or M3P were not significant. Although the linear models were statistically significant, soil pH ($r^2 = 0.0535$) and M3P ($r^2 = 0.2333$) alone were inadequate to accurately predict midtillering tissue P concentrations. The final significant multiple regression model [P concentration = -0.456 + (0.0029 x M3P) + (0.236 x pH) – (0.00008 x M3P^2) – (0.0213 x pH^2); P <0.0001; $r^2 = 0.6509$] included the linear and quadratic terms for soil pH and M3P but not the interaction between soil pH and M3P (P = 0.2024). This model can be used with reasonable accuracy to predict tissue P concentration of rice at the midtillering growth stage. A whole plant P concentration of 0.20% is suggested as the critical concentration for recommending P fertilization according to both soil pH and M3P. The need for P fertilization will increase as soil pH increases and M3P decreases.

Dynamics of Extractable Soil P by Six Methods during Flooding

Xia, Y., Wilson, Jr., C.E., Norman, R.J., Slaton, N.S., and Miller, D.M.

Phosphorus (P) soil test methods currently used in the United States were developed to predict plant available P of soils not subjected to prolonged periods of flooding. Therefore, these methods may not be appropriate for soils used to grow paddy rice. Accurate assessment of available P in both aerated and flooded soils is important for calibration of soil test P critical levels for soils used for rice production. The objective of this study was to evaluate the influence of flooding on the P availability indices of six soil test P methods.

Available soil P was determined on four soils used for paddy rice production by the Mehlich-3, Bray-1, Bray-2, Olsen, Lancaster, and resin methods after incubation under flooded conditions for 1, 4, 7, 14, 21, and 28 d. The four soils were: DeWitt silt loam (fine, smetitic, thermic Typic Albaqualfs), Calhoun silt loam (fine-silty, mixed, thermic Typic Glossaqualfs), DeWitt silt loam (fine, smetitic, thermic Typic Albaqualfs), and Hillemann silt loam (fine-silty, mixed, active, thermic Albic Glossic Natraqualfs) collected from an Arkansas county rice field (DeWitt-BD), the University of Arkansas Pine Tree Branch Experiment Station near Colt, AR (Calhoun), the University of Arkansas Rice Research and Extension Center near Stuttgart, AR (DeWitt-RR), and a Cross County rice field (Hillemann), respectively. These four soils were selected for this study because P fertilization studies had previously been conducted on these growers' farms which provide some general knowledge of rice response to P.

The soils were saturated with double-deionized H_2O and allowed to equilibrate for 1 d. A single resin-capsule was embedded into the center of the soil in each vessel such that they were completely surrounded by soil. The resin-capsule used in this study contained a 1:1 mixture of two different types of resin, a strongly acid cationic resin and a strongly basic anionic resin. The individual resin beads have a uniform, spherical shape, and the total surface of each capsule area was 11.4 cm^2. Each capsule possessed a cation plus anion exchange capacity of 2.2 $cmol_c$. To simulate flooding, double-deionized water was added so that the water depth above the soil surface was 3.5 cm. The bottles were tightly stoppered and incubated at 25^{o}C for 28 d. Nitrogen (N_2) gas was injected into the bottles at 3-d intervals during the incubation period to ensure anaerobic conditions were maintained. A second group of duplicate 200-g air-dry soil samples of each soil was treated with the same procedure described above, but instead of using resin-capsules to test available P under flooded conditions, five chemical soil test methods were employed to determine available P. Resin-capsules were removed 1, 4, 7, 14, 21, and 28 d of after flooding, cleaned with deionized water, and then extracted. Phosphorus sorbed by the resin-capsules was recovered by three sequential desorptions using 20 mL of 2 *M* HCl each time (shaking for 30 min each). Samples of each soil were also collected 1, 4, 7, 14, 21, and 28 d after flooding for determination of extractable P by each of the five chemical soil test methods. The extractions were done on mud samples. The P concentration in all soil extracts was determined by the ascorbic acid method. The experiment was conducted as a completely randomized design with a 6 x 4 x 3 factorial treatment structure with two replications of each treatment.

The initial soil P extracted by the five chemical methods in decreasing concentration order were: Lancaster > Bray-2 > Mehlich-3 > Bray-1 > Olsen. Available soil P determined by resin, Mehlich-3, Bray-1 and Bray-2 methods all increased gradually in the four soils during flooding. Although the Mehlich-3, Bray-1, and Bray-2 P extracted different P concentrations, they showed similar changes in extractable P across the 28-d incubation. In general, the relative increase in extracted P across time by these acidic extractants for the four soils was: DeWitt-RR > DeWitt-BD > Calhoun > Hillemann, which corresponds inversely to soil pH (Hillemann > Calhoun > DeWitt-BD > DeWitt-RR).

The Olsen and Lancaster extractable P increased initially, reached a maximum within 4 to 7 d, and then decreased slightly from 7 to 28 d. The Bray-2 method extracted much larger amounts of P than the Mehlich-3 and Bray-1 methods and may overestimate available soil P for flooded rice. Mehlich-3 and Bray-1 appear to be more suitable than the other methods examined for predicting available soil P under reduced soil conditions. However, each method should be correlated with plant growth parameters. The percent recovery of added fertilizer P depended on the soil, added P rate, and incubation time.

Phosphorus Rate and Application Timing on a Low P, High pH Soil

Walker, T.W., Slaton, N.A., and Street, J.E.

Historically, phosphorus (P) fertilizer was seldom recommended for rice grown in Mississippi. Rice response to P fertilizer has been inconsistent across the southern rice belt. Part of the inconsistency of rice response to P can be attributed to the flooded environment that is introduced at the initiation of tillering. The occurrence of P deficient areas within fields has increased within the last several years in Mississippi. The objective of this study was to determine the optimum rate and application timing of fertilizer P on P-responsive soils.

A study was conducted on a commercial field in 2002 to determine the optimum rate of P. Triple superphosphate was used to apply five rates (0, 22.4, 44.8, 67.2, and 89.6 kg P_2O_5/ha) of P. Phosphorus treatments were broadcast applied at the 3- to 4-leaf stage. A permanent flood was established when rice reached the 4- to 5-leaf stage. Y-leaf tissue samples were collected at 1.3-cm internode elongation (IE), and flag leaf tissue samples were collected at the late boot (LB) stage. Tissue samples were analyzed for total P. The P concentration in the Y-leaf tissue was increased by 100% with the 67.2 kg P_2O_5/ha treatment. This treatment also increased rice grain yield by 44%.

An additional study was conducted in 2003 on a commercial field to determine the optimum rate and application timing of fertilizer P. Triple superphosphate was applied at rates of 28, 56, and 112 kg P_2O_5/ha. These fertilizer P rates were applied at delayed preemergence (DPRE), preflood (PF), IE, and boot (B). The DPRE and PF treatments were broadcasted onto dry soil and the IE and B applications were broadcasted into the flood water. Rice grain yields were affected by application rate and application timing. When averaged across application timings, the 112 kg P_2O_5/ha treatment averaged 6552 kg/ha compared with an average yield of 554.4 kg/ha for the untreated control. When treatments were averaged across rates, the DPRE application resulted in yields that were greater than any of the other timings. The tissue analyses are incomplete, but those data will be presented.

Potassium and Rice Production: Missouri Update

Dunn, D.J., Stevens, W.E., and Beighley, D.

Proper potassium (K) nutrition is critical for maximizing rice grain yields. Incidences of K deficiency in rice have been increasing in Missouri. A 170 kg/ha rice crop removes over 11 kg K_2O/ha each year. Potassium is very mobile within the rice plant. Older leaves are scavenged for the K needed by younger leaves. Profitable rice production hinges on accurate, reliable, and relevant information about plant-soil interactions. A review of the available literature shows that no consistent methodology has been developed correlating K determinations in rice plants to rice grain yields. The objective of this study was to correlate rice tissue K levels with grain yields.

Reference plots for K fertilization were established at the Missouri Rice Research Farm at Qulin, MO, in 2002 and 2003. These plots received one of three levels of K fertilization, deficient (0 kg K_20/ha), adequate (56 kg K_2O/ha), and excessive (224 kg K_20/ha). Soil testing at this site indicated that a K fertilization rate of 56 kg K_20/ha was required for optimum rice production. Plant tissue samples were collected from each plot three times during the growing season, first tiller, internode elongation, and 10% heading. These samples were divided into the plant components, flag leaf, lower leaf, stem, and whole plant. These tissue samples were dried, ground, digested using H_2SO_4-H_2O_2, and analyzed for K% by atomic absorption. Each plot was mechanically harvested for yield. Statistical analyses of the data were preformed with SAS using General Linear Modeling procedures. Fisher's Protected Least Significant Difference (LSD) was calculated at the 0.05 probability level for making treatment mean comparisons. Regression and correlation analysis were performed in accordance with procedures outlined by the SAS Institute.

Flag leaves were found to have greater tissue levels than lower leaves for each K fertilization level. This difference was greater at 10% heading than at internode elongation. The tissue K levels of lower leaves were better correlated to yield than flag leaves. The 2-year average r^2 value between K level and yield at 10% heading for lower leaves was 0.42 vs 0.07 for flag leaves. Potassium fertilization significantly increased rice grain yields (0 kg/ha K = 4536 kg/ha grain, 56 kg/ha K = 5494 kg/ha grain, and 224 kg/ha K = 6098 kg/ha grain).

Potassium Fertilizer Rate and Application Time Effects on Grain Yield and Potassium Uptake by Rice in Arkansas

Pugh, B.C., DeLong, R.E., and Slaton, N.A.

Potassium (K) deficiency of rice, *Oryza sativa* L., has become more common in the United States during the past decade and is usually expressed by foliar deficiency symptoms appearing between panicle initiation (PI) and heading. Because K deficiency of rice has not been a common problem, our knowledge of how to manage K-deficient rice is limited. In Arkansas, growers typically apply K fertilizer before seeding at rates suggested by soil test recommendations. When K deficiency is diagnosed, Arkansas rice growers have been advised to apply K fertilizer to K-deficient rice so long as the rice has not started to head. These recommendations are based on the reasoning that K is not susceptible to the same loss mechanisms as nitrogen (i.e., NH_3 volatilization or denitrification) and, assuming K does not exit the field with runoff, K should remain in the soil for use by the current rice crop or future crops. However, the ability of K fertilizer applications made between PI and the late boot (LB) stage to recover lost grain yield potential, as well as the rice plants ability to recover this K is not well understood. The objective of this research was to investigate rice growth, K uptake, and grain yield response to K fertilization rate and application time on a silt loam soil in Arkansas.

Three studies were conducted on a Calhoun silt loam soil at the Pine Tree Branch Experiment Station in 2000, 2001, and 2002. Each spring, composite soil samples were collected from the 0- to 10-cm depth from each plot and analyzed for soil pH and Mehlich-3 extractable nutrients, including K. ‘Wells’ rice was drill-seeded at a rate of 110 kg/ha into a conventionally tilled seedbed. In 2000 and 2001, rice followed soybean [*Glycine max* (Merr.) L.]. In 2002, rice followed rice with the previous year’s rice stubble removed after harvest. Potassium fertilizer (KCl) was applied to the soil surface at rates of 0, 28, 56, 84, and 112 kg K/ha at four different times, including preemergence (PE), preflood (PF), panicle differentiation (PD), and the LB stages. Each application time was about 25 to 30 d apart. At PE and PF, the K fertilizer applications were applied to the soil surface, whereas at PD and LB stages, the K fertilizer applications were made directly into the floodwater. At the 5-leaf stage, 135 kg N/ha as urea were applied to a dry soil and flooded immediately. For studies conducted in 2001 and 2002, whole aboveground plant samples were harvested from a 0.9-m section from the first inside row at 14, 28, 42, and 56 d after flooding (DAF) and at maturity. At maturity, panicles were removed from the straw at the top node to determine total K uptake (panicle + straw) and K removal (panicle). Samples were dried, weighed, ground to pass a 1-mm sieve, digested with HNO_3 and 30% H_2O_2, and nutrient concentrations were determined. At maturity, the middle five rows were harvested with a small plot combine. Grain yields were adjusted to 120 g/kg moisture content for statistical analysis. Each study was a randomized complete block design with four or five replications and a split-plot treatment structure. Potassium application rate was the whole plot factor and application time was the subplot factor. Grain yield, whole plant K concentration and content, and dry matter were analyzed as a split-split plot treatment structure where year was the main plot. The unfertilized control was considered as a fifth application time (None) and an application rate (0 kg K/ha). Potassium uptake, whole plant K concentration, and dry matter were analyzed by sample time. The Fishers Protected Least Significant Difference (LSD) procedure ($p = 0.05$) was used to compare treatment means. All statistical analyses were performed using SAS version 8.2.

The two- and three-way interactions involving year, K rate, and application time were not significant for grain yield. Only the main effects of K application time and year significantly affected grain yield. Averaged across K rates (28 to 112 kg K/ha), K fertilizer applied at PE (8103 kg/ha) and PF (8103 kg/ha) produced significantly greater yields than K applied at midseason (7884 kg/ha), LB (7823 kg/ha), or None (7803 kg/ha), which were statistically similar.

The K rate % application time interaction was significant for total K uptake at all sample times. In general, K uptake increased as K rate increased and decreased as K application time was delayed. Potassium fertilizer applications made PE and PF resulted in similar K uptake throughout the season and tended to have greater K uptake than midseason applications prior to heading. By maturity, total K uptake was similar among the PE, PF, and midseason application times, which were significantly greater than K applied at LB or when no K was applied. Potassium should be applied before or during early vegetative growth. When K was applied after PI, uptake of fertilizer K decreased and grain yields tended to decrease, which suggests that late-season K applications have a limited ability to compensate for lost yield potential when soil K is only slightly limiting.

Rice Response to Boron Fertilization in Arkansas

Ross, J.R., Slaton, N.A., Mozafari, M., and Espinoza, L.

Rice (*Oryza sativa* L.) and other monocots usually have low boron (B) requirements. Literature contains few reports of B deficiency or growth and yield responses of rice to B fertilization. In Arkansas, interest in rice response to B fertilization has been heightened by i) reports of significant rice yield responses attributed to B fertilization in Missouri, ii) B fertilization recommendations for rice made by some private soil test laboratories, and iii) the recent diagnosis of B deficiency as a yield-limiting factor for soybean, *Glycine max* (Merr.) L., grown on alkaline silt loam soils in northeast Arkansas. Because rice is the primary crop grown in rotation with soybean in Arkansas, growers have inquired about the need for B fertilization of rice, as well as the possibility that B applied to soybean may cause B toxicity when rice is grown. The primary objective of this study was to evaluate rice growth and yield response to various B application rates and times.

Studies evaluating the time and rate of B application to rice were established on an alkaline Calhoun silt loam at the Pine Tree Branch Station, near Colt, AR, in 2002 (PTBS02) and 2003 (PTBS03), and on an alkaline Hillemann silt loam in a commercial production field in Cross County (Cross03), AR, in 2003. Boron deficient soybean had been documented in the Cross03 field in 2001 and 2002. A composite soil sample (0 to 10 cm) was collected from each unfertilized control plot and analyzed for soil water pH and Mehlich-3 extractable nutrients, including B. All sites were conventionally tilled, seeded with 'Wells' rice and managed according to University of Arkansas production recommendations for the direct-seeded, delayed flood production system. Boron was applied at 0, 0.37, 0.74, and 1.12 kg B/ha as Solubor (20.5%B) with a backpack sprayer calibrated to deliver 94 l/ha at four times during the growing season, including preemergence (PE), preflood or 5-leaf stage (PF), late tillering (LT) before internode elongation, and at the early- to mid-boot stages (MB) before flag leaf emergence. Whole, aboveground plant samples were collected at panicle differentiation from a 0.9 m section from the first inside row from the unfertilized control and plots receiving PE, PF, and LT applications of B. Twenty flag leaves were also collected from all plots at the late-boot to early heading stages. Plant samples were dried, weighed, ground to pass a 1-mm sieve, and digested with HNO_3 and 30% H_2O_2 for elemental analysis. At maturity, grain yield was determined by harvesting the middle four rows of each plot. Grain yields were adjusted to 12% moisture content for statistical analysis. Each study was arranged as a randomized complete block with a 3 x 4 factorial treatment arrangement and compared with an unfertilized control. Each treatment was replicated four times. Locations were analyzed separately.

Rice plants in all three studies appeared normal and healthy for the entire season, regardless of B application time and rate. Rice dry matter accumulation at panicle differentiation was affected by B fertilization only at the PTBS02 where B application time (P = 0.0003) significantly affected rice growth. Averaged across B application rates, B applied PE and PF increased dry matter by 20 to 27% compared with the unfertilized control (2441 kg/ha), which was no different than the LT applications (2234 kg/ha) made <14 days before sampling.

Grain yield was not significantly affected by the B application rate x time interaction at any of the three locations. Only the time of B application significantly affected grain yield at the PTBS02 and Cross03 study sites. At both sites, when averaged across the application rates of 0.37 to 1.12 kg B/ha, B applied at LT produced significantly greater yields than the unfertilized controls. Boron applied PE produced numerically lower yields, but statistically similar yields as the PF and MB B applications. Compared with the unfertilized control yields (7963 and 7056 kg/ha for PTBS02 and Cross03, respectively), B applied at the LT stage increased yields by 5 (PTBS02) to 9% (Cross03). The PTBS03 yields were not significantly affected by B rate (P = 0.3533), application time (P = 0.6178), or their interaction (P = 0.7008), but treatments receiving B, averaged across B application rates, produced numerically greater yields than the unfertilized control. Although not statistically significant, similar trends were observed at the PTBS03 site. Although not statistically significant, all B application rates (0.37 to 1.12 kg B/ha), averaged across application times, also produced higher numerical yields than the unfertilized control at each site.

Rice grain yield data suggest that alkaline silt loam soils that require B fertilization to produce maximum soybean yields may also require B to produce maximum rice yields. However, the yield increases observed in two of these three studies were nominal (<10%). If the yield responses are indeed valid, perhaps routine B fertilization of soybean will provide sufficient B for the following rice crop. Additional research is required to determine the consistency of rice grain yield responses to both B rate and application time.

Rice Response to Zinc Fertilization on Clay Soils in Arkansas

Slaton, N.A., Hensley, J., Wilson, Jr., C.E., Branson, J., Norman, R.J., and DeLong, R.E.

Zinc (Zn) fertilizer is not currently recommended for rice, *Oryza sativa* L., grown on clay or clay loam soils in Arkansas. Although Zn-deficient rice is not commonly observed on clay soils, Zn deficiency has been documented on a few clay soils that have been precision graded. When Zn-deficient rice has been diagnosed on clay soils in Arkansas, Mehlich-3 extractable Zn has been very low (<1.0 mg Zn/kg), suggesting that Zn fertilization recommendations for rice grown on clay soils may be needed. The objectives of this research were to determine if i) routine soil test parameters such as Mehlich-3 extractable Zn concentration and soil water pH were correlated with whole plant Zn concentrations at the mid-tillering growth stage and ii) evaluate rice grain yield response to Zn fertilization on clay soils in Arkansas.

Eight field studies were established on three Earle clays, three Perry clays, and two Sharkey clays in 2003. All sites were drill seeded and managed according to University of Arkansas guidelines for the delayed flood production system. A composite soil sample was collected from the 0- to 10-cm depth in each unfertilized control. Soil samples were dried, crushed, and analyzed for soil water pH (1:2 soil:water mixture) and soil nutrient concentrations by Mehlich-3 extraction. Granular Zn fertilizer (31% Zn, as $ZnSO_4$) was applied to the soil surface at rates of 0, 5.6, 11.2, and 22.4 kg Zn/ha before rice emergence. Zinc fertilizer rates were arranged in a randomized complete block design with four replications at each location. Near the 5-leaf stage, urea was applied to a dry soil surface and a permanent flood was established. Whole, aboveground plant samples were taken from a 0.9-m section in the second inside row of each plot 10 to 14 d after flooding. Plant samples were dried, weighed, ground to pass through a 1-mm sieve, and digested with concentrated HNO_3 and 30% H_2O_2 for elemental analysis. At maturity, a small plot combine was used to harvest rice grain from the middle four rows of each plot. Grain yield was calculated using harvested grain weight, grain moisture, and harvested area and adjusted to a uniform moisture content of 120 g/kg (12%) for statistical analysis. Tissue Zn concentration, dry matter accumulation, and grain yield were analyzed in a split-plot design where location was the main plot factor and Zn rate was the subplot factor. Linear, non-linear, and multiple regression models were used to determine if Mehlich-3 Zn, soil pH, or both were correlated with whole plant Zn concentration at the mid-tillering stage. All statistical analyses were performed with SAS version 8.2.

The location x Zn rate interaction was not statistically significant for grain yield (P = 0.6785), whole plant Zn concentration (P = 0.5808), or dry matter (P = 0.8531) at mid-tillering. Location was the only factor that significantly influenced rice dry matter accumulation (P <0.0001) at the midtillering stage and grain yield (P <0.0001) at maturity. Whole-plant Zn concentrations, averaged across Zn rates, ranged from 17.3 to 41.5 mg Zn/kg and were also significantly affected by location (P <0.0001). Only one location had tissue Zn concentrations below the established critical Zn concentration of 20 mg Zn/kg. Despite low tissue Zn at this site, Zn deficiency symptoms were not observed and grain yield showed no response to Zn fertilization. Application of Zn fertilizer rates, ranging from 5.6 to 22.4 kg Zn/ha did not benefit or harm rice dry matter accumulation (P = 0.5059) and yield (P = 0.2727) on these eight clay soils. Zinc application rate (P <0.0001) significantly affected whole plant Zn concentration, but the magnitude of change was not as great as expected. Whole plant Zn concentrations, averaged across locations, increased from 27.5 mg Zn/kg for the unfertilized control to 30.9 mg Zn/kg for 5.6 kg Zn/ha, 30.6 mg Zn/kg for 10 kg Zn/ha, and 34.0 mg Zn/kg for 20 kg Zn/ha ($LSD_{0.05}$ = 1.8 mg Zn/kg). The relatively small changes in tissue Zn concentration in response to Zn rate suggest that broadcast Zn fertilizer rates may need to be much higher for Zn-deficient clay soils than rates recommended for Zn-deficient silt and sandy loam soils.

At the eight sites, the mean soil pH ranged from 6.0 to 8.0 and Mehlich-3 Zn ranged from 1.0 to 5.7 mg Zn/kg. Seven of the eight sites had pH >7.0 and Mehlich-3 Zn >2.8 mg/kg. Correlation of routine soil test parameters showed that linear and nonlinear models, including only Mehlich-3 Zn, were not significantly correlated with tissue Zn concentration. A nonlinear model [Zn (mg Zn/kg) = $119.4x - 9.15x^2 - 352.5$, where x = soil pH] for soil pH was significantly and negatively correlated with tissue Zn concentration ($r^2 = 0.5101$). Multiple regression models that included both soil pH and Mehlich-3 Zn failed to improve the correlation above that found for soil pH alone. Additional studies will be conducted to broaden the range of soil chemical properties included in the database before final Zn fertilization recommendations are developed for rice grown on clay soils.

Six Years of Rice Research Verification in Louisiana: Value as an Education and Research Tool

Saichuk, J.K. and Theunissen, S.J.

The Louisiana Rice Research Verification Program (LRRVP) began in 1997 in three parishes: Allen, Calcasieu, and Jefferson Davis. In 1998, the program was funded and expanded to 10 parishes: Acadia, Avoyelles, Calcasieu, East Carroll, Evangeline, Jefferson Davis, Madison, Morehouse, St. Landry, and Vermilion. In 1999, the program was funded again and conducted in 10 parishes with the absence of Morehouse Parish and the addition of Catahoula Parish. Ten parishes were in the program again in 2000, but Madison Parish was discontinued and Morehouse added. In 2001, the 10 parishes included Acadia, Allen, Avoyelles, Calcasieu, Concordia, Evangeline, Jefferson Davis, Richland, St. Landry, and Vermilion. In 2002, Beauregard Parish was added to the same group utilized in 2001. In 2003, Calcasieu Parish was removed and the other parishes in the program remained the same.

The fields were visited on at least a weekly basis by a specialist, county agent, or the extension associate. Production practice recommendations were made by the specialist or agent. These recommendations included, but were not limited to, fertilization, weed control, disease control, insect control, and water management to a limited degree. The fields were followed from planting to harvest.

Yield and economic data were collected for each field. In some fields water use was measured as part of a program spun off from the Verification Program. Economic data continue to reveal large production cost differences, especially in water costs. It is also clear that more needs to be done to help farmers reduce production costs.

The program continues to provide an accurate evaluation of current recommendations and insight into other areas of research. The educational value of the program to all concerned (farmers, researchers, and extension personnel) increases each year.

A 20-Year Summary of the University of Arkansas Rice Research Verification Program

Branson, J.W., Wilson, Jr., C.E., and Windham, T.E.

In the early 1980s, rice yields were declining, prices were low, and production costs were high. The future of the rice industry in Arkansas was much in doubt. Producers requested that the University of Arkansas field test existing technology to determine the profitability of rice production. In 1983, the Cooperative Extension Service initiated the Rice Research Verification Program (RRVP). The program is an interdisciplinary program that stresses intensive management and integrated pest management to maximize returns. The overall goal is to verify that crop management, according to University of Arkansas recommendations, can result in increased profitability. The objectives of the program are to: (1) conduct on-farm field trials to verify research based recommendations, (2) aid researchers in identifying areas of production that require further study, (3) improve or refine existing recommendations that contribute to more profitable production, (4) incorporate data from RRVP into extension educational programs at the county and state level, and (5) provide in-field training to inexperienced county agents in rice production practices.

The RRVP fields and cooperators are selected prior to the beginning of the growing season. Cooperators agree to pay production expenses, provide expense data, and implement university recommendations in a timely manner from planting to harvest. A designated county agent from each county assists the RRVP coordinator in collecting data, scouting the field, and maintaining regular contact with the producer. Management decisions are based utilizing integrated pest management philosophy based on current University of Arkansas research-based recommendations. An advisory committee, consisting of extension specialists and university researchers with rice responsibility, assists in decision-making, development of recommendations, and program direction. Management begins with variety selection and includes all aspects of production, including seeding rates, fertilizer, pest management, irrigation, and harvest. Management decisions were based on field history, soil test results, variety, and data collected from individual fields during the growing season.

Since 1983, the RRVP has been conducted on 210 commercial rice fields in 33 rice-producing counties in Arkansas. Trials have been conducted on 4890 ha (12,083 A), with an average field size of 23.5 ha (58 A). The Arkansas average rice yield over the last 20 years was 6214 kg/ha, while the RRVP average was 7174 kg/ha. On average, RRVP fields have yielded 16% higher than the Arkansas state average. The average herbicide cost of RRVP fields has been lower than the state average herbicide cost. The average total variable cost of RRVP fields has been less than the state average, while net returns were greater. In 2003, the RRVP recorded the highest yields in the history of the program with an average of 8791 kg/ha while production costs are less than the state average. The trends in yields, management decisions, and profit will be discussed.

The Effect of Rotation, Tillage, Fertility, and Variety on Rice Grain Yield and Nutrient Uptake

Anders, M.M., Olk, D.C., Grantham, J., and Holzhauer, J.

Prior to 1996, rice production in Arkansas and across the United States was regulated through government programs that provided price supports that were tied to crop acres. This resulted in a rotation sequence of rice-soybean-soybean over much of the Arkansas rice production area. With passage of the 1996 farm bill, farmers were free to grow as much rice as they wanted. At the same time, world rice prices have fallen and there is mounting concern that the heavy tillage used in much of the Arkansas rice production is contributing to declining water quality in the region. In 1999, a study comparing six rice-based crop rotations was initiated. Within each rotation, conventional- and no-till comparisons were made along with fertility (standard vs enhanced) and two varieties. Of the six rotations represented in the study, this paper will compare results from continuous rice, rice-soybean, and rice-corn rotations. Fertility treatments consisted of a ‘standard’ recommended application of 112 kg N/ha, 45 kg P_2O_5/ha, 67 kg K_2O/ha and an ‘enhanced’ application of 168 kg N/ha, 67 kg P_2O_5/ha, and 101 kg K_2O/ha. Nitrogen was applied as urea onto dry soil when the plants had reached the 4-leaf stage and just prior to flooding. P and K applications were made prior to sowing with the conventional-till disked in and the no-till left on the soil surface.

Rice grain yields from 1999 to 2002, averaged over all treatments, varied between 9,830 and 6900 kg/ha. Fertility treatments were significantly different the first year of the study (1999) when the ‘standard’ fertility treatment averaged 350 kg/ha more than the ‘enhanced’ treatment. These treatments were not significant for the next 3 years. Rotation accounted for most of the differences in grain yield with the continuous rice rotation yielding significantly less than the rice-soybean or rice-corn rotations in 2001 and 2002. Grain yield in the continuous rice treatments declined from 8010 kg/ha in 2000 to 6650 kg/ha in 2002. Grain yields for the no-till treatments were significantly lower than the conventional-till treatments in 2 of 3 years. Variety differences were not significant in any years of the study.

Total soil nitrogen (N) measured at the beginning of the study averaged 823 kg/ha across all plots. Rice N uptake in the aboveground plant parts averaged between 134 and 169 kg/ha. Differences in N uptake were more related to yield than % N in any plant part. N uptake measured using ^{15}N in the continuous rice and rice-soybean rotations in 2002 showed a reduction in fertilizer N uptake in the continuous rice rotation when compared with the conventional-till in the same rotation and no tillage differences in the rice-soybean rotation. For both tillage treatments, fertilizer N uptake was lower in the continuous rice rotation when compared with the rice-soybean rotation. Total N uptake for the continuous rice rotation was 107 and 114 kg/ha for the no-till and conventional-till treatments, respectively, and 145 and 149 kg/ha for the no-till and conventional-till treatments in the rice-soybean rotation, respectively.

Soil phosphorus (P) levels averaged 14 kg P/ha (7:1 KCl extraction ratio) at the beginning of the study. As with N there were no clear differences between treatments in the % P in the grain, leaf, or stem. Total P uptake in the aboveground plant averaged 34 kg/ha with plant biomass accounting for most uptake. Soil P levels indicated a decrease in P in the no-till plots when compared with the conventional-till plots the first 2 years. By 2003, there was an average increase in soil P of 5 kg/ha in the enhanced fertility treatment, regardless of tillage treatment. This increase in soil P was not reflected in grain yield.

Soil potassium (K) levels averaged 180 kg/ha (7:1 KCl extraction ratio) at the beginning of the study. Above-ground K uptake was influenced more by plant biomass than % K in grain, leaf, or stem. For the continuous rice rotation there was an increase in K soil test values for the ‘enhanced’ fertility treatment when compared with the ‘standard’ fertility treatment by 2002. This increase in soil K values was not reflected in increased grain yield.

While there were significant differences in grain yield for the fertility treatment comparison in the first year of the study, there were no significant differences in the following 3 years. Differences in rotation treatments were significant in all 3 years they were compared while tillage treatments were significantly different in 2 of the 3 years. Rotation and tillage treatments appear to affect nutrient uptake more than the fertilizer treatments in this study.

Water and Fertilizer Management Impact on Ratoon Crop Rice

McCauley, G.N., Turner, F.T., Way, M.O., and Vawter, L.J.

Production costs continue to increase and rough rice prices remain constant or decline. For the Texas rice industry to survive and rebound from acreage decline over recent years, it must take advantage of its strengths. The long growing season is a major strength and should be exploited in ratoon crop (RC) production. RC rice has a lower per unit cost as the only inputs are water and fertilizer. Research is desperately needed to better define guidelines on when to pursue a RC and develop an integrated management system to increase and stabilize RC yields. These studies look at the impact of RC water and nitrogen (N) management on RC production. RC N is defined as all N applied after main crop (MC) heading.

Experiment I was conducted from 1986 to 1992 at the Texas A&M University research site near Eagle Lake The plot areas were located on a Nada fsl. The research area was rotated with 1-yr rice and 2-yr fallow. The plot area had been fallow for 2 years prior to the 1986 cropping season. Plots were on the same land area in 1986, 1989, and 1992; 1987 and 1990; and 1988 and 1991. Lemont rice was drill seeded in 30-45x4 m bays on 0.2-m centers at 112 kg/ha on 21 March ± 4 d. The plots consisted of 10 rows. The center eight rows were harvested for MC yield and the center four rows were harvested for RC yields. The strips of rice were mechanically divided into 5 to 8 m subplots. Subplots were separated by 1.3-m alleys. Each of the 30 bays was surrounded by levees for individual irrigation and draining. These areas received standard and uniform management, except for the MC drain time, RC reflood time, and RC N management. Applications of phosphorus and potassium were made based on soil tests. The MC received 190.4 kg N/ha in the MC applied as urea in three applications [25% preplant incorporated, 35% prior to flood establishment, and 40% at panicle differentiation (PD)]. Standard field plot techniques were used and a 10-cm flood was established when the rice reached the 5-leaf stage and was maintained until the prescribed MC drain times.

A split plot design with three replications was utilized. Drain and reflood times were main plots and RC N rate and timing were subplots. Drain times were 15, 20, and 25 d after 5% MC heading. RC was flooded either 1 d after harvest, 10 d after harvest, or flushed and flooded 10 d after harvest. RC N applied pre-MC drain was applied 10 d after 5% heading in the MC which was 5 d before the first scheduled drain. N rates for this application was one third of the total RC N but never more than 37 kg/ha. RC N treatments were 78 or 112 kg/ha applied in one application just prior to RC flood or split with one application prior to MC drain and the remainder applied prior to RC flood, and 168 kg/ha with one application prior to MC drain and remaining N applied equally at preflood and PD. MC and RC yields and milling were monitored using standard techniques.

Experiment II conducted in 2003 with Cocodrie was similar to Experiment I, except for the RC N management. RC N consists of 78 or 112 kg/N applied in one application or split as described above. The splits were either applied prior to MC drain and RC preflood or preflood and RC PD.

Experiment I – Optimum MC and RC yields were obtained with 112 kg/ha of N applied in two splits. Splitting RC N was only beneficial when total RC N exceeded 78 kg/ha. The post MC heading split did increase MC yield but did not increase milling quality. Optimum MC yields were obtained when the MC flood was drained 20 d after 5% MC heading. The RC yield appeared to be more sensitive to the duration of the dry period between the MC drain and RC flood. For yield, the optimum duration was 15 to 25 d. RC whole milled grain was also sensitive to the duration of the dry period and the optimum was 10 to 15 d. Extending the dry period above 15 d reduced the RC whole milled grain by 5 to 8%. Delaying the RC flood after MC harvest reduces the whole milled grain by as much as 6%. For the yields in this study, a reduction of 6% in the whole milled grain would reduce income by $18.82/ha (August, 2003 marketing). This would translate to $3,802 income reduction for a 202-ha rice farm.

The MC and RC yields and RC milling were affected by RC water and N management. Based on the conditions of this study, the optimum water management would be to drain the MC 20 d after 5% heading. The RC should be flooded immediately after MC harvest. This would produce a dry period of 15 d. The optimum RC N management was 37 kg/ha applied 10 d after MC heading and 75 kg/ha applied prior to RC flood.

Experiment II – Initial results were similar to Experiment I.

Fluid Fertilizer Efficiency When Flooding at the 4- or 6-Leaf Growth on Clay Soil in Texas

Turner, F.T., Jund, M.F., Hagler, D.R., and Hebert, M.

Fluid fertilizer appears to offer two potential advantages for improving fertilizer efficiency that apparently have not been tested in southern U.S. flood irrigated rice production. Banding and subsurface placement of fluid fertilizer should provide increased efficiency of urea and ammonium nitrogen (N) fertilizer in flooded rice production because of reduced NH_3 volatilization and denitrification. Our objective was to compare conventionally managed dry granular fertilizer with banded fluid fertilizer. Drill-planted rice was flood irrigated at the 4- or 6-leaf stage on clay soil in Texas. Basic fertilizer treatments consisted of dry urea or liquid fertilizer applied preplant at 168, 118, or 50 kg N/ha. Treatments receiving less than 168 kg N preplant were topdressed with enough urea N at panicle differentiation (PD) to total 168 kg N/ha. These treatments were compared individually and with a 3-way split of urea-N (i.e. 50, 68, and 50 kg N/ha applied preplant, preflood, and PD, respectively). Fluid fertilizer was banded 5 to 10 cm below the soil surface between every other drill row spaced 20 cm apart (i.e. spacing between fertilizer bands was 40 cm so that each fertilizer band supplied two drill rows and seedlings were within 10 cm of a fertilizer band.), phosphorus (P_2O_5) and potassium (K_2O) rates were 50 and 25 kg/ha, respectively. There were at least four replications of each treatment on 1.6 x 5.5 m plots. ‘Cocodrie’ was planted April 15, 2003. Standard cultural practices were used, and treatments were flooded at the 4- or 6-leaf growth stage.

Treatment effects on % N in plant, biomass near PD, and rice yield were measured under two flood irrigation systems (a 10-cm deep flood established at either the 4- or 6-leaf growth stages). Flooding at the 4-leaf stage maximized the efficiency of both fluid and dry N. When measured by % N in plant or N uptake near PD growth stage, banded fluid fertilizer was more efficient than granular preplant, incorporated fertilizer at either floodwater establishment stage. Under a 4-leaf flood, banded fluid fertilized plants contained 1.7% N and 115 kg N/ha compared with dry fertilizer plants containing 1.4% N and 92 kg N/ha. Under a 6-leaf flood, fluid fertilized plants contained 1.6% N and 104 kg N/ha compared with 1.3% N and 74 kg N/ha for plants receiving dry fertilizer.

When rice yield was used as a measure of N fertilizer efficiency and the flood was established at the 6-leaf stage, banded fluid fertilizer applied at 168 kg N/ha yielded about 7000 kg/ha compared with 5900 kg/ha for similar rates of dry, preplant incorporated fertilizer. However, when the same fertilizer treatments were flooded at the 4-leaf stage, both dry and fluid fertilizer yielded about 7700 kg/ha. Had N rates been lower than 168 kg N/ha, the fluid fertilizer would likely have yielded higher than equivalent amounts of dry fertilizer because fluid fertilized plants contained higher % N at the PD growth stage than plants receiving dry fertilizer.

Plants flooded at the 4-leaf stage yielded 500 to 1100 kg/ha more than plants flooded at the 6-leaf stage. The importance of flood establishment time was further illustrated when the 2-way N split (118 kg N @ preflood + 50 kg N @ PD) of dry fertilizer yielded only 6100 kg/ha under 6-leaf flood, but yielded 7600 kg/ha under 4-leaf flood (on par with the highest yielding N treatment). Even plants without fertilizer yielded about 600 kg/ha higher when flooded at the 4- rather than 6-leaf stage.

This study on clay soil illustrates the pronounced effect of N fertilizer placement and flood establishment time on rice yields. Subsurface banding of fluid fertilizer at planting coupled with establishing the flood at the 4-leaf stage optimized yields. These practices also increased N efficiency and production economics by allowing fewer flushes and less herbicide.

Comparison of Growth Characteristics and Competitiveness of Rice Cultivars, Wells, CL161, and XL8 at Reduced Seeding Rates

Ottis, B.V., Malik, M.S., Scherder, E.F., and Talbert, R.E.

New rice cultivars have been released that have yield potential greater than 10,000 kg/ha. However, in order to achieve high yields, it is important to have the proper fertility, seeding rate, and weed control. It is not well understood how these new, high-yielding cultivars respond to varying weed control levels. The most recent research established barnyardgrass threshold levels of 5 to 10 plants/m^2 using older cultivars.

Studies were established in 2002 and 2003 at the Rice Research and Extension Center at Stuttgart, AR, to evaluate the innate competitive abilities of two new rice cultivars and one hybrid at various seeding rates. Representatives from each of the three classes of long-grain rice were selected. ‘Wells’ represented conventional long-grain rice, ‘CL161’ represented semidwarf, imidazolinone-tolerant rice, and ‘XL8’ represented hybrid rice. A randomized complete block design with four replications was used. Treatments were arranged factorially, consisting of three rice cultivars/hybrid, four plant populations (10, 20, 40, and 80 plants/m row), and four levels of barnyardgrass control (25, 50, 75, and 100%). Rice was drill-seeded on 18-cm row spacings.

Weed control was managed with timely herbicide applications in an effort to achieve the above control levels. Barnyardgrass control ratings were taken on weekly intervals. Plant populations were verified by stand counts after rice emergence. Harvest index [(economical yield/biological yield) * 100%] and combine yield from each plot were also collected. Ground cover was evaluated within 100% control plots to determine canopy closure at weekly intervals using a digital camera. Digital images were analyzed using SigmaScan software, which essentially counts the number of green pixels in a digital image in relation to other pixels to estimate canopy coverage. Grain yield was measured and adjusted to 12% moisture prior to analysis. Statistical analysis was done using the PROC REG function in SAS.

Harvest index results from 2002 showed a significant cultivar/hybrid by barnyardgrass control interaction; with barnyardgrass presence in plots having a greater impact on CL161 harvest index than Wells. Results from 2003 indicated that cultivars/hybrid were not significant for harvest index. However, seeding rate and barnyardgrass control were significant, with harvest index increasing with decreasing seeding rates and increasing with increasing barnyardgrass control. Cultivar/hybrid and seeding rate were not significant for yield in 2003, but as barnyardgrass control increased, yield increased in a quadratic fashion. Canopy coverage data from 2003 indicated that XL8 achieves complete canopy closure 1 and 2 weeks prior to CL161 and Wells, respectively. For Wells, canopy coverage decreased significantly at lower seeding rates, while canopy coverage remained constant across seeding rates for CL161 and XL8.

Organic N Sources for Rice in Texas

Jund, M.F., Turner, F.T., and Hagler, D.R.

Recent regulations limiting phosphorus build-up in the soil have caused poultry producers to seek alternative land on which to apply litter removed from poultry houses. In addition, large quantities of municipal sewage sludge are becoming available for use on agricultural land. Possibly, these and other organic materials may serve as nitrogen (N) fertilizer sources. Our objective was to evaluate some of these organic fertilizers as possible N sources for rice production in Texas.

During the 2002 and 2003 growing season, we evaluated three organic N sources under conventional management practices for 'Cocodrie' rice on clay soil near Beaumont, Texas. The organic N sources were: (1) Chicken litter (CL) from East Texas broiler houses with N content of 3.6% in 2002 and 2.2% in 2003, also containing 1 to 2% P_2O_5 and 1% K; (2) Vital Cycle (VC) – a dry, granular, municipal sewage sludge with a nutrient analysis of 3-6-0; (3) Nature Safe (NS) – a pellet material made from animal by-products having a nutrient analysis of 12-2-0. Cost per kg N was $0.66 (or $0.30/lb) to $0.88 (or $0.40/lb) for CL, $0.66 (or $0.30/lb) for VC and $4.40/kg (or $2.00/lb) for NS.

Organic fertilizer application rates were adjusted for moisture and N content. In 2002, applying CL, NS, or urea preplant at rates to provide 90 kg N/ha produced rice yields of 3779, 5787, and 5670 kg/ha. Supplementing organic treatments with an additional 45 kg urea N 7 days after flooding increased rice yield to 4244 and 7653 kg/ha for CL and NS, respectively; while 120 kg urea N/ha applied preplant yielded 6608 kg/ha. Delaying the supplemental 45 kg urea N until panicle differentiation reduced yield to 3950 kg/ha for CL and 6776 kg/ha for NS. When CL was supplemented with NS 7 days after flooding, yield was 5783 kg/ha; however, when NS was delayed until panicle differentiation, yield was reduced to 4456 kg/ha.

In 2003, CL, VC, and NS were applied at N rates of 45 or 90 kg N/ha. Urea N treatments ranging from 34 to 202 kg N/ha were compared with rice yields of organic N treatments. Rice yield was significantly lower across all treatments compared with 2002. Applying organic fertilizer at rates to provide 90 kg N/ha produced rice yields of 2970, 3604, and 2877 kg/ha for CL, NS, and VC respectively, compared with 3860 kg/ha where urea was applied at 101 kg N/ha. By plotting organic fertilizer yield against yield obtained from urea treatments ranging from 34 to 202 kg N/ha, we estimate the urea N equivalent of CL, VC, and NS to be 67, 60, and 88 kg/ha, respectively, when organic fertilizer was applied at a rate calculated to provide 90 kg N/ha. These urea N equivalent data indicate CL, VC, and NS are 74, 67, and 98%, respectively, as effective as preplant urea as an N source for rice plants on clay soil in Texas.

These data indicate that organic fertilizers differ in their ability to supply N to rice plants. NS is apparently mineralized rapidly since it is similar to urea in providing available N to the rice plant. The cost of $4.40/kg N ($2.00/lb) makes it impractical for commercial rice production; however, it may have a place in organic systems. Although VC has produced rice yields similar to urea in other research in 2003, VC produced yields similar to CL. Apparently, all of the N in VC and CL did not become available to the plant during the rice growing season. It should be recognized that although N from CL and VC may not be as available to rice, other benefits such as phosphorus, micronutrients, and added organic matter (OM) should be considered when accessing their value.

To determine if an application of OM would improve yields of the immediate rice crop, 45 kg of organic N/ha as CL, VC, or NS were applied preplant to supplement 202 kg/ha urea N. The OM application rate to achieve 45 kg of organic N was 2900, 750, and 375 kg/ha for CL, VC, and NS, respectively. Organic matter application did not improve rice yield. Urea N with the recommended phosphorus and potassium produced approximately 7000 kg rice/ha with or without OM application.

The Effect of Seeding Date on Kernel Smut of Rice

Boothe, D.L., Slaton, N.A., Norman, R.J., DeLong, R.E., Cartwright, R.D., Wilson, Jr., C.E., and Duren, M.

Kernel smut, *Neovossia horrida* [*Tilletia barclayana* (Bref.)], has reduced rice (*Oryza sativa* L.) grain quality and, to a lesser extent, grain yield in the midsouth rice-producing area for more than 50 years. Because grain yield losses attributed to kernel smut are usually small, research efforts have focused on other diseases that cause greater yield losses. Although environmental conditions are known to influence the incidence and severity of kernel smut, the specific conditions that increase kernel smut are not well defined. Therefore, the objective of this research was to evaluate the effect of seeding date on kernel smut incidence and severity of several cultivars at two locations.

In 2003, seeding date studies were established on a Dewitt silt loam at the Rice Research Extension Center (RREC), near Stuttgart, AR, and on a Sharkey clay soil at the Northeast Research Extension Center (NEREC) at Keiser, AR. Six cultivars, Ahrent, CL161, Cocodrie, Francis, LaGrue, and Wells, were common to all seeding dates at both locations and evaluated for kernel smut. At the RREC, rice was drill seeded at a uniform rate of 110 kg/ha on 1 April, 25 April, and 20 May. At the NEREC, rice was drill seeded at a uniform rate of 125 kg/ha on 18 April, 30 April, 27 May, and 10 June. At the 5-leaf stage, a single application of urea fertilizer (46% N) was broadcast to a dry soil surface and a permanent flood (6 to 10 cm deep) was established within 4 days. The preflood N rate was 135 kg N/ha at the RREC and 168 hg N/ha at the NEREC. No midseason N was applied at either location. About 10 days before each seeding date was harvested, 20 panicles were randomly collected from each plot, placed in a paper bag, and stored at room temperature until evaluated for kernel smut. Rice panicles were submerged in 0.27 M KOH overnight, rinsed three times in water, and then inspected over a light box to identify smutted kernels. Soaking panicles overnight in KOH made the rice hulls translucent, allowing for the identification of partially and completely smutted kernels. The smutted and total kernels on each panicle were counted. The total number of partially and completely smutted kernels on the 20 panicles was summed, divided by the total kernel number, multiplied by 100, and reported as severity or the percentage of the kernels infected with kernel smut. The number of panicles with at least one smutted kernel was summed, divided by 20 (number of panicles evaluated per plot), and multiplied by 100 to determine kernel smut incidence. Each seeding date was arranged as a randomized complete block design with cultivars replicated three (RREC) or four (NEREC) times. Grain yield, kernel smut incidence, and kernel smut severity data were analyzed as a split-plot design where seeding date was the whole plot factor and cultivar was the subplot factor. Locations were analyzed separately because actual seeding dates and environmental conditions differed between locations. The Fisher's Protected Least Significant Difference (LSD) procedure ($p = 0.05$) was used to compare treatment means when appropriate.

Panicle evaluations of only Cocodrie and LaGrue cultivars for all seeding dates and locations have been completed. The two-way interaction between seeding date and cultivar was not significant for kernel smut incidence or severity at either location. At the NEREC, seeding date was the only variable that significantly affected kernel smut incidence and severity. Incidence, averaged across cultivar, was lowest (35%) when rice was seeded on 18 April, increased to 60% for the 30 April seeding, reached a maximum of 81% for the 27 May seeding, and declined numerically to 67% for the 10 June seeding ($LSD0.05 = 25\%$). Incidence behaved similarly with the lowest incidence of 0.50% for the 17 April seeding, intermediate incidences of 1.0% for 30 April, and 1.8% for June 10 seeded rice, and a maximum incidence of 3.0% for the 27 May seeding ($LSD0.05 = 1.3\%$). Seeding date also affected kernel smut incidence and severity at the RREC with trends similar to that described for the NEREC. Incidence was lowest (8%) for rice seeded on 1 April and increased to 34 and 83% for rice seeded on 25 April and 20 May, respectively ($LSD0.05 = 23\%$). However, severity was similar for rice seeded on 1 April (<0.1%) and 25 April (0.4%) but significantly lower than severity for 20 May (2.1%) seeded rice ($LSD0.05 = 0.7\%$). Although not significant at the 5% level, Cocodrie tended to have greater numerical incidence and severity values than LaGrue for all seeding dates and both locations. Data for these two cultivars, which are rated highly susceptible to kernel smut, suggest that kernel smut poses a more significant problem for late-seeded rice than early seeded rice. Data for the remaining four cultivars, for which evaluations are not yet complete, will also be reported and may change the described relationships.

Draining Rice for Harvest

Counce, P.A., Vories, E.D., Popp, M.P., and Siebenmorgen, T.J.

University of Arkansas research indicated that rice irrigation could be ceased earlier than most growers normally practiced without reducing rice grain yield. We conducted a subsequent study to determine the effects of early draining on both rice grain yield and rice milling quality. This research was done at two locations in Arkansas (Stuttgart on a Crowley silt loam and Keiser on a Sharkey silty clay) for 4 years and at Colt, Arkansas, on a Calhoun silt loam soil for 2 years. No rough rice yield reductions or head rice yield reductions were found when rice was drained at 2 weeks after 50% heading compared with 4 weeks after 50% heading. There were reductions in both rough rice yield and head rice yield when rice was drained at 50% heading. Our work done from 1987 through 1990 demonstrated that rice could be drained for harvest 2 weeks after 50% heading without reducing rough rice yield or milling quality. Results from research conducted in Texas yielded similar results. A related economic study indicated water savings from implementing production practices based on these results could reduce water costs by \$56.81/ha (\$23/A) or more in some cases. Even more importantly, if irrigation water was in short supply for soybean irrigation, the increase in total profit permitted by diverting irrigation water from rice to soybeans was substantial. Tillage and land forming costs can be reduced as well. Since our initial study, the rice growth staging system was developed for improved communication of rice research results and production practices. Members of the Arkansas Rice Research and Promotion Board desired to have draining guidelines for rice similar to those available for soybean irrigation. Consequently, we set about to drain rice based on reproductive growth stages R5-R9. Randomized complete block design experiments were conducted in the greenhouse at Stuttgart, Arkansas. Soil was a Dewitt silt loam. Pot volumes were 6 l with a 4-l soil volume. Rice was drained at R5 to R9 for rice with one plant per pot. Draining was accomplished by removing the drain plug from the bottom of the pot and allowing the exit of all gravitational water from the pots. Pots were drained when plants were at R5, R6, R7, R8, and R9 growth stages. Consequently, within a short period after draining (less than 3 days in most cases), there was very little available water. Cypress yields were reduced at the R5 growth stage draining, but the R6, R7, R8, or R9 draining treatments did not differ. Any draining earlier than R9 reduced Guichao yields. Lemont was not reduced when drained at R7 compared with later drain dates. The safe growth stage for draining U.S. rice cultivars was R6 to R7, but Chinese cultivar Guichao was sensitive to early draining. This growth staging/draining research is being continued. Since the effect of draining rice for harvest depends on soil water availability to the rice plants, the ability of the soil to retain water is a critical factor. Arkansas rice producers have successfully adopted these findings to their rice farming operations. In Arkansas, we are currently recommending ceasing irrigation 2 weeks after 50% heading on many rice soils. The results of our studies indicate substantial opportunities for farmers to adapt these results to their farms to save water, tillage, and land forming costs without reducing rice grain yield or milling quality.

Abstracts of Posters on Rice Culture
Panel Chair: J. Oard

Evaluation of Soil Amendments for Increasing Rice Yields on Freshly Graded Ground

Kenty, M.M., Dunn, D.J., and Helms, R.S.

Land leveling is a common occurrence throughout the rice producing areas of the Mississippi River Valley to improve water use. The grade or cut of the land may be as little as a few centimeters to as much as 2 m in extreme situations. It is generally accepted that leveling impacts fertility and will reduce rice yield potential. In an attempt to restore or balance the lost fertility, producers may utilize manure in their fertility program. Although beneficial, manure can be cumbersome to handle, costly due to distance of delivery, and difficult to apply uniformly. This study was conducted to determine if alternatives to chicken litter could enhance rice production.

Experiments were conducted in 2003 at three locations, two in Arkansas and one in Missouri. The locations represented a light cut (MO), intermediate cut (AR1), and a deep cut (AR2). The deep cut was approximately 2 m. Small replicated plots were established in a randomized complete block design at each location with varying rates and combinations of chicken litter, triple super phosphate (TSP) 0-46-0, and a granular organic acid compound (HM9754A) applied preplant. Chicken litter was applied at 1120 or 2240 kg/ha, TSP was applied at 112 kg/ha, and HM9754A was applied at 44.8 kg/ha. A total of 12 treatments, including the untreated check, were evaluated for nutrient uptake, grain yield, and milling quality. Normal agronomic practices were followed throughout the season. At physiological maturity the middle rows were harvested and weighed. The yield data were analyzed across locations using the PROC MIXED procedure.

All treatments improved yields over the untreated check. Yields for the low and high rate of chicken litter, TSP, and HM9754A were 945, 753, 668, and 981 kg/ha, respectively, more than the untreated check of 6761 kg/ha. The combination of chicken litter at 2240 kg/ha + TSP at 112 kg/ha + HM9754A at 44.8 kg/ha provided the greatest improvement in yield at 7981 kg/ha. This research indicates that soil amendments such as TSP and HM9754A used alone or in combination with chicken litter can be utilized on freshly cut ground to improve rice yields.

Effects of Rotation and Tillage on Soil Strength, Aggregate Stability, Water Retention and Use, and Runoff in Rice Production Systems

Anders, M.M., Daniel, T.C., Olk, D.C., Grantham, J., and Holzhauer, J.

Conservation tillage has been widely adopted into existing crop rotations in some areas of the United States. This has not been the case with rice production systems through much of the Mississippi Alluvial Valley (MAV) area. There are numerous reasons for this, one of which is a lack of knowledge on the effect of adopting no-till agriculture into a crop rotation that includes rice; a crop that traditionally is grown after extensive tillage. Farmers' growing rice in the MAV are aware that soil quality has declined over the years and that they are being asked to address issues of soil, air, and water quality. If there is a move to more reduced tillage rice production systems, it must be preceded by a firm understanding of what impact conservation tillage will have on grain yields, profitability, and resource quality. The lack of such information prompted the initiation of a long-term study in 1999 that contains six rice-based rotations that compare conventional-till and no-till.

The study was initiated in 1999 at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. The soil at the experimental site was a Stuttgart silt loam (fine, smectitic, thermic Albaqultic Hapludolf). The study also contained variety and fertility treatment comparisons within each rotation and tillage combination. Data will be presented for the following rotations: 1) continuous rice, 2) rice-soybean, and 3) rice-corn. Soil strength measurements were completed in March of 2002 and 2003. Water retention data were collected at the same time soil strength was measured in 2003. Soil moisture above and below the plow layer was measured on selective crops in 2000. Aggregate stability samples were collected from the continuous rice and rice-soybean rotations in 2003. Runoff data were collected in 2003.

No-till reduced soil resistance for a period of 4 years as much as 2000 KPa in the 6 to 25 cm soil profile depth for the continuous rice rotation. At the same time, there was a small increase in soil moisture (%) through the top 35 cm of the soil profile. There was a significant decrease in soil resistance in the no-till plots compared with the conventional-till plots through the 10- to 40-cm profile depth when the previous crop was soybeans in a rice-soybean rotation. This difference was less following rice in the same rotation. Soil moisture (%) values for the no-till treatment in the rice-soybean rotation were continuously, but not significantly, higher. Soil resistance in the rice-corn rotation was greater in the no-till treatment compared with the conventional-till treatment following corn while there was an improvement in the 10- to 20-cm profile following rice. Including soybeans in a rice rotation under no-till conditions reduced soil compaction when compared with continuous rice or corn-rice.

Water content (%) data collected on conventional- and no-till corn during the growing season showed different patterns. Water content values above and below the clay pan for the no-till treatment followed a similar pattern throughout the season. Water content values below the clay pan in the conventional-till treatment were above 0.4% much of the season while those above the clay pan were as low as 0.3%; a value seldom found in the no-till treatment. These results suggest uniform water extraction took place in the no-till plots while water was removed primarily from above the plow layer in the conventional-till plots. The same relationships between conventional- and no-till water content were found in soybeans following rice. Water content below the clay pan area was consistently lower in the no-till treatment while values above the clay pan were higher in the conventional-till treatment.

Soil aggregation is a general test of soil quality. Samples taken from the conventional- and no-till continuous rice and rice-soybean rotations in 2003 showed an increase of 2.9% in aggregates from 0.25 to 4.00 mm in the no-till rice-soybean rotation over the conventional-till treatment in the same rotation. For the continuous rice rotation, the increase was 2.4%. Beginning values for the two rotations were 9.27 and 8.44% compared with a 55% value from a native prairie area.

Runoff quantity and quality measurements carried out in 2003 showed that the runoff volume, regardless of tillage or rotation, was nearly 70%. No-till produced 10 times less erosion than conventional-till across three rotations. No-till produced 17 times less turbidity than conventional-till and reduced total phosphorus in runoff by 40%. These data indicate the potential of no-till to improve water and soil quality in rice production systems.

The Effect of Seeding Date on Rice Variety Yields in Missouri

Beighley, D., Dickens, C., and Beck, B.

Rice planting in southeast Missouri has historically occurred in the period between mid-April and the first week of May. In this region, there is a wide range of varieties grown that represent very short season types (Cocodrie) to medium-season types (Drew). They are usually planted as the weather and field conditions permit. However, the planting date may vary from year to year based on the weather conditions during that period of the year. Very little information is available concerning varietal performance when planted at different dates either earlier (before April 15) or later than May 10 up until after wheat harvest is completed in mid-June. Preliminary data indicate that planting as early as April 1 can result in higher yields than obtained when planting at the traditional optimum planting of mid-April to early-May.

Nitrogen Uptake and Loss when Agrotain, Ammonium Sulfate, and Urea are Applied Preflood to Rice

Bushong, J.T., Ross, W.J., Griggs, B.R., Boothe, D.L., Norman, R.J., Wilson, Jr., C.E., and Slaton, N.A.

Urea is the primary nitrogen (N) source used in the delayed flood rice cultural system. Urea has many fine qualities, but it also has an undesirable characteristic in that it is prone to ammonia volatilization losses if not soil incorporated within a couple of days after surface application. In the delayed flood system, the floodwater is used to incorporate the large, preflood N fertilizer application. Many farmers cannot get the floodwater across their fields within a few days following preflood N fertilizer application. When a farmer cannot flood timely after N application, might it be better to use an N source that is not so easily prone to ammonia volatilization losses? Ammonium sulfate is much less prone to ammonia volatilization losses compared were urea. Urease inhibitors have been promoted as a means to significantly slow ammonia volatilization losses from urea fertilizer. Agrotain is a urea fertilizer that contains the urease inhibitor NBPT and may potentially be another ammonium fertilizer that can be used when a flood cannot be applied timely. Some have also questioned if a mixture of ammonium sulfate and urea helps to reduce ammonia volatilization losses. In light of these questions, the objectives of this study were to determine the influence of ammonium sulfate, Agrotain, urea, and a mixture of ammonium sulfate and urea on ammonia volatilization losses and grain yield of drill-seeded, delayed flood rice.

The study was conducted in 2002 and 2003 at the University of Arkansas Pine Tree Branch Experiment Station on a Calloway silt loam (Glossaquic Fragiudalfs) having a soil pH between 7.0 to 7.5 at the time of measurement. The treatments were arranged as a randomized complete block design, with a factorial arrangement of 4 (N source) x 3 (rate) x 3 (application time) and four replications. Fertilizer N sources were: i) urea, ii) Agrotain, iii) ammonium sulfate, and iv) ammonium sulfate + urea. The ammonium sulfate blend with urea was a 1:1 blend on an N weight basis. Fertilizer N rates were 0, 67, and 134 kg N/ha. The application times for the preflood N fertilizer were: i) 10 days prior to flooding, ii) 5 days prior to flooding, and iii) 1day prior to flooding. All N fertilizer applications were applied to the dry soil surface with no incorporation. The rice was grown upland until the 4- to 5-leaf growth stage and then a permanent flood was applied and maintained until maturity. At maturity, the plots were harvested with a small plot combine. Ammonia volatilization of the different N sources applied to the soil was determined by applying 134 kg N/ha to chambers 10 days prior flooding and ammonia volatilization was measured 2, 5, 10 (flood), 15, and 20 days after application. Statistical analyses were performed on grain yield and ammonia volatilization data with SAS and mean separations were based upon Fisher's protected LSD where appropriate.

Over 20 and 15% of the urea N, only 5 and 3% of the ammonium sulfate N, and only 3 and 2% of the Agrotain-N was lost via ammonia volatilization within 5 days of application in 2002 and 2003, respectively. By 10 days after application and time of flooding, the losses from ammonia volatilization where leveling off at about 25 and 17% for the urea, 10 and 4% for the Agrotain and 5 and 3% for the ammonium sulfate in 2002 and 2003, respectively. The ammonium sulfate losses from ammonia volatilization at 10 days were not significantly different from those measured at 5 days or at 15 or 20 days after application. By 10 days after application and the time of flooding, ammonia volatilization ceased from all of the N sources. When ammonium sulfate was blended with urea, the ammonia volatilization losses were about 13 and 10% at 5 days after application and about 15 and 11% at 10, 15, and 20 days after application in 2002 and 2003, respectively. Therefore, the ammonia volatilization from the ammonium sulfate + urea blend was greater than the urea and less than ammonium sulfate. Rice grain yields increased as N fertilizer rate increased for all N sources at each application time. There was no significant difference in rice grain yield among N sources when applied 1 day before flooding at either N application rate in 2002 and 2003. As N application time prior to flooding increased to 5 and then 10 days, the similarities and differences in grain yields between N sources became apparent. Application of Agrotain and ammonium sulfate produced the highest grain yields, which were quite similar and were significantly higher than those produced with urea when flooding was delayed for 5 and 10 days in both years. Rice grain yields did not decline or declined only slightly as application time before flooding increased to 5 and 10 days when Agrotain or ammonium sulfate were applied in either year. Ammonium sulfate + urea and especially urea displayed a significant grain yield decline as the time between N fertilizer application and flooding was increased to 5 and 10 days in both years. Application of ammonium sulfate + urea resulted in rice grain yields that were slightly lower in 2002 and significantly lower in 2003 than those produced by application of ammonium sulfate and Agrotain 5 days before flooding. When the flood was delayed for 10 days, ammonium sulfate + urea had significantly lower grain yields than those produced with Agrotain and ammonium sulfate but higher than those produced with urea alone. Thus, application of urea resulted in the lowest grain yields when applied at 5 and 10 days prior to flooding in both years.

Using a Cardy Meter to Determine Rice Potassium Status at Midseason

Dunn, D.J., Stevens, W.E., Kenty, M., and Beighley, D.

The increased cost of rice production paired with low commodity prices necessitates more efficient nutrient management for the crop. The ability to monitor nutrient levels throughout the growing season is critical. This allows detected deficiencies to be corrected on a timely basis and improves the possibility of achieving optimal yields. Plant tissue analysis is available to the producer from university and independent labs. A common problem of traditional lab analysis is the time lag between sample collection and results returned to the crop advisor. Sampling and conducting the tissue analysis the same day can eliminate this time lag.

One method of same day analyses is the Cardy portable electrode-based ion meters (Horiba, Ltd., Kyoto, Japan). The Cardy potassium (K) ion meter offers crop advisors the ability to quickly evaluate crop K levels. Cardy meters have been widely used in vegetable production with NO_3-N and K thresholds established for several crops.

This study evaluates the Cardy meter as a tool for determining in-season rice plant K status. Plots with one of three levels of K fertilization were established. Three times during the growing season tissue samples were collected from each plot. These times were internode elongation (IE), IE + 7 days, and IE + 14 days. These tissue samples were then analyzed for K content by two different methods. Approximately 30 cm of row from each plot were collected. The aboveground portion of this sample was separated from the roots using a garden pruning shear. The remaining portion of the lower stem was washed of soil and algae using tap water. The basal 10 cm of the plants were separated from the leaves and retained for analysis. These stem sections were dried with paper towels. Half the stems were then placed oriented up and the other half oriented down. Five cm from each sample were cut into 1-cm pieces. These pieces were frozen over night and sap was extracted using a sap press. The extracted sap was then analyzed for K content using the Cardy meter. The remaining 5 cm of sample were dried and ground, digested using H_2SO_4 and H_2O_2. The results of these two analyses were then compared.

It was difficult to extract sap from the rice stems. At growth stages before IE, there was not enough stem tissue available to extract the sap. As the sampling occurred after establishment of a permanent flood several problems were encountered. Algae were sometimes present on the basal stem. Washing with tap water was necessary to remove the algae. Drying of the stems with paper towels was then necessary to remove the tap water. If the water was not removed before sap extraction the Cardy meter determinations were quite variable. Freezing the stems overnight served to rupture the cell walls within the stems and allow more sap to be extracted.

The Cardy meter determinations were well correlated with traditional lab K analysis, with an r^2 value of 0.66.

N, P, and K Fertilization of Water-Seeded Rice in Missouri

Dunn, D.J., Stevens, W.E., and Beighley, D.

Approximately 8,000 ha of water-seeded rice are cultivated each year in southeast Missouri. This represents 7 to 10% of the total rice acreage in Missouri. In this production system, pre-germinated rice seeds are aerially seeded into established floodwater. The University of Missouri currently does not supply soil test recommendation specific for water-seeded rice. Instead, soil test recommendations for drill-seeded rice are used. Yields for water-seeded are generally lower than for the same rice varieties grow in a drill-seeded system. A series of soil fertility evaluations was undertaken to determine if soil test recommendations needed to be modified for a water-seeded production system. We found that the optimum nitrogen (N) rate for drill-seeded rice is usually appropriate (using the same cultivar) for water-seeded rice. However, the efficiency of N in water-seeded rice is affected by timing. In fields with no history of algal blooms, applying most of the N preflood produced the highest yields. Fields with continuous water-seeded rice often have some algae in the floodwater. Applying preflood N significantly increased algal blooms. Algae reduced rice stands as much as 50% in our tests. The soil test used to determine P levels in Missouri is the Bray 1 method. Results are expressed in lb P/A. Phosphorus recommendations are based on a target level of 15 mg P/kg for rice production. A rice crop will remove 0.34 kg of P_2O_5/ha. To account for this loss, a crop removal factor is included for soils testing between 15 and 23 mg P/kg. Recommendations are given in lb P_2O_5/A. An evaluation of P rates for water-seeded rice was conducted on a Crowley silt loam soil. This soil tested 18 mg P/kg and was not expected to respond to P fertilization. Grain yields were maximized with a 56 kg P_2O_5/ha fertilizer rate. The soil test used to determine K levels is an extraction with neutral, 1 N ammonium acetate. Results are expressed in lb K/A. Potassium recommendations are based on a target level of 63 + 5 X CEC. For silt loam soils this is about 95 mg K/kg. For clay (gumbo) soils, this number is about 200 mg K/kg. Rice yields have been found to drop off quickly when a soil test is below these levels. For low testing soils, a factor for building the soil to maximum productive levels is included in the fertilizer recommendation. The current recommendation package allows the producer to choose how quickly to build soil K levels. A rice crop removes 0.22 kg K_2O/ha. A crop removal factor is included to account for this. Recommendations are given in lb K_2O/A. An evaluation of K rates for water-seeded rice was conducted on a Crowley silt loam soil. This soil tested 95 mg K/kg and was not expected to respond to K fertilization. All levels of K fertilization numerically increased grain yields. However, additions of K did not significantly affect rice grain yields.

An Analysis of the Relationship between Soil Variations and Yield

Greenwalt, A., Jayroe, C., and Baker, B.

Soil variation can be a direct source of yield differences due to the diverse ratios of sand, silt, and clay. These differences affect the water holding capacity, nutrient leaching, and plant root stability in soils. For this analysis, electrical conductivity was observed over several Arkansas rice and soybean fields with a Veris $EC_{a.}$ A final analysis was made with yield data and correlations were based on developed interpolations developed from each data layer in a GIS. Correlations between yield and EC_a measurements were more significant with soybean yield than rice. However, in fields that had been precision leveled, patterns were distinguishable in both. Special attention will be directed to areas where “cuts” have been made and alternatives are being considered where severe yield reductions are a result.

Comparison and Evaluation of Phosphorus Soil Test Methods for Predicting P Availability under Flooded Conditions

Xia, Y., Wilson, Jr., C.E., Norman, R.J., Slaton, N.A., Miller, D., Frizzell, D.L., Boothe, D.L., and Branson, J.W.

Routine soil-test methods for phosphorus (P) were developed for making P fertilizer recommendations to upland crops using air- or oven-dried soil samples. These methods may not provide satisfactory indices of P availability for flood-irrigated rice (*Oryza sativa,* L.) because available P usually increases under flooded conditions. Despite their limited ability to predict rice response to P fertilization, routine soil test P methods are still being used to assess soil P availability for flood-irrigated rice by testing available P in air- or oven-dried soil samples. The objective of this study was to compare chemical P extraction methods with the ion-exchange resin capsule method for predicting P availability of flooded soils.

A total of 110 soil samples with a range of soil pH (4.9 to 8.4) and soil test P concentrations (4 to 86 mg/kg) were selected and required to have a history of rice production and be silt or sandy loams. All the soils were oven-dried at 66^{o}C, crushed, and passed through a 2-mm sieve when submitted to the soil test laboratory. For this study, the soils were separated into four groups according to soil pH: 1) pH < 6.0; 2) 6 ≤ pH ≤ 6.5; 3) 6.5 < pH ≤ 7; and 4) pH > 7.0. Also, soils were separated into three groups according to Mehlich-3 extractable Ca^{2+}: 1) <1000 mg/kg, 2) 1000-1500 mg/kg, and 3) >1500 mg/kg arbitrarily.

Resin-sorbed P was used as an index of plant P uptake in this study because of the good correlation of resin-sorbed P with plant P uptake in previous studies. Relationships of soil-extractable P determined by six extractants (Mehlich-3, Bray-1, Bray-2, Olsen, Lancaster, and modified Morgan) to resin-sorbed P were determined on 110 silt loam soil samples. Resin-sorbed P after 4 d of flooding was regarded as readily available P, and the resin-sorbed P after 7, 14, and 21 d of flooding was regarded as slowly available P.

There were statistically significant differences among the six soil extractants for P. Linear regression of the resin-sorbed P and the amount of soil P extracted by the six chemical methods showed that none of the six chemical methods could accurately predict the readily available P, although the Mehlich-3 method was slightly better than other methods. Combining soil test P with soil pH improved the predictability of the readily available P. For soils with pH > 6.0, Mehlich-3 and Bray-1 were better than other methods; soils with pH < 6.0, the Lancaster method was the best, but was not acceptable. Mehlich-3 and Bray-1 extractable P were highly related with readily available P on soils with pH > 6.0. The slowly available P during prolonged flooding greatly affected the predictability of the six P soil test methods. Available P determined by the selected soil test methods in combination with soil pH needs to be calibrated by plant growth parameters to establish critical thresholds for developing P fertilizer recommendations.

Methane Emission from a Flooded Rice Field with High Residual Organic Matter

Kongchum, M., Hudnall, W.H., Bollich, P.K., DeLaune, R.D., and Lindau, C.D.

Excessive residual plant material can reduce the survival of young rice plants. Under anoxia condition, the decomposition processes enhance organic acid production and soil reduction. Both the organic acids and strongly reducing soil conditions are unfavorable for rice seedlings. This study was conducted to determine if draining can increase the establishment of rice plants and to quantify methane emission among different rates of straw incorporation. A 2 x 5 factorial experiment was arranged in a split plot design with two water management practices as main plot treatments (continuously flooded, and alternately flooded and drained), five rates of rice straw incorporation as subplot treatment (0, 3, 6, 12, and 24 t/ha), with four replications. The experiment was established on a Crowley silt loam (Typic Albaqualfs) at the LSU AgCenter's Rice Research Station in Crowley, Louisiana. Rice straw was incorporated into 2.1 x 6 m plots. N, P, and K were applied at the rates of 180, 75, and 75 kg/ha, respectively. Platinum and pH electrodes were placed in the soil at a 10-cm depth. Redox and pH data were recorded hourly from plot establishment until harvesting via data loggers. Pregerminated seeds of Cocodrie variety were sown at the rate of 153 kg/ha.

Methane emission was measured at nine different growth stages from three replications. Plant height and density were recorded at five different times. Rice grain yield was obtained from both 0.5 m^2 and whole plot harvesting. Soil redox potential of the alternately flooded and drained treatment after draining was slightly higher than that of the continuously flooded treatment. Soil pH of the alternately flooded and drained treatment fluctuated less (5.2-5.6) after draining than the continuously flooded treatment (5.0-6.2). Plant height in the alternately flooded and drained plots (78 cm) was greater than the continuously flooded (60 cm) plots ($p < 0.05$). Dry matter and grain yield of the alternately flooded and drained treatment was greater than that of the continuously flooded treatment ($p < 0.05$). Rice straw was related to both dry matter and grain yield ($p < 0.05$) but was not significantly different within the alternately flooded and drained treatment ($p > 0.05$). Methane emission was highly related to the rate of rice straw incorporation for both water management treatments ($p < 0.01$). The highest straw incorporation rate (24 t/ha) of the alternately flooded and drained treatment had 55% less methane emission than the continuously flooded treatment.

A Comparison of Clearfield and Conventional Rice Varieties in Commercial Fields

Saichuk, J.K. and Theunissen, S.J.

A study similar to the current Louisiana Rice Research Verification Program (LRRVP) was undertaken to compare performance of and economics associated with the Clearfield rice production system with that of conventional rice production in Louisiana.

In south Louisiana, Acadia Parish specifically, the comparison was between a water-seeded field of Cocodrie and a drill seeded field of CL161. It was felt this comparison was a fair representation of the two scenarios most likely to be encountered in south Louisiana. In north central Louisiana, Concordia Parish, the comparison was between the same varieties, but both were drill seeded as is typical for that area of the state.

In Acadia Parish both the Cocodrie field and the CL161 field were second cropped resulting in outstanding yields in both fields. Interestingly, the Cocodrie field produced the highest first crop yield while the CL161 field produced the highest ratoon crop yield. It cost about $35/A more to grow CL161 than it did Cocodrie and about $.47/cwt more for CL161 than Cocodrie. When these costs were combined with the 292 lb/A higher yield of Cocodrie, there was a $58.73/A higher return with Cocodrie.

In Concordia Parish, where no ratoon crop was attempted, CL161 yielded 209 lb/A more than Cocodrie. Costs were $29.80/A higher with CL161 than Cocodrie, but only $.28/cwt higher with CL161 than Cocodrie. Returns on variable costs were $14.13 higher with Cocodrie than CL161.

When yield and variable costs were averaged for each variety Cocodrie produced 41 lb/A more than CL161. Considering the acreage involved and the lack of replications similar to small plot research, this figure represents no difference in yield between the two varieties. Cocodrie did return $33.32/A or $.37/cwt more than CL 161 for an increase in return over variable costs per acre of $36.43.

The information gathered from this study indicates it is more expensive to grow CL161 than Cocodrie, but it does not measure the value of red rice control. The difference in premiums was not taken into account in the prices used to calculate returns.

The general conclusion is that Clearfield rice is an excellent choice when red rice is a problem; however, until varieties with more competitive yields are available, it might not be as profitable in fields where red rice pressure is minimal or can be managed through more traditional means. Where red rice pressure is serious, Clearfield rice clearly offers distinct advantages to rice growers.

Nitrogen Management in Water-Seeded Rice in a Field with Algae Infestation

Stevens, W.E., Sheckell, P.A., Dunn, D.J., and Beighley, D.

Algal blooms are a major problem for water-seeded rice production in southeast Missouri. Large masses of *Ulothrix* and *Chlamydomonas* floating on the water surface of flooded fields inhibit rice seedling emergence through the water. An extension survey conducted in 1999 showed that only 13% of water-seeded rice fields received preflood nitrogen (N). The general consensus among farmers is that N promotes algae growth and increases the potential for blooms at planting. In 2002, we began a series of greenhouse and field experiments to study the effects of N management on water-seeded rice stand establishment and yield. In a greenhouse experiment, soil was collected from two southeast Missouri rice fields with histories of algal blooms. The bottoms of glass tanks (0.14 m^2 each) were filled 8 cm deep with a loam soil and a clay soil from the fields. Treatments were no preflood N (check) and the equivalent of 100 kg N/ha (urea) applied before flooding with 5 cm of water. Treatments were replicated four times with each soil. Pre-germinated rice seeds were broadcast into the flood at a rate of 540 seeds/m^2. Two weeks after seeding, each tank was visually rated for percent algae on the water surface and number of rice plants that had emerged with at least one leaf above the water. More algae growth was found in tanks with the loam soil than the clay soil. Applying preflood N significantly increased algal blooms for both soils. Algae reduced rice stands as much as 50% in tanks with heavy algal blooms. Regression analysis showed a strong negative correlation (R^2=0.87) between percent algae on the water surface and emerged rice plants/m^2. A field study on a clay soil conducted in 1996 and 1997 showed the optimum timing for applying the first N application on water-seeded rice was 30 to 40 days after seeding. A second field study was initiated in 2002 to further study the effect of N rates and timing on water-seeded rice stand establishment. Rice fields at Portageville and Glennonville, Missouri, were water-seeded with pre-germinated Cocodrie rice seeds. A factorial arrangement with three N rates combined with six different fertilizer application timings was used. Total N rates were 125, 168, and 210 kg/ha for the season. Fertilizer timings were (1) all preflood before planting, (2) preflood + two 34 kg/ha at midseason in 7-day intervals, (3) seedling emergence from flood + two 34 kg/ha at midseason, (4) first tiller + two 34 kg/ha at midseason, (5) three even splits beginning at first tiller in 7-day intervals, and (6) four even splits beginning at first tiller. An algal bloom occurred in plots at Portageville after the rice was planted. Rice seedlings in plots with heavy algae growth were matted and many plants did not emerge above the water surface. Stand counts at first tiller showed that treatments with preflood N had reduced stands compared with other treatments. No algae growth was found in the field at Glennonville. At this location, treatments with preflood N applications yielded higher than delayed N treatments.

Seeding Rate Evaluations for Cocodrie, Francis, Priscilla, Wells, and Cheniere on an Alligator Clay Soil

Walker, T.W. and Street, J.E.

The commonly grown rice (*Oryza sativa* L.) cultivars in Mississippi for 2003 have 1000-seed weights that range from 21.9 to 27.1 g. In addition, much of the new technology that enters the market is increasing and will continue to increase seed costs. Therefore it is essential that we refine seeding rate recommendations based on a target plant population as opposed to planting seed based on weight, i.e., kg/ha. Currently, the Mississippi State University Extension Service recommends that a target plant population of 130 to 215 plants/m^2 will produce satisfactory yields.

A seeding rate experiment was conducted on a production field in 2003. The soil type was an Alligator (Very-fine, smectitic, thermic Chromic Dystraquerts) clay soil. Five cultivars (Cocodrie, Francis, Priscilla, Wells, and Cheniere) were drill seeded into a stale seedbed with a cone planter at five seeding rates (22.4, 44.8, 67.2, 89.6, and 112.0 kg/ha). The row spacing was 20.3 cm. Stand counts were determined from 0.9-m of row when rice reached the 3- to 4-leaf stage. Four center rows of rice were harvested with a Kubota plot combine. Rice grain yields were adjusted to a moisture content of 120 g/kg. Separate tests were conducted for each cultivar and each test was arranged as a randomized complete block design with four replications. Analysis of variance procedures for yields and plant populations were conducted with the PROC GLM procedure in SAS. Trend analyses were conducted by using orthogonal contrasts. Means were separated using Fisher's LSD at the 0.05 level of significance.

A seeding rate of 44.8 kg/ha provided a plant population of 242.1, 235.4, 185.6, and 205.8 plants/m^2 for Cocodrie, Francis, Priscilla, and Cheniere, respectively, which were within or just above the current plant population recommendation. The recommended plant population was reached with a seeding rate of 22.4 kg/ha for Wells (133.2 plants/m^2). No differences in yields were detected among treatments for any cultivars; however, there were some apparent trends. Cocodrie yields tended to increase with increasing seeding rate and reached a maximum yield of 11,034 kg/ha. Priscilla yields increased from the lowest seeding rate to the 89.6 kg/ha seeding rate, but then decreased at the highest seeding rate. Wells yields increased from the lowest seeding rate to the 67.2 kg/ha seeding rate (10,258 kg/ha) but then decreased as the seeding rate continued to increase. Cheniere yields increased from the 22.4 and 44.8 kg/ha seeding rate but then decreased as the seeding rate increased. Although Francis yields tended to increase with increasing seeding rate, lodging also increased with increasing seeding rate. These preliminary data suggest that seeding rates should consider seed size and the target plant population; however, conclusions will not be made until further data are collected.

Tolerance of Seedling Rice to Simulated Hail Injury

Wilson, Jr., C.E., Norman, R.J., Slaton, N.A., Frizzell, D.L., Boothe, D.L., and Branson, J.W.

Hail injury can cause significant yield loss to several crops when it occurs during specific growth stages. In previous research conducted in Arkansas, rice (*Oryza sativa*, L.) susceptibility to hail injury has been shown to be significant when the crop reaches the reproductive growth stage. As the flag leaves and panicles are damaged, resulting yield losses can be 10 to 15%. However, injury during the seedling growth stage was not found to significantly reduce yields. Crop insurance is available to producers to protect them against losses due to hail storms. However, it is an expense that producers must weigh against the probability of experiencing hail injury. Recently, questions have been raised by producers, insurance adjusters, and other officials on the potential yield loss from hail injury at seedling growth stages. Therefore, this study was conducted to evaluate the influence of simulated hail injury to four rice cultivars at two seedling growth stages on tiller production and grain yield.

The study was conducted during 2001, 2002, and 2003 at the Southeast Research and Extension Center near Rohwer, AR, on Perry clay (very fine, smectitic, thermic Chromic Epiaquerts). Four rice cultivars were seeded at the recommended rate of 430 seeds/m^2 into four rows that were 15 cm apart and 4.88 m long. The cultivars 'Bengal,' 'Cocodrie,' 'Drew,' and 'Wells' were evaluated in 2001 and 2002. In 2003, 'Francis' was substituted for Drew. Nitrogen fertilizer was applied at a rate of 168 kg N/ha as urea on June 24 immediately prior to the permanent flood.

To simulate hail injury, plots were defoliated at four levels by removing a portion of the aboveground tissue (0, 33, 66, and 100%). For the 33 and 66% defoliation rates, the aboveground tissue was removed by removing 2.5 or 5 cm for each 7.5 cm row. Defoliation was performed at either 2 wk after emergence (2-leaf growth stage) or 4 wk after emergence (4- to 5-leaf growth stage). All of the plant material removed from each plot was dried at 65°C to constant moisture and weighed. Tiller counts were made 1 and 14 d after the first defoliation and 14 d after the second defoliation. Grain yields were determined by harvesting a 3.66 m section of the two center rows at maturity and adjusted to moisture content 120 g/kg. The experiment was a randomized complete block design with a factorial arrangement of cultivars (four levels), defoliation rates (four levels), and defoliation dates (two levels).

Results from this study suggest that simulated hail to seedling rice may have no negative effects on grain yields. Grain yields were not significantly different among any defoliation treatments in 2001 or 2003. In 2001, grain yields averaged 10,382, 10,534, 10,332, and 9979 kg/ha for the 0, 33, 66, and 100% defoliation levels, respectively. Similarly, grain yields averaged 9067, 9077, 8785, and 8649 kg/ha for the 0, 33, 66, and 100% defoliation levels, respectively. Although 100% of the above-ground dry matter was removed, the rice cultivars in this study demonstrated an incredible ability to tiller and recover. In contrast, yields were reduced by an average of 16% at the 100% defoliation rate. Of the four cultivars, yields of Drew were most severely affected, with a 31% decrease in yields. Cocodrie was least affected with only 9% reduction in yields at the 100% defoliation rate.

Tiller counts immediately following defoliation were approximately 160, 108, 54, and 0 tillers/m^2. However, 2 weeks later, all treatments had tiller counts that were approximately 450 tillers/m^2. These data suggest that rice can withstand a significant amount of defoliation at the seedling growth stage due to hail without significant yield losses.

The results obtained in 2002 contrast greatly with those obtained in 2001 but are similar to 2003. During the spring of 2002, the weather was unusually cool and rice did not grow or develop normally. Similarly, in 2003, heavy rainfall and cool temperatures delayed recovery. It is important to note that the simulated injury in this study did not appreciably affect the growing point. As long as the growing point, which is usually below the soil surface, is not disturbed, rice can recover from this type of injury. However, further studies are needed to evaluate the influence of removing rice below the growing point on its ability to recover. Rice can be grown successfully with thin stands (54 plants/m^2) as long as the stand is uniform. More research is needed to determine ways of determining the potential loss from unevenly thinned stands.

The California Statewide Rice Variety Testing Program

Wennig, R L., Hill, J.E., Mutters, R.G., Williams, J.F., Canevari, W.M., Greer, C.A.,
Jodari, F., Johnson, C.W., and McKenzie, K.S.

The statewide rice variety testing program is a cooperative effort involving the University of California Cooperative Extension, University of California Davis, California Cooperative Rice Research Foundation, and the United States Department of Agriculture. The program compares advanced breeding lines with commercially available rice varieties and evaluates advanced breeding lines to determine their adaptation to the principal rice growing areas of California. Twenty-two rice variety evaluation tests are conducted in seven of the nine rice growing counties in the Sacramento and San Joaquin Valleys annually. Entries in the tests included lines and varieties developed by the California Cooperative Rice Research Foundation rice breeders at the Rice Experiment Station, Biggs, CA, as well as a limited number of proprietary cultivars. Pregerminated seed is hand sown into the water at a planting rate of 161 kg/ha (144 lb/A). Seedling vigor, days to 50% heading, plant height, lodging at harvest, grain moisture at harvest, and grain yield at 14% moisture are measured at each location. This program has participated in the development of 37 improved rice varieties since the accelerated research program supported by the California rice grower's check-off began in 1969. Greater than 90% of the California rice acreage in 2003 was planted to public varieties. The program is partially funded by the Rice Research Board and supported by cooperating growers who provide on-site management and field support.

Abstracts of Papers on Rice Weed Control and Growth Regulation
Panel Chair: B.J. Williams and E.P. Webster

The Effect of Flooding Time on Red Rice Control with Newpath Applied at Different Rice Stages

Avila, L.A., McCauley, G.N., Senseman, S.A., Chandler, J.M., and O'Barr, J.H.

Newpath (active ingredient imazethapyr) is a new tool to control red rice in commercial rice production. It can provide good control of red rice, but water management may also affect red rice control when using this material. Field studies were conducted at the Texas Agricultural Experiment Station (TAES), near Beaumont, in 2002 and 2003 to evaluate the timing of flood establishment on red rice control with imazethapyr applied at different rice stages. The experiment was conducted as a randomized complete block design with a factorial arrangement and four replications. The treatments included flooding time as a main factor and imazethapyr stage of application as a secondary factor. The rice stages included early post (EPOST, 3- to 4- leaf stage) and late post (LPOST, 5- leaf stage). Permanent flood was established at 1, 7, 14, and 21 days after herbicide treatment (DAT). One untreated check was added for each combination of flooding time and application stage. Imazethapyr was applied preemergence (PRE) at 70 g/ha followed by 70 g/ha postemergence (POST) at the two rice stages (EPOST and LPOST). The imidazolinone-tolerant rice variety planted was 'CL161.' The results showed that the flooding needs to be established within 14 DAT when imazethapyr was applied at EPOST to provide greater then 97% red rice control. However, flooding needs to be established within 7 DAT to achieve greater then 95% red rice control when imazethapyr is applied LPOST.

BAS 772H, a New Herbicide from BASF Corporation

Youmans, C.D., Atwell, S.A., Guice, J.B., Newsom, L.R., Rhodes, A.R., and Stapleton, G.S.

Trials were conducted in Clearfield rice (*Oryza sativa L.*) in Arkansas, Louisiana, Mississippi, Missouri, and Texas in 2003 to evaluate BAS 772H efficacy in Clearfield rice. BAS 772H 75DF consists of a mixture of quinclorac:imazethapyr at a 4.8:1 ratio. The expected use rate is 0.56 l/ha (7.7 oz/A) formulated product either applied preemergence (PE) or postemergence at 1-leaf (PO1), in Clearfield rice. BAS 772 must be used in conjunction with Newpath (imazethapyr) in Clearfield rice to control grasses, broadleaves, and sedges. BAS 772 applied alone at 0.56 l/ha resulted in 57 and 79% red rice (*Oryza sativa L.*) control when applied PE or PO, respectively. BAS 772 (0.56 l/ha PE) followed by either Newpath at 0.292 l/ha (4 oz/A) postemergence at 4-leaf (PO4) or BAS 772 (0.56 l/ha PO4) resulted in 97 and 95% red rice control, respectively. BAS 772 (0.56 l/ha PO1) followed by either Newpath at 0.292 l/ha at tillering (POT) or BAS 772 (0.56 l/ha POT) resulted in 97 and 98% red rice control, respectively. BAS 772 (0.56 l/ha) resulted in 81 and 97% barnyardgrass (*Echinochloa crus-galli*) control when applied PE or PO1, respectively. BAS 772 (0.56 l/ha PE) followed by either Newpath (0.292 l/ha PO4) or BAS 772 (0.56 l/ha PO4) resulted in 98 and 90% barnyardgrass control, respectively. BAS 772 (0.56 l/ha PO1) followed by either Newpath (0.292 l/ha at POT) or BAS 772 (0.56 l/ha POT) resulted in 98 and 97% barnyardgrass control, respectively. BAS 772 applied alone at 0.56 l/ha resulted in 97 and 99% hemp sesbania (*Sesbania exaltata*) control when applied PE or PO1, respectively.

Red Rice Control and Crop Tolerance with Imazamox in Clearfield Rice

Guice, J.B., Atwell, S.A., Newsom, L.R., Rhodes, A.R., Stapleton, G.S., and Youmans, C.D.

Two applications of imazethapyr (Newpath) provide 95 to 100% red rice control in Clearfield rice. However, with severe red rice infestations, some imazethapyr-susceptible red rice plants may survive due to application errors and/or environmental factors. A third application of imazethapyr is not permitted, in the current EPA registration. Imazamox (Beyond) is very efficacious on many annual grass species, and has less rotational restrictions than imazethapyr. Therefore, trials were conducted to evaluate red rice control with, and Clearfield rice tolerance to imazamox.

Weed free trials were conducted to evaluate crop response and yield affects. Imazamox rates ranged from 35 g ai/ha (0.031 lb ai/A) to 106 g ai/ha (0.094 lb ai/A). Imazamox was applied to CL161 and CLXL8 rice at growth stages from 1- to 2-leaf through flowering. Some minor chlorosis and stunting were observed in one trial. Averaged over locations, there were no significant differences in yield for CL161 or CLXL8. Rough rice yield ranged from 5921 to 6330 lb/A and 6937 to 8312 lb/A for CL161 and CLXL8, respectively.

In the imazamox efficacy trials, conventional herbicides were utilized to control all weeds except red rice. Imazamox was applied to red rice in the 1- to 2-tiller, 3- to 4-tiller, boot, and flowering growth stages. Imazmox rates were 35, 45, and 53 g ai/ha (0.031 to 0.47 lb ai/A). At the 1- to 2-tiller application, red rice control ranged from 83 to 93%, and increased as imazmox rate increased. Red rice control was excellent with all imazamox rates when applied to 3- to 4-tiller red rice. Erratic control occurred when imazamox was applied to booting red rice. Red rice control was excellent when imazamox was applied in the early boot stage but decreased when herbicide applications were delayed until late boot. Red rice control was unacceptable when imazamox was applied to flowering red rice.

Imazamox Versus Imazethapyr for Salvage Red Rice (*Oryza sativa*) Control in Imidazolinone-Resistant Rice (Clearfield)

Kendig, J.A., Cobill, R.M., Hinklin, B.A., and Ezell, P.M.

Like all herbicides, imazethapyr (Newpath or Pursuit) occasionally provides inadequate weed control. However, due to the possibility of outcrossing of imidazolinone-resistance from Clearfield varieties to red rice, near-perfect red rice control is desirable. The current registration and labeling for imazethapyr suggest two applications for adequate control but does not allow additional applications should there be failures. According to BASF, it is likely that imazamox (Beyond or Raptor) could be registered via a Special Local Need (24c) label for salvage/cleanup applications.

In previous soybean research, imazethapyr and imazamox had many similarities in weed control spectrum and activity, with imazamox having slightly less soil persistence and slightly better grass activity. However, in limited research, imazamox provided excellent red rice and barnyardgrass control in imidazolinone resistant rice, and it is unclear whether imazamox or imazethapyr is the superior product. An experiment was conducted to compare imazethapyr and imazamox and to determine what application schemes were needed for salvage/clean-up applications around the time of permanent flood when a grower knew that an earlier application had failed.

Treatments were arranged in a 4 x 4 x 2 factorial with four “set up” treatments, four “salvage” treatments, and a comparison of imazethapyr versus imazamox. The four set up treatments were designed to provide various levels of control failures for the salvage treatments. The setup treatments were: 1) preemergence (PRE) only; 2) mid postemergece (MPOST) at 4- to 5-leaf rice); 3) PRE, followed by (fb) MPOST; and 4) early postemergence (EPOST) at 1-to 2-leaf rice fb MPOST. The four salvage/cleanup treatments were: 1) approximately 3 days preflood (preflood), 2) approximately 7 days postflood (postflood), 3) sequentially preflood fb postflood, and 4) a no-salvage control. The imazethapyr vs. imazamox comparison was made with the following two programs: 1) imazethapyr was used for the setup treatments with imazamox used for salvage/cleanup treatments or 2) imazamox used for the setup treatments and imazethapyr for salvage. All treatments were made at rates of 0.07 and 0.04

kg/ha (4 and 5 fl oz/A) for imazethapyr and imazamox, respectively. Postemergence treatments were applied with a label-recommended surfactant, and all plots received an application of acifluorfen for control of hemp sesbania (*Sesbania exaltata*) and other broadleaf weeds.

Standard weed science methods were used. Plots were 2.2 x 3.7 m, and were drill-planted with CL161 rice. The experiment was arranged as a randomized complete block with four replications. Treatments were applied with CO_2-pressurized backpack sprayers at 187 l/ha (20 gpa) using flat-fan tips and a spray pressure of approximately 170 kPa (25 psi). The plot area was infested with red rice (*Oryza sativa*) and barnyardgrass (*Echinochloa crus-galli*). Visual control ratings were collected at the same time as the MPOST and preflood applications, as well as late season. A description of the late-season weed control follows.

When no salvage applications were made, PRE-only treatments provided less than 25% red rice control, MPOST-only treatments provided 40% or less red rice control, PRE fb MPOST treatments provided 60% control or less, and EPOST fb MPOST provided 86 and 71% red rice control. Imazethapyr tended to provide better red rice control than Imazamox in the setup-only programs. However, when a preflood, "salvage" application of imazamox was made, red rice control was 100%, regardless of the setup program and regardless of whether the salvage treatment was a single preflood application or a preflood fb postflood treatment. A salvage application of imazamox provided poor (less than 50%) red rice control when applied following the worst set-up treatment (imazethapyr, PRE); however, all other salvage treatments of imazamox provided 85 to 100% red rice control.

Rice yields closely reflected the weed control that was observed. The highest yield observed from imazethapyr applied EPOST followed by MPOST followed by imazamox preflood followed by imazamox postflood.

All of the setup treatments, including the EPOST-MPOST sequential treatments benefited from salvage/cleanup treatments. These data suggest that the currently proposed use patterns (imazethapyr for pre-planned EPOST followed by MPOST and imazamox for salvage/cleanup) are the best. No detrimental effects were observed on rice, even when imazethapyr and imazamox were both applied twice.

Clearfield Rice – Newpath and Beyond….

Baldwin, T.L.

Three studies were conducted with Clearfield rice in 2003: a red rice competition study, a general efficacy study, and a red rice efficacy study with imazapyr (Beyond). In the red rice competition study, four rice varieties and four red rice densities were included. The rice varieties were Francis, CL161, XL8 and CLXL8. The two varieties were seeded at 84 kg/ha (75 lb/A) and the hybrids were seeded at 39 kg/ha (35 lb/A) Red rice seeding rates were 0, 7.1, 21.5, and 43 seed/m^2, hoping for a plant density of one-half the seeding rate. The red rice seed were included in with the planting seed. A conventional herbicide program was used on the Francis and XL8 plots and a red rice control program that included two postemergence applications of imazethapyr (Newpath) was used on the CL161 and CLXL8 plots. Plot size was 3 x 6 m with rice planted in the center 1.6 m. There were four replications. Rice yields in the zero red rice plots were 8926, 8926, 7918, and 9430 kg/ha for the Francis, XL8, CL161, and CLXL8 respectively: and each was a grade 1. Yields and (grades) in the low red rice density were 2531 (5), 3021 (5), 2960 (2), and 3695 (2) kg/ha for the varieties in the same order as above. For the medium red rice density, the numbers were 1755 [Sample grade (SG)], 2266 (SG), 2858 (1), and 4103 (1) kg/ha; and at the high density, the numbers were 755 (SG), 1510 (SG), 2796 (2), and 3756 (1) kg/ha for yield and grades for the varieties listed in the same order as above.

The general red rice efficacy study was planted with CLXL8 at a seeding rate of 39.2 kg/ha. Plots were 6 x 6 m, with rice planted in the center 1.6 m. There were four replications. Herbicides were applied with a backpack sprayer and normal rice cultural practices were used. In general, preemergence applications of Newpath were somewhat less effective on red rice than preplant incorporated or postemergence treatments. Several programs provided excellent weed control. A broadleaf herbicide was needed to control hemp sesbania. Rice yields in the cleanest plots averaged over 15,129 kg/ha. The program most often recommended in Clearfield rice by this author includes clomazone (Command) applied preemergence followed by Newpath at the 2- to 3-leaf stage of red rice growth, followed by Newpath plus a broadleaf herbicide applied preflood.

The efficacy study with Beyond was similar to the above study except the rice variety was CL161 and the rice was seeded in the center 2.3 m of the 3 x 6 m plots. Conventional herbicides were blanket-applied to control all weeds except red rice in the study. Beyond was applied at rates of 0.29, 0.37, and 0.58 l/ha. Treatments were applied as single applications at the 1- to 2-tiller, 3- to 4-tiller, or boot stages of the red rice. In general, the 0.37 and 0.58 l/ha rates resulted in better control compared with the 0.29 l/ha rate. Red rice control was above 90% at the higher rates at all three growth stages. Actually, at the boot stage application, the red rice plant was not killed, but near 100% seedhead suppression was achieved. Rice yields were near 10,086 kg/ha in plots treated at the higher rates and earlier timings compared with 4337 kg/ha in the check. Yield in the boot stage plots was not significantly different from that in the check. Even though complete seedhead suppression was achieved, yield loss due to competition was complete at the time of treatment.

Rice Yield and Grade as Affected by Rice Cultivar and Seeding Rate and Red Rice Density

Smith, K.L., Scott, R.C., and Kelley, M.B.

Red rice is considered to be the most troublesome weed in U.S. rice production. In 1979, red rice was listed as a severe problem in rice, resulting in an almost 50 million dollar loss each year. Red rice not only competes with field rice and causes yield reduction but also results in loss of market value. The strawhull variety of red rice has a larger leaf area index and grows faster than the blackhull red rice and matures later than Lemont or Newbonnet white rice varieties. Grain yields of Lemont and Newbonnet being reduced 86 and 52%, respectively, by red rice competition that lasted for 120 days after emergence have been reported. Another study showed Mars to be 24 to 33% more competitive with red rice than Lemont. These past studies show the effects of red rice competition with older white rice varieties. Many new varieties of rice have been introduced with different growth characteristics and yield potential. Many seed companies are also suggesting lower seeding rates for these new varieties. There is little information concerning the competition of red rice with modern white rice varieties or the effects of red rice competition with lowered white rice seeding densities.

Field studies were conducted at Lonoke and Rohwer, Arkansas in 2002 and 2003 to evaluate the competitiveness of modern rice varieties with red rice at varying red rice densities and commercial rice seeding rates. In the first study, Lemont, LaGrue, Cocodrie, CL161, and XL8 rice varieties were drill seeded at a rate of 101 kg/ha in a silt loam soil. Red rice seeding rates were 0, 0.36, 0.54, 1.0, 2.2, 3.3, 5.4, and 10.8 seeds/m^2. The experimental design was a randomized complete block design with four replications per treatment. The plot size was 1.4 x 6.1 m. Number of red rice plants, number of red rice heads, total grain yield, and percent red rice were measured.

In the second study, Cocodrie, LaGrue, and XL8 rice varieties were planted at 33.6, 67.2, and 100.8 kg/ha. Red rice seeding rates were 0, 1.0, and 3.3 seeds/m^2. Again, the experimental design was a randomized complete block design with four replications per treatment and plot size was 1.4 x 6.1 m. Number of red rice plants, number of red rice heads, total grain yield, and percent red rice were measured. All data collected were evaluated by analysis of variance (ANOVA) and means separated by LSD=0.05.

Herbicide Resistance Profiles in Clearfield Rice

Wenefrida, I., Croughan, T.P., Utomo, H.S., Meche, M.M., Wang, X.H., and Herrington, J.A.

Clearfield rice has a mutation that confers resistance to imidazolinone herbicides. Imidazolinone herbicides inhibit acetohydroxy acid synthase (AHAS), a central enzyme in the synthesis of the amino acids leucine, isoleucine, and valine. The objective of this study was to determine herbicide resistance profiles for eight Clearfield rice germplasm lines using four imidazolinone herbicides. The eight Clearfield rice germplasm lines were 93AS3510, PWC-16, PWC-23, CMC-29, CMC-31, WDC-33, WDC-37, and WDC-38. Line 93AS3510 is the parent of tolerant Clearfield rice cultivars CL121 and CL141. PWC-16, PWC-23, CMC-29, CMC-31, WDC-33, WDC-37, and WDC-38 were derived from the rice cultivar Cypress. PWC-16 is the original resistant germplasm from which a seed increase was used to directly produce the highly resistant Clearfield rice cultivar released as CL161. Four imidazolinone herbicides, Cadre (imazapic), Raptor (imazamox), Arsenal (imazapyr), and NewPath (imazethapyr) were used in this study. Herbicide resistance profiling was conducted using a randomized complete block design with a factorial arrangement. Each treatment combination was replicated 10 times. Results indicated that each Clearfield line had a somewhat different response to the herbicide treatments. The herbicide resistance profiles of PWC-16, PWC-23, CMC-29, CMC-31, WDC-33, and WDC-37 were closely related. However, substantial differences were found among 93AS3510, PWC-23, WDC-33, and WDC-38. Based on the NewPath (imazethapyr) test, 93AS3510 had a tolerance level 10 times that of the non-tolerant check Cypress. In turn, PWC-16, PWC-23, CMC-29, CMC-31, WDC-33, WDC-37, and WDC-38, respectively, had tolerance levels of approximately 8, 10, 9, 6, 8, 8, and 4 times that of 93AS3510.

Insights into the Parentage of Rice/Red Rice Crosses Using SSR Analysis of U.S. Rice Cultivars and Red Rice Populations

Gealy, D.R., Yan, W., Eizenga, G., Moldenhauer, K., and Redus, M.

Since the introduction of herbicide (imidazolinone)-resistant rice cultivars into the southern United States in 2002, the land area planted to these cultivars has increased steadily, primarily due to the dramatic improvement in control of red rice. At the same time, however, the rice industry has become increasingly concerned about timely and accurate identification of herbicide-resistant and non-resistant red rice crosses that may develop in these rice fields. The objectives of this work were to employ SSR marker analysis to differentiate among weedy red rice types and crosses and to identify the probable parents of putative crosses.

Numerous weedy red rice accessions obtained from rice fields in the southern United States were genotyped using 180 fluorescently-labeled SSR markers dispersed across the rice genome. The markers were visualized with a microcapillary automated DNA sequencer (ABI 3700). Cultivar standards for genotypic comparisons included approximately 90 of the most prevalent rice cultivars grown commercially in the United States during the past century. A similar number of additional standards (with red or non-red seed coat color) that originated from rice growing areas throughout the world were obtained from existing *Oryza spp*. collections containing domesticated, wild, and weedy lines or crosses. Genetic distances (GD) among *Oryza* entries were determined from the proportion of SSR alleles shared by the two entries over all markers. GD data were then subjected to hierarchical cluster analysis.

These analyses differentiated (GD > 0) between nearly all rice cultivars, red rice types, putative red rice crosses, and known crosses. Multidimensional scaling (MDS) plots provided visualization of the GD between and among rice, red rice, and crosses and provided insights as to the confirmation of putative crosses being actual crosses, and the inclusion or exclusion of particular *Oryza* entries as probable parents of a cross. Ultimately, these findings may allow the identity and potential source of suspected red rice types or their crosses in contaminated fields or seed lots to be confirmed.

Considerations for Managing Gene Flow from Clearfield Rice to Red Rice

Burgos, N.R., Shivrain, V.K., Rajguru, S.N., Sparks, O.C., Moldenhauer, K.A.K., Anders, M.M., and Gealy, D.R.

Gene transfer from rice to red rice is affected by several factors, which are rice cultivar, red rice biotype, spatial separation, and environmental conditions. Effective red rice management has been made possible by Clearfield rice technology. The sustainability of this system hinges upon mitigation of gene transfer from Clearfield rice to red rice. Studies have been conducted at the Rice Research and Extension Center (RREC), Stuttgart, AR, to determine effective distance of pollen flow and the effects of planting date and Clearfield cultivar on incidence of outcrossing.

Clearfield cultivars CL121 and CL161 were seeded at 112 kg/ha in circles 10 m in diameter on April 25 and May 21, 2002. Each of these plots was located at the center of a 20-m diameter circle, which has a natural population of Stuttgart strawhull red rice. The cultivars were planted in three replications at each planting date. At grain filling, Clearfield panicles were removed from the inner circle. At maturity, red rice panicles were collected at 0, 0.5, 1, 2, 3, 4, and 5 m from the edge of the inner circle. The remaining red rice was allowed to shatter. Plots were left undisturbed throughout the winter and red rice plants that emerged in 2003 were sprayed with Newpath at 0.07 kg ai/ha three times. The density of red rice and number of survivors were recorded. Leaf tissues were collected from the survivors for DNA analysis. Confirmation of F_1 hybrids was done using the simple sequence repeat primer (RM180). Genomic DNA was extracted from leaf tissues and used as a template for the polymerase chain reaction (PCR) using the SSR primer. Amplified DNA fragments were separated by electrophoresis in a polyacrylamide gel. The gel was stained with Sybr Green and photographed using a Kodak 290 digital camera. Primer RM180 produced one band that was polymorphic between Clearfield rice and red rice. Hybrids produced two bands. The May 21 planting date produced 48 and 39 resistant red rice hybrids for CL161 and CL121, respectively. On average, CL161 produced more outcrosses than CL121 in the later planting date. DNA analysis of April survivors and those from hand-collected samples is on-going.

Clearfield cultivars (CL161 and CL121) and Stuttgart strawhull red rice were planted weekly between April 15 and May 19. Red rice was seeded between two rows of Clearfield rice. Flowering was monitored. At grain filling, panicles of red rice were bagged and harvested at maturity. Seeds collected will be screened for resistance to Newpath in 2004 and survivors will be tested for hybridization. For the planting dates of April 15 to May 6, CL161 did not flower at the same time with strawhull red rice. Later plantings overlapped in flowering time with strawhull red rice. CL121 flowered earlier than CL161. When planted on April 15, CL121 had minimum overlap in flowering with red rice; however, subsequent planting dates showed increased synchrony in flowering of CL121 and Stuttgart strawhull red rice.

To minimize the incidence of outcrossing, it is important to know the flowering times of red rice and Clearfield rice relative to major planting periods. Ditches and areas surrounding fields planted to Clearfield rice should be kept free of red rice since pollen can move at least within 6 m from the source. A related study has shown rice pollen to move more than 25 m.

Tolerance of Arkansas Red Rice Biotypes to Imazethapyr, Glyphosate, and Glufosinate

Shivrain, V.K., Burgos, N.R., Scott, R.C., and Sparks, O.C.

Red rice (*Oryza sativa* L.) is the most troublesome weed of rice production in Arkansas, Louisiana, and Missouri. Red rice and domesticated rice belong to the same genus and species and share the same biological and physiological characteristics; thus, it is not possible to selectively control red rice in rice using traditional herbicides.

Herbicide-resistant rice cultivars offer new options for red rice control. In concert with this innovation is the risk of gene flow, which can result in the transfer of the resistant gene to red rice and, thus, render the red rice control measures ineffective. Many factors affect outcrossing potential; one of the important factors is herbicide efficacy on the red rice.

This experiment was initiated to evaluate the efficacy of three herbicides on red rice biotypes in Arkansas. One hundred thirty six red rice accessions were collected from 30 rice growing counties of Arkansas in the summer of 2002. One hundred twelve accessions, which had enough seed, were used to evaluate differential tolerance to imazethapyr, glyphosate, and glufosinate in the summer of 2003. The experiment was conducted in Lodge Corner, Arkansas, using a split-split plot design with two replications. Each accession had a maximum of 10 plants per treatment. Herbicides were applied at 0 X, 0.25 X, 0.5X, and 1 X at the 4- to 5-leaf stage of red rice or at 0.5 X, 30 days after the first application. Red rice accessions showed significant variation in tolerance to the herbicides used.

Ninety-two accessions survived 0.5 X of glufosinate whereas only six accessions survived 1 X rate. Seventy-six and nine accessions survived 0.5 X and 1 X rate of imazethapyr, respectively. Fifty accessions survived the 0.5 X rate of glyphosate and 10 survived the 1 X rate of glyphosate. Seven accessions survived the 0.5 X of glyphosate applied 30 days later than the other treatments. Most accessions survived the 0.25 X and the late application of imazethapyr and glufosinate. This experiment will be repeated in 2004, but preliminary results indicated that some red rice biotypes may not be totally controlled by one application of these herbicides at recommended rates. On the other hand, some biotypes can be controlled by lower herbicide rates. Herbicide efficacy can be altered by the red rice biotype.

Characterization of Herbicide-Resistant and Susceptible Biotypes of Barnyardgrass

Malik M.S., Talbert R.E., Burgos N.R., Ottis B.V. and Rajguru, S.N.

Different herbicide-resistant barnyardgrass *(Echinochloa crus-galli)* biotypes have been reported in Arkansas. Experiments were conducted at Stuttgart, AR, in 2002 and 2003 to compare the growth characteristics of barnyardgrass accessions, namely propanil-resistant (PR) from Arkansas, quinclorac-resistant (QR) from Louisiana, quinclorac/propanil-resistant (Q/PR) from Arkansas, susceptible (S) barnyardgrass from Arkansas, and the rice cultivar 'Wells' in a non-competitive environment. The experiment was conducted in a split-plot design with biotype as main plot and harvest date as subplot. Seeds were planted in the greenhouse and four seedlings were transplanted into each corner of 1 m^2 subplots. Plants were harvested and growth characteristics including height, number of tillers, leaf area and dry weights were recorded from 3 to 10 weeks after emergence. The QR barnyardgrass had a prostrate growth habit compared with other barnyardgrass biotypes. QR biotype was the tallest, with an average height of 120 cm while rice was 75 cm tall. Q/PR barnyardgrass had the most profuse growth as it produced four times more tillers (250) than rice (65). It had a maximum leaf area of 14,000 cm^2/plant and dry weight of about 988 g/plant 10 weeks after emergence. Crop Growth Rate (CGR) was greatest for Q/PR barnyardgrass (6 $g/m^2/d$), which was about four times more than rice (1.5 $g/m^2/d$) in both years. PR barnyardgrass had greater CGR than the S biotype. The barnyardgrass biotypes were not greatly different from each other.

Molecular characterization of these biotypes was done by using the Amplified Fragment Length Polymorphism (AFLP) DNA fingerprinting technique. Barnyardgrass biotypes were selfed for two generations to produce homozygosity in populations. Sixty-four EcoR1 and Mse1 primers were tested on the barnyardgrass biotypes. Four primers E-AAG/M-CTG, E-AAC/M-CTT, E-ACC/M-CAC, E-ACG/M-CTC showed genetic polymorphism between biotypes. The QR barnyardgrass was genetically different from S, PR, and Q/PR biotypes. Polymorphic markers ranged in size from 150 to 600 base pairs. Reciprocal crosses between QR and S biotype will determine if any of these markers are linked to quinclorac resistance. Further tests need to be done to obtain polymorphic markers between S, PR, and Q/PR biotypes.

Grass Control in Rice with Fenoxaprop and Fenoxaprop plus Safener Combinations

Baldwin, F.L. and Smith, K.L.

Some rice growers and weed scientists alike have reported erratic barnyardgrass control with fenoxaprop plus safener (Ricestar). Some have felt the product contained too much safener, resulting in excellent crop safety but also resulting in reduced grass control. As a result, various mixtures of fenoxaprop (Whip 360) and Ricestar were being tried by growers in the field. Experiments were conducted at Lonoke and Rohwer, Arkansas, from 2001 through 2003, to compare various ratios of Ricestar and Whip and also to determine the reasons for erratic performance. The experiments at Lonoke (2) and Rohwer (3) were conducted on silt loam and clay soils respectively. All experiments had two application timings: an early timing between 2- to 3-leaf and 4-leaf barnyardgrass and a later timing at preflood to tillering barnyardgrass or postflood. In general, timing of application was more important than herbicide ratio on barnyardgrass control. While the experiments were not designed to compare herbicide performance at different soil moisture levels, soil moisture appeared to have a dramatic effect on performance. In years and at locations, where soil moisture was excellent, all treatments provided excellent control at the earlier timings. In most studies, barnyardgrass control decreased dramatically at the later timings. However, in 2003, at Lonoke, all treatments provided excellent control at both timings as soil moisture was near field capacity in both cases. In contrast, control at the later timing in 2002 at Lonoke and in all years at Rohwer, control was near zero with all treatments at the later timings. In studies where the herbicide activity was extremely high at the early timing, the performance from Ricestar alone was equivalent to that of Whip alone or any of the mixtures. However, in studies where herbicide performance was moderate, the barnyardgrass control with Whip alone and mixtures or Ricestar and Whip was higher than from Ricestar alone. In some cases, it was a trend toward higher control, and in other cases, it was significantly higher. In 2003, cyhalofop (Clincher) was included for comparison. Barnyardgrass control was significantly higher, at both locations and timings, with mixtures of Ricestar and Whip compared with Clincher. Both application timings were preflood. In some studies, significant visual rice injury occurred with Whip applied alone. Injury was not observed with Ricestar/Whip ratios consisting of 266 ml (9 oz) or more of Ricestar and 236 ml (8 oz) or less of Whip. The total product in all mixtures was 502 ml (17 oz). In summary, all Ricestar and Ricestar plus Whip treatments provided excellent control when applied to barnyardgrass 4-leaf or smaller and under conditions of excellent soil moisture. When barnyardgrass was larger or when soil moisture was less than ideal, some of the mixtures provided better control with good crop safety compared with Ricestar alone. One of the mixtures that was particularly consistent was 266 ml of Ricestar and 236 ml of Whip. From the general observations in these studies, performance can be optimized by applying Ricestar or Ricestar/Whip to barnyardgrass 4-leaf and smaller and soon after a rain or flush. The addition of Whip can increase control in certain situations with no observed increase in injury risk compared with Ricestar alone.

Ricestar and Ricestar/Whip Combinations for Reduced Injury Potential and Weed Control

Leon, C.T., Webster, E.P., Zhang, W., Griffin, R.M., and Mudge, C.R.

Studies were conducted at the Rice Research Station near Crowley, Louisiana, during 2002 and 2003 to evaluate Ricestar, Whip, and combinations of the two to determine weed control efficacy and crop response. The experimental design was a randomized complete block. During both years of the study, rice (*Oryza sativa* L.) was drill seeded using conventional tillage practices. Treatments were applied as a single mid-postemergence (MPOST) or early-postemergence (EPOST) followed by (fb) a late-postemergece (LPOST) application. MPOST treatments consisted of 86 g ai/ha Ricestar, 64 g ai/ha Whip, or 76 plus 10, 61 plus 25, 46 plus 40, 30 plus 55, or 15 plus 70 g ai/ha Ricestar plus Whip, respectively. EPOST fb LPOST treatments included 76 fb 76 and 66 plus 86 g/ha Ricestar. The remaining sequential treatments received 66 g ai/ha Ricestar EPOST fb 76 plus 10, 61 plus 25, 46 plus 40, 30 plus 55, or 15 plus 70 g ai/ha Ricestar plus Whip, respectively. Visual ratings were taken for weed control and crop injury, and crop height and yield were also determined. Weeds evaluated were barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], Amazon sprangletop [*Leptochloa panicoides* (Presl) Hitchc.], and broadleaf signalgrass [*Brachiaria platyphylla* (Griseb.) Nash].

In 2003, cloudy, cool conditions resulted in 38% rice injury for Whip applied alone 14 d after MPOST. Regardless of application timing, most treatments containing 25 g ai/ha or more Whip resulted in 10 to 21% injury. Rice heights 7 d after LPOST were 29 to 44 cm. Treatments applied MPOST or containing 55 or 70 g ai/ha Whip resulted in heights less than 40 cm.

Barnyardgrass control 35 d after LPOST was 90 to 93% for all EPOST fb LPOST applications or Whip applied alone MPOST. Likewise, Amazon sprangletop control was 80 to 86% for treatments containing at least 64 g ai/ha Whip or any sequential Ricestar plus Whip combination containing more than 25 g ai/ha Whip. All treatments controlled broadleaf signalgrass at least 84%. Sequential treatments controlled broadleaf signalgrass 92 to 94%. No rice injury was observed 35 d after LPOST.

By 50 d after LPOST, barnyardgrass control was at least 91% with 40 g ai/ha Whip applied MPOST. Treatments applied EPOST fb LPOST controlled barnyardgrass 95 to 99%. EPOST fb LPOST treatments controlled Amazon sprangletop 84 to 94%. An EPOST fb LPOST application containing more than 40 g ai/ha Whip LPOST controlled Amazon sprangletop 93 to 94%. The MPOST treatment of 86 g ai/ha Ricestar controlled broadleaf signalgrass 88%. All other treatments controlled broadleaf signalgrass 91 to 99%, 50 d after LPOST.

By harvest, total plant heights were 88 to 92 cm, regardless of treatment. Rice yields were 6400 to 8190 kg/ha. Rice treated with 66 g ai/ha Ricestar fb 46 g ai/ha Ricestar plus 40 g ai/ha Whip yielded 8190 kg/ha; however, it did not differ from other single or sequential applications. Rice treated with 64 g ai/ha Whip MPOST, which injured rice 38%, yielded 7180 kg/ha.

The relationship between herbicide rate and timing with Ricestar and Whip is not very clear but is most likely related to rice growth and environmental conditions at the time of application. Even though rice heights had recovered by harvest, any reduction in rice height could possibly be considered a positive effect during years of inclement weather at harvest if the shorter rice could better withstand wind and rain. Higher rice injury soon after application did not result in reduced yields. Reduced weed control from a single herbicide application probably was the reason for a reduction in rice yield.

Rice Growth and Yield as Influenced by Regiment

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Field research was conducted in 2003 to evaluate the effects of Regiment (bispyribac-sodium) on rice growth and yield. Experiments were conducted at the Texas Agricultural Experiment Station Research and Extension Centers near Beaumont and Eagle Lake, TX. Each experiment was conducted as a randomized complete block and treatments were replicated four times. Treatments of Regiment were applied early postemergence (EPOST), preflood (PREFL), and postflood (POSFL) alone; EPOST followed by (fb) PREFL or POSFL; and PREFL fb POSFL. Regiment rates were 22.2, 28, and 33.6 g ai/ha for all EPOST, PREFL, and POSFL applications, respectively. An EPOST combination of Stam, Bolero and Facet was applied for comparison. A weedy check was included at Beaumont; however, a blanket application of Command was applied in Eagle Lake to provide season long weed control throughout the study. Rice was visually evaluated for stunting, and plant samples were measured biweekly for root and shoot length and dry weight. Yield was determined by mechanically harvesting the center four rows of each 6-row plot.

All Regiment combinations, except for the POSFL treatment, injured rice 10 to 15% at 14 days after treatment (DAT) of PREFL at Beaumont. By 34 DAT rice had recovered from injury, with the exception of Regiment POSFL (10%). At 5 DAT in Eagle Lake, only treatments that included a PREFL application caused injury (26-30%). By 42 DAT, rice injury had diminished to 5% or less. Root length decreased proportionally with increasing total amount of Regiment applied in Beaumont at 14 DAT PREFL. By 42 DAT, root stunting had diminished and did not differ between treatments. Root weight at Beaumont 14 DAT was significantly reduced by EPOST and EPOST fb PREFL applications. Root weight with the EPOST treatment remained significantly lower at 42 DAT, but root weight with the EPOST fb PREFL treatment had recovered. At 14 DAT in Eagle Lake only the single PREFL application significantly reduced root weight. At 42 DAT, there were no significant differences among root weights, regardless of rate or timing of applications.

Shoot length at Beaumont 14 DAT did not differ from the control, with the exception of Regiment EPOST fb PREFL. There were no differences in shoot length at 42 DAT. Regiment applied EPOST and EPOST fb PREFL reduced shoot weight at 14 DAT, but shoot weight had recovered by 42 DAT. There were no differences in shoot weight detected in Eagle Lake at either evaluation date. Rice yield at Beaumont did not significantly differ among Regiment treatments, and all herbicide treatments yielded higher than the weedy check. Rice yields with Regiment at Eagle Lake were not different from the weed-free check. The only yield reduction with Regiment treatments occurred with Regiment PREFL (7280 kg/ha) compared with Regiment EPOST (8198 kg/ha).

In conclusion, Regiment application, especially at the PREFL timing, injured rice up to 30%. Root injury, expressed as root length and weight, increased with Regiment rate. Regiment treatments had little effect on shoot length and weight. Rice injury had diminished by harvest, and in general, rice injury did not translate into yield reductions.

Tolerance of Rice Cultivars to Regiment

Zhang, W., Webster, E.P., Leon, C.T., Mudge, C.R., and Griffin, R.M.

Regiment (bispyribac-sodium) is an ALS herbicide used for postemergence weed control in rice. Risks of rice injury associated with Regiment application exist and rice cultivars may differ in their tolerance to this herbicide. A field study was conducted at the Rice Research Station near Crowley, Louisiana, in 2002 and 2003 to evaluate tolerance of seven existing or new rice cultivars to Regiment applied at different rates and timings. Regiment at 20 and 40 g ai/ha was applied to 2- to 3-leaf rice as early postemergence (EPOST) or to 4- to 5-leaf rice as late postemergence (LPOST). Two medium-grain cultivars 'Bengal' and 'Earl,' three conventional long-grains, 'Cocodrie,' 'Cypress,' and 'Wells,' and two imidazolinone-resistant long-grains 'CL141' and 'CL161' were evaluated. Visual rice injury ratings at 21 days after treatment (DAT), rice population at 21 DAT, rice height at 21 DAT and at harvest, and rice grain yield were recorded.

No rice cultivar by Regiment rate or rice cultivar by Regiment timing effects was observed for any of the parameters; therefore, data were averaged over Regiment rates and timings and presented by rice cultivar. At 21

DAT, rice injury was 10 and 11% for medium-grain Bengal and Earl, respectively, compared with 3 to 6% for the long-grain cultivars. At 21 DAT, Regiment treatments reduced plant height of Bengal and Earl more than any of the long-grain cultivars. Regiment also resulted in reduction in plant population of Bengal and Earl compared with all other cultivars. However, Earl was the only cultivar with height and grain yield reduction at harvest.

In summary, the medium-grain variety Earl was less tolerant to Regiment as reflected by greater injury, shorter plants, and fewer plants at 21 DAT and shorter plants and lower grain yield at harvest when compared with the nontreated Earl. Medium-grain Bengal was initially inhibited by Regiment; however, plant height at harvest and rice grain yield of Bengal were not negatively impacted by Regiment. All long-grain cultivars displayed tolerance to Regiment. The results indicate that rice cultivars vary in their tolerance to Regiment and that evaluating rice tolerance at both early and late growth stages is important in order to have a thorough assessment.

Comparison of Herbicides for *Echinochloa polystachya* Control

Griffin, R.M., Webster, E.P., Zhang, W., Leon, C.T., and Mudge, C.R.

Echinochloa polystachya (Kunth) Hitchc. is a perennial grass native to South America that has been found in Florida, Louisiana, Texas, and Puerto Rico. It has recently been found in rice producing areas of Acadia Parish, Louisiana. Found mainly in the Amazon flood plain, it is well adapted to flooded conditions found in rice (*Oryza sativa* L.) patties. It is a highly competitive C4 plant that has a CO_2 uptake and water use efficiency that is comparable with fertilized corn (*Zea mays* L.).

A greenhouse study was conducted at the Louisiana State University in Baton Rouge during 2003 to evaluate herbicides for control of *Echinochloa polystachya*. The experimental design was a randomized complete block with four replications. Treatments consisted of: 1260 g ae/ha glyphosate, 497 g ai/ha glufosinate, 314 g/ha cyhalofop, 9 g/ha V-10029, 71 g/ha imazethapyr, 86 g/ha fenoxaprop/S (fenoxaprop plus safener), 560 g/ha quinclorac, 46 g/ha fenoxaprop/S plus 40 g/ha fenoxaprop, 3361 g/ha propanil, and a nontreated was added for comparison. Crop oil concentrate at 2.5% (v/v) was used with cyhalofop and at 1% (v/v) with quinclorac. An organo-silicon surfactant at 0.125 % (v/v) was used with V-10029. A nonionic surfactant at 0.25% (v/v) was used with imazethapyr. Twenty-five cm stem sections of *Echinochloa polystachya* were planted in 35 x 25 cm containers at a depth of 1 cm and allowed to grow for 21 d. Treatments were applied to 2- to 3-leaf *Echinochloa polystachya* with a CO_2-pressurized backpack sprayer calibrated to deliver 94 l/ha at 140 kPa. Visual control ratings were taken at 7, 14, 20, and 28 days after treatment (DAT) and fresh weights were taken after final visual ratings.

Echinochloa polystachya control 7 DAT was 83 to 86% for glufosinate and glyphosate, respectively. Control with all other herbicide treatments was 43 to 58%. At 14 DAT, glyphosate and glufosinate controlled *Echinochloa polystachya* 98 and 91%, respectively. However, control was below 61% for all other treatments evaluated.

Strategic Concepts for Herbicide Resistance Management in California Rice

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California rice is largely mono-cropped on heavy clay soils, mostly unsuitable for growing other crops. Aerial water seeding has been the principle method of stand establishment, adopted for ease of planting, as well as weed suppression. However, weeds adapted to the water-seeded and continuously flooded system have now become the most serious production problem. Although flooding provides considerable weed suppression, some problematic weeds, such as the watergrasses (*Echinochloa oryzoides* (Ard.) Fritsch and *Echinochloa phyllopogon* (Stapf) Koss.), sedges (particularly *Schoenoplectus mucronatus* (L.) Palla syn. *Scirpus mucronatus* L. and *Cyperus difformis* L.), and broadleaf weeds (*Ammannia auriculata* Wild. and *A. coccinnea* Rottb.), are only partially controlled by flooding and thus weed control is strongly herbicide-dependent. Herbicide resistance, resulting from the continuous use of a few available herbicides, is threatening the viability of chemical control, and restrictions to herbicide registration limit the availability of new compounds. Innovative concepts for integrated weed management in California rice will rely heavily upon breaking weed cycles through rotation of stand establishment methods and alternating herbicides modes of action, as well as effective crop interference to reduce herbicide use.

Broadleaf Weed Control with Carfentrazone Tank Mixtures in Rice

Ellis, A.T., Talbert, R.E., Scott, R.C., Smith, K.L., and Ottis, B.V.

An experiment was conducted in 2003 to evaluate the performance of carfentrazone (Aim) tank mixed with various broadleaf herbicides. The experiment was conducted at the Rice Research and Extension Center at Stuttgart, Arkansas, on a Dewitt silt loam. The experimental design was a randomized complete block with four replications. 'Francis' was the variety used in the experiment. Broadleaf weed species, hemp sesbania (*Sesbania exaltata*), pitted morningglory (*Ipomoea lacunosa*), and northern jointvetch (*Aeschynomene virginica*) were sown in rows perpendicular to the drilled rice.

A blanket application of clomazone (Command) at 0.44 kg/ha was applied to the entire study area. Carfentrazone at 0.028 kg/ha + NIS 0.25% V/V was applied alone and with tank mixtures preflood applications of bentazon + aciflurofen (Storm) at 0.28 kg/ha, triclopyr (Grandstand) at 0.028 kg/ha, bispyribac-sodium (Regiment) at 0.042 kg/ha, propanil (Stam) at 4.45 kg/ha, and halosulfuron (Permit) at 0.028 kg/ha. Carfentrazone was also in a tank mixture at 0.028 kg/ha + NIS 0.25% V/V with 2,4-D amine (Savage) at 0.28 kg/ha applied postflood.

Greater than 98% control of hemp sesbania was achieved with all treatments except for carfentrazone + triclopyr (28%) and carfentrazone + bispyribac-sodium (46%). Pitted morningglory was controlled at 100% with all treatments. Northern jointvetch control was >80% with carfentrazone + 2,4-D amine, carfentrazone + halosulfuron and carfentrazone + bispyribac-sodium with carfentrazone (22%), acifluorfen + bentazon (26%), triclopyr (32%), and propanil (68%). No significant crop injury was observed.

Using the Rice Growth Staging System with Weed Research - Example with 2,4-D

Counce, P.A., Singh, M.P., and Burgos, N.R.

The herbicide 2,4-D, a synthetic auxin, is a cheap effective broadleaf herbicide for rice. The application window is fairly narrow. In Arkansas, the recommended time of application is between beginning internode elongation and internode elongation of 1.25 cm (1/2 inch). Beginning internode elongation occurs shortly after panicle initiation (the R0 growth stage), and internode lengths of 1.25 cm (1/2 inch) are approximately the time of panicle differentiation (R1 growth stage). Growth stage R0 occurs in VF-4 vegetative growth stage. Growth stage R1 occurs in the VF-3 growth stage. Consequently, the reproductive and vegetative growth stages are coordinated. Because of its low cost and effectiveness, farmers have asked whether 2,4-D could be applied at an earlier growth stage. The use of the growth staging system will permit understanding as to whether the application window for 2,4-D could be safely broadened. The goals of the study were (1) to illustrate how the growth staging system can be used to enhance rice weed control research and (2) to determine whether the application window for 2,4-D could be broadened to earlier applications. We conducted two greenhouse experiments with 2,4-D applications. In the first experiment, applications were made at V3, V4, V5, V6, V7, V8, V9 and V10 growth stages. The cultivar in the first experiment was Cocodrie. The herbicide, 2,4-D was applied at different growth stages to determine its effect on rice yield components. We found severe injury, including stunting, twisting, tiller death, and chlorosis, at V3, V4 and V5 growth stages. We found less damage from V6 through V10 growth stages. However, there was a steady increase in tiller number per plant, tiller grain yield, and main stem grain yield when 2,4-D was applied from V6 until V9. Applications of 2,4-D at V9 and V10 were about the same. We repeated part of this work with an experiment with six cultivars treated at the V3 growth stage and found the damage at that growth stage was substantial as in the first experiment for all six cultivars. In conclusion, the growth staging system was quite effective in framing the experiment, and the Arkansas recommendations for applying 2,4-D are certainly justified based on the findings of these experiments.

Impact of Gibberellic Acid Seed Treatment and Seeding Rate on Crop Production of Drill-Seeded CL161

Dunand, R.T. and Dilly, R.R.

Seed cost of herbicide-tolerant crops is generally higher compared with conventional varieties. To make this technology cost effective, one option is to plant at lower than recommended seeding rates. In 2003, in Louisiana, the range in recommended seeding rates for drill-seeded rice was 84 to 101 kg/ha, and this range in rates will result in a minimum of 108 plants/m^2. In general, plant populations below 108 plants/m^2 are considered a limitation on grain production. In addition, seed treatment with gibberellic acid has been shown to increase emergence and seedling density. Therefore, a study was conducted to determine the feasibility of seed treatment with gibberellic acid and lower than recommended seeding rates on crop production of imazethapyr-tolerant rice.

The imazethapyr-tolerant long-grain variety, CL161, was drill-seeded on 18-cm row spacings on April 2, 2003. Plot size was 2.7 (15 rows) x 7 m. Seeding rates were 34, 67, and 101 kg/ha. The rate of gibberellic acid (Release, Valent BioSciences, Libertyville, IL) was 22 ppm (22 mg/kg seed). Recommended agricultural practices were followed to provide adequate pest control and fertility. The study was conducted in the absence of red rice, and imazethapyr was not applied.

Seed treatment with gibberellic acid significantly increased seedling population (stand), hastened maturity, and increased panicle density. The effects were noted across all seeding rates. Stand was increased over 40%, averaging 76 vs 108 plants/m^2. Crop maturation was evaluated at heading and harvest. Time to 50% heading was 2 days earlier, averaging 96 vs 98 days from planting to 50% heading, and grain moisture was 0.4% lower, averaging 17.8 vs 18.2%. Panicle density was increased 25%, averaging 238 vs 292 panicles/m^2. Mature plant height was unaffected, ranging between 106 and 107 cm, and there was a numerical increase in grain yield of slightly over 200 kg/ha (10,670 vs 10,888 kg/ha).

Seeding rate significantly affected stand, maturity, panicle density, and grain yield. The effects were consistent, regardless of seed treatment with gibberellic acid. Stand increased proportionately with each incremental increase in seeding rate (43, 86, and 140 plants/m^2 for the 34, 67, and 110 kg/ha rates, respectively). Time to 50% heading and seeding rate were inversely related. As seeding rate decreased, heading was delayed (99, 97, and 96 days for the three rates). Panicle density, like stand, increased proportionately (216, 270, and 313 panicles/m^2) with increases in seeding rate. Grain yield was lowest (10,295 kg/ha) at the lower seeding rate and similar at the intermediate and high seeding rates (10,911 and 11,129 kg/ha, respectively). Mature plant height was unaffected by seeding rate, ranging between 106 and 108 cm, and grain moisture at harvest was 18% at each seeding rate.

Seed treatment with gibberellic acid can improve plant population, and seeding rates below 67 kg/ha can result in insufficient plant populations for optimum yield. When attempting to reduce expenses associated with seed cost by reducing seeding rate, seed treatment with gibberellic acid offers the potential to minimize the loss in yield due to inadequate stands resulting from a low seeding rate.

Impact of Plant Growth Regulators on Lodging and Rice Production

Dunand, R.T. and Dilly, R.R.

In 2003, over half of the recommended rice varieties for Louisiana were susceptible or moderately susceptible to lodging. In the southern U.S., lodging commonly occurs in association with strong winds and rain. In addition, lodging is increased by high nitrogen fertility and diseases that weaken rice stems. Lodging is primarily related to plant height, and tall varieties are more prone to lodge than short and semidwarf varieties. Plant growth regulators, known as growth retardants, can reduce plant stature in rice. A study was conducted to determine the potential of a growth suppressant to reduce plant height and lodging in rice and the subsequent impact on crop production.

Earl, a variety that is susceptible to lodging, was drill-seeded on 18-cm row spacings at 101 kg/ha on April 19, 2002. Plot size was 2.7 (15 rows) x 7 m. Recommended agricultural practices were followed to provide adequate pest control and fertility. Trinexapac-ethyl (Palaside, Syngenta Crop Protection, Inc., Greensboro, NC) was applied at the beginning of stem development (internode initiation, II) and near the end of stem development (late boot, LB). Rates were 15 and 30 g/ha. Lodging occurred as the result of a thunderstorm several days prior to harvest.

At maturity, the applications of trinexapac-ethyl resulted in significant effects on plant stature, lodging, and grain production. Plant height (distance between the soil surface and the tip of the panicle extended vertically) was 114 cm in the control. Trinexapac-ethyl applied at II reduced plant height 7 and 19 cm at the low and high rates, respectively. The effects were less with the LB application, with a height reduction of 4 cm and no difference between rates. Lodging was 38% (based on plot area and degree of declination) in the control and ranged between 0 and 8% in the trinexapac-ethyl treatments. As a result of the lodging and rain, grain moisture was high (30.7%) in the control compared with 20.8% in the II treatments, regardless of rate. The LB treatments, although reducing lodging significantly, delayed maturity. Grain moistures were 23.4 and 24.8% for the low and high rates, respectively. Grain yield was decreased by the lodging, with 7954 kg/ha in the control. The II treatments had yields of 9442 and 8240 kg/ha with the low and high rates, respectively. Since lodging was 0% with the high rate of trinexapac-ethyl applied at II, the yield reduction was due to injury from the plant growth regulator, although no visual symptoms were observed. The LB timing resulted in approximately 9072 kg/ha with no rate effect.

Growth suppressants, such as trinexapac-ethyl, can reduce lodging in susceptible rice varieties. Height reductions on the order of 4 to 7 cm are adequate to improve lodging resistance, and improvements in lodging resistance can result in 1000 kg/ha higher grain yield when conditions conducive to lodging occur. Height reductions on the order of 19 cm, although capable of imparting adequate lodging resistance, can be injurious to rice and reduce yield. Mature rice that lodges during a thunderstorm has increased grain moisture at harvest. Higher harvest moisture increases drying costs and can decrease milling yield. Plant growth regulators that impart lodging resistance to rice can provide multiple benefits during and after harvest.

Influence of Messenger on Rice Yield

Guy, C.B., Helms, R.S., and French, N.M.

Messenger is the first commercialized product from a new class of chemistry called harpin proteins. Harpin $_{Ea}$, the active ingredient in Messenger, activates the natural growth and stress-defense responses in plants that increase plant vigor and result in better overall plant health. EDEN Bioscience has classified Messenger as a Plant Health Regulator, a new class of crop production technology. A series of replicated trials were conducted in 2000, 2001, and 2002 to investigate the influence of Messenger on rice yield. This report is a compilation of those field trials.

Trials were conducted by independent cooperators located in Arkansas, Louisiana, and Mississippi. Experimental design of each trial was a randomized complete block, and treatments were replicated four to six times. Plot size was 1.8 to 3.6 m by 5.2 to 9.1 m, and plots were well buffered. The use rate of Messenger was 0.158 kg/ha at 46.8 or 93.5 l/ha. Messenger application timings included 2-leaf, 4-leaf, 2-tiller, 4-tiller, panicle initiation, and panicle differentiation, and each trial included an untreated control. Cooperators were requested to apply Messenger treatments with ground equipment utilizing a shielded spray boom and to apply each plot as a single pass. Plant growth inputs, insects, diseases, and weeds were managed according to locally accepted practices, and all plots were treated identically. These trials were not inoculated with plant diseases. Measurements consisted of rice stand count, plant height, machine-harvested rice yield, and milling quality. Data were analyzed by ANOVA or T-Test, and some across trial results are summarized as percentages without statistical analysis.

From each plot, rice was carefully hand harvested from two 61-cm subsample areas, and subsamples were pooled. Rice stems were cut at the soil surface, placed in a cloth bag, and dried to ~12% moisture. The entire contents of the cloth bag were weighed for total grain and straw. All panicles were removed and weighed intact. Percent resource partitioning (harvest index) to grain as weight of panicles/weight of total grain and straw was calculated. Numbers of panicles in each sample were recorded (converted to number of panicles/cm^2). From a random subsample of 10 typical panicles, numbers of whole grains and sterile florets blanks were recorded. Data were converted to percent filled spikelets and percent sterile, and number of florets (rice kernels) per panicle was calculated. Weight was recorded for a random sample of 100 seed per plot, and seeds per cloth bag sample and 1,000-seed weight were calculated.

Panicle weights were approximately 10% higher with Messenger than the untreated control. Harvest indexes and number of panicles/area were 5 to 6% higher with Messenger than the untreated, which indicates that rice is partitioning slightly more resources to panicles instead of straw or non-reproductive growth. Differences in 1,000-seed weight, total milling (%), and head milling (%) were very small. When assessed across all three locations and varieties Cocodrie, Cypress, and Lemont, a single application of Messenger at the 2-leaf stage of rice consistently improved rice yields 514 to 625 kg/ha (10.5 to 12.4 bu/A) or approximately 8 to 9% above untreated rice.

A single application of Messenger (0.158 g/ha) at the 2-leaf stage is the most common timing evaluated in replicated rice trials. Compared with the untreated control, a positive yield response to Messenger at 2-leaf stage was observed in 12 of 15 datapoints (n=15, 80% positive) for varieties Cocodrie, Cypress, Experimental, Lemont, and Wells and averaged a significant yield increase of 388 and 514 kg/ha (mean and median, respectively). Ahrent was not as responsive to Messenger compared with other varieties. Below a yield threshold of 9,584 kg/ha (190 bu/A), Messenger-treated rice yielded significantly higher (521 kg/ha) than the untreated control (n=12, 92% positive).

The ideal timing window appears to be from the 2-leaf stage to at least 4-tiller (after preflood) and perhaps to panicle differentiation. In timing trials not adversely influenced by weather or herbicide injury, Messenger averaged significant yield differences (+4.2 to +9.4% and 353 to 797 kg/ha) from UTC for 2-leaf to 4-tiller timings and +6.7% (559.6 kg/ha) for these four timings pooled (timing trials with UTC yield of <9,584 kg/ha, n=16). Assuming a price of $7.50/cwt, an average yield increase of 560 kg/ha (6.7%) would have a value of $92.50/ha.

Replicated, small plot trial results indicate one application of Messenger at 0.158 kg/ha consistently provides an economical increase in rice yield and that Messenger can serve as a new tool in rice production.

Timing the Newpath Application in Clearwater-Planted Clearfield Rice

Strahan, R.E. and Eskew, E.

Field studies were conducted in 2002 and 2003 in growers' fields near Jennings, LA, to determine the imazethapyr application timings that optimize red rice control in Clearwater-planted CL161. Producers' fields that were used in the studies were heavily infested with a natural population of red rice that had severely limited rice yields in previous crops.

For both years, single applications of imazethapyr applied preplant to the soil or at rice spiking provided unsatisfactory red rice control (<50%). In 2002, sequential applications of imazethapyr applied at the 3 leaf rice growth stage (red rice at the 2- to 3-leaf stage) following either preplant or spiking applications provided near 100% red rice control. Delaying sequential applications until the 5-leaf rice stage (red rice at 1-2 tillers) significantly reduced red rice control. The period of delay between the 3- and 5-leaf sequential applications was 5 days. In 2003, inclement weather delayed sequential applications until the 4-leaf rice (red rice at 4-leaf stage) and 1-tiller rice stage (red rice at 5-leaf stage), respectively. Due to excellent growing conditions, the period of delay between the 4-leaf and 1-tiller sequential application was only 2 days. Red rice control was excellent (>95%) following sequential applications.

Water-Seeded Rice Weed Management

Webster, E.P., Zhang, W., Leon, C.T., Mudge, C.R., and Griffin, R.M.

Herbicide options for rice weed control have changed in the past five years. Herbicides carfentrazone, cyhalofop, clomazone, imazethapyr, bispyribac-sodium, and fenoxaprop received federal labels between 1998 and 2002. Theses new herbicides have given producers new alternatives for weed control in rice other than the standard rice herbicides propanil, molinate, and quinclorac.

In Louisiana, 75% of the total rice acreage is planted in a water-seeded system. In south Louisiana, approximately 90% of the acreage is water-seeded. Historically, rice producers who employ a water-seeded system have fewer herbicide options. The development of the new herbicides has given water-seeded rice producers choices for herbicide applications that have only been available for drill-seeded rice.

Clomazone was first labeled for use in drill-seeded rice. However, in 2001 rice producers in several parishes in Louisiana were allowed to apply clomazone in water-seeded rice. Clomazone has given producers the option to use an economical herbicide with residual activity on many problem grasses. In order to apply clomazone on water-seeded rice, the herbicide must be impregnated on fertilizer. The impregnated fertilizer must be applied at a minimum of 168 kg/ha. This treatment is usually applied after rice is planted and the seeding flood is removed to allow for seedling establishment. The application occurs once the root of the rice plant begins to protrude into the soil, often referred to as the pegging stage. This occurs approximately 4 to 7 days after planting. When applying clomazone in this manner the field should not be surface irrigated for approximately 24 to 48 hours after application. This will allow time for the herbicide to release from the fertilizer granule and bind to soil particles.

Clearfield rice is tolerant to the imidazolinone herbicide family. This tolerant rice will allow producers to apply imazethapyr to control red rice in Clearfield rice. In 2002, Clearfield rice could only be grown in a drill-seeded system. 'CL161' rice is a new Clearfield line with enhanced-tolerance to imazethapyr, and CL161 was approved and available in 2003 for a water seed system. In south Louisiana spring weather patterns are often wet and producers do not have the option of drill-seeding rice. This flexibility of CL161 will give producers more production options. Imazethapyr can now be applied as two postemergence applications at 70 g/ha for a total of 140 g/ha. The first application should be applied on pegging rice and followed by an application 10 to 14 days later to obtain acceptable control of red rice and other troublesome rice weeds.

All of the previously mentioned herbicides are labeled for use in water-seeded rice. These new herbicides will allow producers to have more options when determining weed control programs.

Clomazone plus Bensulfuron or Halosulfuron Combinations in Water-Seeded Rice (*Oryza sativa*)

Mudge, C.R., Webster, E.P., Zhang, W., Leon, C.T., and Griffin, R.M.

A field study was conducted in 2002 and 2003 at the Rice Research Station, near Crowley, Louisiana, to determine the effects of clomazone plus bensulfuron-methyl or halosulfuron on water-seeded rice. 'Cocodrie' was water-seeded at 168 kg/ha. Treatments included clomazone at 0.45 kg ai/ha plus bensulfuron at 42, 31, 21, and 10 g ai/ha or halosulfuron at 53, 39, 26, and 13 g ai/ha impregnated onto urea (46-0-0) and applied at a rate of 168 kg/ha. Treatments were applied at the pegging (PEG) stage of rice. Three comparison treatments included: 1) a single application of clomazone impregnated on urea, 2) clomazone impregnated on urea followed by a postemergence (POST) application of 42 g/ha bensulfuron on 3- to 4-leaf rice, and 3) clomazone impregnated on urea followed by a POST application of 53 g/ha halosulfuron on 3- to 4-leaf rice. POST treatments were applied 14 days after PEG (DAPEG) with a CO_2 backpack sprayer calibrated to deliver 140 l/ha. Data collected included crop injury (in the form of bleaching), barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] control, rice flatsedge (*Cyperus iria* L.) control, and rough rice yield.

Bleaching of rice foliage with single applications of clomazone alone was 40 to 42% at 7 d after pegging (DAPEG). However, Clomazone plus the addition of any rate of bensulfuron or halosulfuron impregnated on urea reduced bleaching to 23 to 30%, indicating a safening effect. At 21 DAPEG, clomazone plus bensulfuron or halosulfuron at

31 and 39 kg/ha reduced bleaching to 7 and 8%, respectively, compared with 21% bleaching when rice was treated with clomazone alone. At 14 DAPOST, a single application of clomazone controlled rice flatsedge less than 20%. All treatments containing bensulfuron or halosulfuron at PEG or POST controlled rice flastsedge 76 to 95%. Treatments containing clomazone plus halosulfuron PEG controlled rice flatsedge 92 to 95%. Barnyardgrass control was 92 to 97% for all treatments at all rating dates. Minimal yield differences between the impregnation and POST treatments were observed. Rice yield was 6000 to 7200 kg/ha for treatments containing clomazone impregnated with bensulfuron or halosulfuron compared with 6500 kg/ha for bensulfuron or halosulfuron POST following clomazone at PEG.

In 2003, a laboratory study was conducted at the Louisiana State University in Baton Rouge to determine the effects of clomazone plus bensulfuron or halosulfuron on chlorophyll content. Three rice varieties evaluated were ‘Bengal’ (medium grain), Cocodrie (long grain), and ‘Pirogue’ (short grain). Plants were grown in a hydroponic solution in 150 ml Erlenmeyer flasks. Clomazone was applied alone at 0.68 kg/ha or with bensulfuron at 42 g/ha or halosulfuron at 53 g/ha. Fresh leaf and stem samples were ground and chlorophyll was extracted in an 8:2 acteone:water solution. A nontreated plant of each variety was included for comparison. Chlorophyll A and Chlorophyll B content were measured with a spectrophotometer set at 645 nm and 663 nm, respectively. Chlorophyll content was expressed in µg of chlorophyll/gram of fresh weight.

Differences in Chlorophylls A and B were observed when rice was treated with clomazone, clomazone plus bensulfuron, and clomazone plus halosulfuron for the long-grain Cocodrie. The Chlorophyll B content in Cocodrie was 59 and 58 µg/g for clomazone plus bensulfuron and halosulfuron, respectively, compared with 48 µg/g for clomazone alone. The nontreated chlorophyll content was 88 µg/g. Chlorophyll content of A and B was higher for the nontreated rice varieties compared with any rice treated with clomazone or clomazone plus bensulfuron or halosulfuron.

These results indicate that producers can use clomazone plus bensulfuron or halosulfuron impregnated on urea fertilizer. These combinations can safen rice from bleaching caused by clomazone without a reduction in weed control and yield. Such combinations help broaden weed control spectrum and reduce number of applications, variable cost, and off-site clomazone movement.

Weed Control and Crop Tolerance of Penoxsulam in Dry and Water-Seeded Rice

Langston, V.B., Mann, R.K., Richburg, J.S., Haack, A.E., Lassiter, R.B., Wright, T.R., Simpson, D.M., Gast, R.E., and Nolting, S.P.

Penoxsulam (DE-638) is a new broad-spectrum triazolopyrimidine sulfonamide herbicide being developed globally for rice weed control. In U.S. field trials from 1998 to 2003, penoxsulam at 20 to 40 g ai/ha as a postemergence foliar application preflood in dry-seeded rice and as a postemergence foliar application in water-seeded rice provided good to excellent control of all annual and perennial *Echinochloa* species, as well as many annual rice weeds including hemp sesbania (*Sesbania exaltata*), northern jointvetch (*Aeschynomene virginica*), dayflower (*Commelina diffusa*), ducksalad (*Heteranthera limosa*), alligatorweed *(Alternanthera philoxeroides*), Texas/Mexicanweed (*Caperonia* spp), smartweed (*Polygonum* spp), annual sedge (*Cyperus* spp), annual arrowhead (*Sagittaria* spp), water plantain (*Alisma plantago-aquatica*), and ricefield bulrush (*Scirpus mucronatus*). Penoxsulam can be tankmixed with cyhalofop, triclopyr, propanil, clomazone, pendimethalin, and thiobencarb to increase the weed control spectrum. Penoxsulam trade names will be Grasp in the southern United States and Granite in California.

DE-638 for Weed Control in Rice

O'Barr, J.H., McCauley, G.N., Chandler, J.M., and Langston, V.B.

DE-638 (penoxsulam) was evaluated in production fields near Eagle Lake and Rock Island, TX for alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.] control in rice. Experimental design was the same at each location, a randomized complete block design (RCBD) with four replications. Treatments were made at two timings; early post emergence (EPOST) at the rice 3-leaf stage with alligatorweed 8 to 12 cm tall, and late postemergence (LPOST) at the rice 5-leaf stage and alligatorweed 15 to 20 cm tall. DE-638 was applied at 30 g ai/ha alone and in combination with 2.24 kg ai/ha Stam and 0.26 l/ha Grandstand EPOST and with 4.48 kg ai/ha Stam and 0.35 l/ha Grandstand LPOST. A tankmix of Stam/Grandstand without DE-638 was also evaluated at each application timing. DE-638 alone provided greater than 80% alligatorweed control, regardless of timing. The addition of Grandstand to DE-638 improved alligatorweed control to better than 93%. A tankmix of DE-638 with Stam provided less than 50% control, indicating some antagonism. A tankmix of Stam/Grandstand without DE-638 provided less than 20% control. Optimum alligatorweed control was observed with DE-638 under moist soil conditions, but control was decreased under dry soil conditions.

Evaluation of DE-638 in Drill-Seeded Rice

Williams, B.J., Burns, A.B., and Copes, D.B.

The efficacy of DE-638 (penoxsulam) was evaluated in 2003 at the Northeast Research Station near St. Joseph, La. and at Woodsland Plantation near Monroe, Louisiana, on a Sharkey clay soil. A water- and dry-seeded study were conducted at St. Joseph and an alligatorweed (*Alternathera philoxeroides*) study was conducted at Woodsland Plantation on fallow ground. Herbicide treatments were applied, using a CO_2 pressurized backpack sprayer calibrated to deliver 140 l/ha, to plots measuring 2 by 4.5 m. 'Cocodrie' was drill-seeded at 101 kg/ha on a 19-cm spacing in dry-seeded rice and broadcast at 170 kg/ha in water-seeded rice. After draining the seeding flood, plots were flushed weekly and flooded 4 WAP in the water-seeded rice trial. In the dry-seeded trial, plots were flushed as needed and flooded 5 WAP. The experimental design for the experiments was a randomized complete block. Weed control ratings, rice injury ratings, and rice yield data were subjected to analysis of variance. Means were separated using Fisher's Protected LSD at the 5% level. Penoxsulam at 0.039 and 0.054 kg/ha was as effective as 0.042 kg/ha bensulfuron at controlling ducksalad (*Heteranthera limosa*) in water-seeded rice. Ducksalad was not controlled by 0.026 kg/ha bispyribac or 0.030 kg/ha penoxsulam. Tank mixing 0.03 kg/ha penoxsulam with 0.021 kg/ha carfentrazone or 0.42 kg/ha quinclorac improved ducksalad control from 78% to 82 and 87%, respectively. In water-seeded rice, penoxsulam 0.054 kg/ha and bispyribac controlled rice flatsedge (*Cyperus iria*) 87 and 88%, respectively. Lower rates of penoxsulam were not as effective as 0.054 kg/ha. However, tank mixing 0.030 kg/ha penoxsulam with carfentrazone improved flatsedge control from 80% to 88 and 85%. Bensulfuron did not control flatsedge. In dry-seeded rice, a preemergence application of 0.03 kg/ha penoxsulam plus 0.56 kg/ha clomazone controlled barnyardgrass (*Echinochloa crus-galli*) 90%, Amazon sprangletop (*Leptochloa panicoides*) 70%, rice flatsedge 86%, and hemp sesbania (*Sesbania exaltata*) 40% 2 WAF. Clomazone applied alone controlled barnyardgrass 60% and sprangletop 70% and did not control flatsedge or sesbania. Penoxsulam was more effective POST than PRE. At 6 WAF, barnyardgrass, flatsedge, and sesbania control was at least 85% when clomazone was followed by penoxsulam compared with only 60% barnyardgrass, 77% flatsedge, and no sesbania control from clomazone plus penoxsulam applied PRE. Cyhalofop plus penoxsulam applications resulted in good to excellent control of barnyardgrass, sprangletop, flatsedge, and sesbania control. Overall, weed control was best when penoxsulam was tank mixed with the first cyhalofop application. Penoxsulam at 0.035 kg/ha controlled alligatorweed (80%), as well as 0.28 kg/ha triclopyr at 4 WAT but dropped to less than 70% by 6 WAT. The best alligatorweed control, 90% 4 WAT and 85% 6 WAT, was observed from 0.054 kg/ha penoxsulam. Tank mixing low rates of penoxsulam with triclopyr did improve alligatorweed control over that observed with triclopyr alone. Overall, penoxsulam compared very well with standard herbicides and has the potential to control some important broadleaf weed problems in rice. Higher rates need to be evaluated, especially if substantial residual weed control is expected from PRE applications.

Economics of Effective Weed Control in Texas

McCauley, G.N., O'Barr, J.H., and Chandler, J.M.

Effective weed control and the associated cost are primary issues with Texas rice producers. Weeds reduce rice yields and grain quality. The objectives of this research were to determine the most effective weed control and the associated cost using selected commercially available herbicide programs. Studies were conducted near Beaumont, Eagle Lake, and Ganado, Texas, in 2003. The Beaumont site is located in Jefferson County on a League c, the Eagle Lake site is located in Colorado County on a Nada fsl, and the Ganado site is located in Jackson County on an Edna fsl. Cocodrie rice was planted on 9 April at Eagle Lake, 10 April at Ganado, and 15 April at Beaumont. At Eagle Lake and Ganado, rice was drill seeded to moisture (approximately 2 cm deep) then culti-packed prior to the preemergence application. At Beaumont, the rice was drill seeded to a depth of approximately 1 cm culti-packed prior to the preemergence application. The plots were then flushed to facilitate soil seed contact and germination. Rice was flush irrigated as necessary from this time until flood establishment at 6-leaf or 1-tiller. Fertility management was uniform across all plots and followed normal recommendations. Icon seed treatment was used for water weevil control. No other insect or disease controls were required. Five commercial early season herbicide treatments and six commercial preflood herbicide treatments were selected for evaluation. Untreated checks were included to evaluate weed species present and relative pressure. Applications were made preemergence, early postemergence, or late postemergence (preflood) based on the herbicide labels. The study was a split plot design with four replications. The late postemergence treatments were the main plots and the preemergence and early postemergence treatments were the subplots. Applications were made with a carbon dioxide back pack sprayer in a carrier volume of 187 l/ha. All combinations of the early and late treatments were evaluated for crop injury and weed control at each location. Ratings were taken at 7-d intervals starting 7-d after the application until flood establishment. Then, ratings were taken at 14-d intervals until 5% heading in the rice. Average herbicide and application costs were determined by surveying eight dealers.

Rice was harvested when the rice was between 180 to 200 g/kg grain moisture and grain yield was calculated on 120 g/kg grain moisture basis. Effective weed control was evaluated by 1) no significant yield reduction based on LSD (P=0.05) or 2) herbicide programs providing greater than 90% weed control for most of the rating period.

At Eagle Lake, the only rice injury occurred with Command applied preemergence. Injury ranged from 8 to 14% and was not detectable at 14 d. The dominate weed at Eagle Lake was broadleaf signalgrass with moderate pressure from annual sedge. Rice yield was not reduced using 21 of the 30 herbicide treatment programs. There was close agreement between the two evaluation systems. The only single applications not causing yield reductions were Bolero + Propanil early postemergence and Clincher applied late postemergence. Nineteen herbicide programs resulted in at least 90% weed control for at least three of the rating periods. These 19 were included in the 21 programs not reducing yield. The cost of the 21 programs ranged from about $78 to $233/ha as yields ranged from 6950 to 7850 kg/ha.

At Ganado, the only rice injury occurred with Command applied preemergence. Injury ranged from 8 to 14% and was not detectable at 14 d. Broadleaf signalgrass control was evaluated. Yield was not significantly reduced by 23 of the 30 herbicide programs. This was in close agreement with the 90% control method. No late postemergence application alone provided effective weed control. Single applications of Command preemergence and early postemergence applications of Command, Bolero + Propanil, and Bolero+Propanil+Facet all provided effective weed control. The cost of the 23 programs ranged from about $79 to $233/ha as yields ranged from 6850 to 7660 kg/ha.

At Beaumont, 10 to 12% rice injury was obtained with early postemergence applications of Bolero+Propanil and Bolero+Propanil+Facet. This injury was detectable during the first two ratings. The weed spectrum was more complex with barnyardgrass, hemp sesbania, and annual sedge. Rice yield was not significantly reduced using 19 of the herbicide programs. No single application at late postemergence provided effective control. Single, early postemergence applications of Bolero+Propanil and Bolero+Propanil+Facet resulted in no significant yield reduction. There was reasonable agreement between the two evaluation systems. The cost of effective control ranged from about $71 to $233/ha as yields ranged from 6700 to 7500 kg/ha.

Metabolomics of Tillering in Rice

Kebrom, T.H., Duran, A.L., Tarpley, L., and Sumner, L.W.

A metabolomics approach was pursued using rice (*Oryza sativa* L. cv. IR-36) to investigate the early- to mid-stage developmental events associated with tillering. Tillering during the seedling stage is known to be an important component of yield for rice. Previous studies of tillering have primarily involved morphology, developmental mutants, and agronomy. Little information is available that connects the environmental conditions leading to poor development, while in a genetic base with good tiller potential, to specific cellular- or tissue-level blocks in development. Metabolomics, by providing a (biochemically) large-scale profile of early tiller development, establishes a framework for specifying environmental effects on tiller bud initiation and early growth. We can then manipulate the genetics or growth regulator treatments to optimize tillering patterns under field conditions.

Seedlings were thinned for uniformity, then sampled in both time (2- to 4-day intervals) and space (2-mm intervals along the developing stem, with alternate sections used for metabolomics) starting 1 week after emergence, for a total of six sampling dates over a 12-day period that bridged the 3- to 5-leaf plant developmental stages. Each replicate contained tissue from an average of 50 seedlings, i.e. 2-mm sections from the same culm position for each of 50 seedlings. Sections were plunged directly into liquid nitrogen until all sections were collected. Sections were then stored at -80 C in nitrogen-purged vials until lyophilized for use in the metabolomics procedures. There were three replicates, each with sections from 50 seedlings.

Polar and lipophilic metabolite extractions were performed on each sample. The extracts were analyzed for metabolite composition using GC-MS (Hewlett Packard 6890 gas chromatograph, 5973 mass selective detector). All samples were injected in duplicate. Metabolites were identified using GC/MS spectra and database matching against the current National Institute of Standards and Technology library (NIST02) and custom databases of the Noble Foundation.

As a tiller bud develops, we would expect to see an early large deviation from the metabolite composition of the internode tissue. The ability to separate and interpret this deviation is critical to this study. The data were examined for both indicators of change in growth and development and indicators of change in underlying cellular regulation. Statistical analyses included descriptive statistics, and analysis of metabolite patterns using a combination of principal components analysis, hierarchical cluster analysis, correlation analyses, network analyses, and an “all possible ratios” approach to accentuate changes in metabolite distribution in time and space.

Polar metabolite analysis included 190 peaks. Lipophilic analysis included 187 peaks. Sucrose was the dominant peak in polar extracts. Galactose, glycerol, and linolenic acid were the dominant peaks in lipophilic extracts.

Abstracts of Posters on Rice Weed Control and Growth Regulation
Panel Chair: B.J. Williams and E. P. Webster

Rice Herbicide Residues in the Vacacaí River during the Rice Growing Season

Marchezan, E., Zanella, R., Machado, S.L.O., Ávila, L.A., Camargo, E.R.

The study of the environmental fate of rice pesticides is very important due to the proximity of the rice fields to water bodies and to the amount of water used in the field. The detection and quantification of pesticides in surface water will provide basis for management strategies to minimize the environmental impact.

Monitoring was carried out for 3 years (2000-2001, 2001-2002, and 2002-2003) in the Vacacaí and Vacacaí-Mirim Rivers, located in Rio Grande do Sul state, Brazil, to detect and quantify the residuals of clomazone, quinclorac, and propanil during the rice growing season. The samples were taken from 15 locations along the Vacacaí River and eight locations along the Vacacaí-Mirim River. The samples were taken in three places in the river profile, one in the center of the river and two on the edges. The samples were immediately sent to the laboratory for analyses. The herbicides were detected and quantified by HPLC/UV.

The water analyses showed that, in the first year of sampling, the herbicide concentrations were mostly below the limit adopted by the European Union, but in the second and the third year, an increase was observed in herbicide concentration, with an increase of the number of samples with level above 3 μg/L (ppb). This increase was probably due to low rainfall after herbicide application in the second year, reducing herbicide loss and in the third year due to a very intense rainfall that diluted the herbicide in the river. The herbicide clomazone was detected in a greater number of samples and was the most persistent in the water. The maintenance of water in the rice field and better water management to avoid loss of water are tools to reduce the input of herbicide residues in the rivers.

Herbicide Residues in Water of Irrigated Rice Fields

Machado, S.L.O., Zanella, R., Marchezan, E, Ávila, L.A., Primel, E.G., Goncalves, F.F., and Villa, S.C.C.

In Rio Grande do Sul state, in southern Brasil, rice production areas have been identified as potential nonpoint sources of surface water contamination; although, there are not enough data to prove this. To evaluate this possibility, in 2000/01, 2001/02, and 2002/03 rice growing seasons, a study to monitor the water quality in pregerminated rice fields was conducted. Four plots (16 m^2) had the herbicides bentazon (960 g/ha), clomazone (500 g/ha), propanil (3600 g/ha), quinclorac (375 g/ha), 2,4-D (200 g/ha), and metsulfuron-methyl (2 g/ha) applied. Water samples were collected before herbicide applications and in the 1^{st}, 2^{nd}, 3^{rd}, 5^{th}, 7^{th}, 10^{th}, 14^{th}, 21^{st}, 28^{th}, 35^{th}, and 60^{th} days after application. The extraction of herbicides from the water was carried out using a 500-mg C-18 solid phase extraction cartridge (SPE) and eluted two times with 0.5 ml of methanol. The herbicide quantification was determined in a HPLC with UV detector, using mobile phase water:methanol (1:1) and a C-18 column. The results showed that herbicide concentrations decreased with time of sampling and herbicide application. At the end of the first week, the concentration of the herbicides, excluding propanil and metsulfuron-methyl, were above 3 μg/L, which is the limit adopted by some environmental agencies. The results suggest that water should be retained inside the rice fields for propanil and metsulfuron-methyl for 7 days, 2,4-D for 10 days, quinclorac for 14 days, and bentazon for 21 days will reduce herbicides to safe levels. As a security measure, the water should be retained in the field for 30 days after herbicide application, mainly when using clomazone.

Acetolactate Synthase (ALS) Activity in Red Rice Ecotypes (*Oryza* spp.) and Imidazolinone Tolerant/Resistant Rice Cultivars (*Oryza sativa*) in Response to Imazethapyr Treatments

Avila, L.A., Lee, D.J., Senseman, S.A., McCauley, G.N., Chandler, J.M., and Cothren, J.T.

Imazethapyr has been effective in controlling red rice in imidazolinone tolerant rice. However, some red rice ecotypes have demonstrated tolerance to imazethapyr including the blackhull TX4. An experiment was conducted to determine if three red rice ecotypes have acetolactate synthase resistant to imazethapyr. The red rice ecotypes (LA5, MS5, and TX4) were compared with a tolerant ('CL121'), a resistant ('CL161'), and a conventional ('Cypress') rice variety. Based on enzymatic activity, the mean I_{50} values were 1.5, 1.1, 1.5, 1.6, 20.8, and 590.6 μM of imazethapyr, respectively, for LA5, MS5, TX4, Cypress, CL121, and CL161. Based on these values, CL161 was the most resistant of the plants tested and was 32 times more resistant than CL121 and approximately 447 times more resistant than the average of the red rice ecotypes and Cypress. The results indicated that CL161 resistance is probably due to an altered ALS enzyme. The red rice ecotypes did not differ from the Cypress cultivar and showed high susceptibility to imazethapyr when compared with the tolerant CL121 and the resistant CL161. This demonstrates that resistance to ALS-inhibiting herbicides has not yet developed in these red rice ecotypes as far as enzyme activity is concerned. Other mechanisms may be causing resistance, such as increased herbicide metabolism or differential absorption and translocation.

Risk Assessment and Genetic Analysis of Natural Outcrossing in Louisiana Commercial Fields Between Clearfield Rice and the Weed, Red Rice

Zhang, W., Linscombe, S.D., Webster, E.P., and Oard, J.H.

Red rice (*O. sativa* L.) is a noxious weed in Louisiana and other U.S. southern rice growing states that can significantly reduce grain yield and depress economic returns. The Clearfield varieties CL121 and CL141 were released in 2002 and grown in commercial fields for the first time in Louisiana to control red rice and other grass weeds. Because these varieties have the potential to hybridize with red rice, there is a need to determine the risk and consequences of outcrossing between the Clearfield varieties and different weedy biotypes. The objective of this research was to determine the timing and frequency of outcrossing between the Clearfield varieties CL121, CL141, and various red rice biotypes collected in Louisiana commercial fields. During 2002, mature seed and data for six agronomic traits were collected from each of 100 randomly sampled red rice biotypes at each of 12 commercial Clearfield sites in southwest Louisiana. A majority (75%) of the sites produced red rice plants that flowered at about the same time as the commercial variety. Red rice infestation varied considerably, from 0.5 to 50.0%, across the 12 locations. Extensive variation was detected among red rice biotypes for all six measured agronomic characters. In April 2003, seed from the red rice biotypes and Clearfield varieties collected the previous year from all locations were drill-seeded in single rows at the LSU AgCenter Ben Hur Farm, Baton Rouge, LA. Seedlings at the 2-leaf stage were sprayed with a 2X field-use rate of Newpath herbicide followed 10 days later with an additional 2X Newpath application. CL121 and CL141 survived the Newpath treatments, although growth rate and maturity were slowed compared with unsprayed controls. A total of 81 out of 46,629 seedlings (0.2%) survived the Newpath applications and tillered profusely but never flowered during the normal growing season. All 81 plants exhibited rough leaves while the Clearfield varieties were smooth. An *in vitro* enzyme assay revealed that all 81 Newpath-tolerant plants after spraying showed high activity at the predicted herbicide site of action (acetohydroxyacid synthase [AHAS]) while the Clearfield variety controls were sensitive. One location produced 42% of all herbicide-tolerant plants evaluated while no red rice-Clearfield hybrids were detected at four locations. Hybrid F_1 plants, produced from controlled crosses of Clearfield varieties and 30 randomly selected red rice biotypes were extremely tall compared with commercial varieties and never flowered during the growing season. Results from this study suggest that outcrossing did occur at low rates of < 1% between the Clearfield varieties and red rice biotypes. Results from this study should provide guidance and insight to management strategies that will prolong effective use of Clearfield technology.

Challenges in Developing Commercially Acceptable Weed Suppressive Rice Cultivars for the Southern United States

Gealy, D.R., Black, H.L., and Moldenhauer, K.A.

Weed control remains a key challenge to profitable rice production systems in the United States. In previous screening efforts, rice cultivars (e.g. PI 312777 and PI 338046) with good to excellent weed suppressive characteristics were identified from world rice collections as potential components of reduced herbicide systems. Although grain yields and weed suppression levels for these lines have sometimes been promising, other agronomic characteristics and grain quality characteristics generally have not been commercially acceptable. Thus, a rice breeding program was initiated to combine the desirable grain quality and agronomic characteristics of the commercial rice 'Katy' with the weed suppression potential of PI 338046 and PI 312777. In drill-seeded field plots, F_5 or later generations of PI 338046/Katy crosses and PI 312777/(PI 338046/Katy) crosses were evaluated along with the original parental lines, as well as additional commercial and weed suppressive rice standards. Plots were sprayed postemergence with 1.1 kg/ha propanil, one fourth of the standard use rate. Plant height, days to heading, tiller production, grain yield, milling quality, lodging potential, and visual control of barnyardgrass were among the characteristics evaluated. Certain selections from these original crosses produced commercially acceptable yields and moderately elevated levels of weed suppression. However, these selections generally yielded less than their commercial parents and suppressed barnyardgrass less than their suppressive cultivar parents.

Roundup Drift Problems

Kurtz, M.E. and Street, J.E.

Field studies were conducted from 1996 to 2000 to determine the effect of Roundup Ultra [glyphosate (isopropyl amine salt)] on rice injury and yield when applied postemergence to dry-seeded rice to simulate drift. There were 16 treatments in a randomized complete block design with a factorial treatment structure of 4 growth stages x 4 herbicide rates. Soil type was Sharkey clay (very fine, montmorillonitic, nonacid, thermic Vertic Haplaquept) with a pH of 7.0 and 1.4% OM. Rice was dry-seeded at 100 kg/ha in drills spaced 20 cm apart. Plots were 2.4 m wide and 4.5 m long. Roundup rates were 0, 70, 140, 280, 560, and 1120 g ai/ha. The rates of 560 and 1120 g/ha resulted in rice mortality at all growth stages in 1996 and these rates were discontinued.

Roundup at 140 and 280 g/ha applied at the 3- to 4- leaf, mid-tiller, and panicle initiation growth stages resulted in the greatest visible injury, and 280 g/ha was more injurious than 140 g/ha. Roundup treatments were the least visibly injurious to rice when applied at the boot stage. Rough rice yield was reduced by Roundup applied at 280 g/ha to rice in the mid-tiller growth stage 3 out of 4 years. Applied to rice in the panicle initiation stage, Roundup at 140 g/ha reduced yields 2 out of 4 years and 3 out of 4 years when applied at 280 g/ha. Boot stage applications of Roundup at 70, 140, and 280 g/ha reduced yields 2 out of 4, 3 out of 4, and 4 out of 4 years, respectively.

In general, visible rice injury was not correlated with yield losses except at the high rate of 280 g/ha at the mid-tiller and panicle initiation growth stages. Yield losses were consistently higher at the boot growth stage, yet visible rice injury was the least at this stage. Conversely, visible injury at the 3- to 4- leaf stage at 140 and 280 g/ha of Roundup was high yet there were no consistent yield losses. Though rice yields varied between years, which may be attributed to cultivar response differences, it is clear that a drift rate of 280 g/ha onto rice in the mid-tiller, panicle initiation, or boot growth stages will most likely result in significant rice yield reductions. At 280 g/ha, simulated drift rate onto rice in the mid-tiller, panicle initiation, and boot stages reduced yields 3 out of 4, 3 out of 4, and 4 out of 4 years, respectively. Similarly, a drift rate of Roundup at 140 g/ha onto rice in the panicle initiation and boot stages reduced yields 2 out of 4 and 3 out of 4 years, respectively. Even 70 g/ha applied at the boot stage reduced yields 2 out of 4 years. It is also apparent that the most susceptible growth stages associated with yield loss are the panicle initiation and boot stages, with the boot stage more susceptible than the panicle initiation stage. This indicates a need for some measure to indicate injury other than visible foliar symptoms.

Penoxsulam (XDE-638) for Rice Weed Control

Ottis, B.V., Lassiter, R.B., Malik, M.S., and Talbert, R.E.

Two studies were established during the summer of 2003 at the Rice Research and Extension Center near Stuttgart, AR, to evaluate the potential of penoxsulam (XDE-638) as part of a rice weed control program. XDE-638 was recently granted Reduced Risk Pesticide Status by the EPA. It is a member of the triazolopyrimidine sulfonamide family of herbicides, which inhibit the acetolactate synthase (ALS) enzyme of susceptible species. In Study 1, XDE-638 applied alone and in tank mixtures early postemergence (EPOST) (2-lf rice, 1-lf grass, 2-lf weeds) was evaluated while Study 2 evaluated XDE-638 applied alone and in tank mixtures mid postemergence (MPOST) (4- lf rice, 3- to 4-lf grass, 3-lf weeds) following a preemergence application of clomazone. Plots were established in a randomized complete block design with four replications. The rice variety 'Francis' was drill-seeded at 78 kg/ha. Weeds evaluated were barnyardgrass (*Echinochloa crus-galli*), broadleaf signalgrass (*Brachiaria platyphylla*), hemp sesbania (*Sesbania exaltata*), northern jointvetch (*Aeschynomene virginica*), and pitted morningglory (*Ipomoea lacunosa*). A CO_2 backpack sprayer calibrated to deliver 93 l/ha was used for all applications.

In Study 1, barnyardgrass control was at least 99% at 21 days after treatment (DAT) with XDE-638 alone and in tank mixtures with clomazone, clomazone + cyhalofop-butyl, and propanil. Hemp sesbania, northern jointvetch, and pitted morningglory control was less than 30% with XDE-638 combinations, while propanil + quinclorac provided 63% control of these weeds. Yields ranged from 7120 to 8580 kg/ha, with the treatment of XDE-638 + propanil having a significantly higher yield than treatments of XDE-638 alone, XDE-638 + clomazone, or propanil + quinclorac. In Study 2, barnyardgrass control was at least 95% with applications of clomazone PRE alone or followed by (fb) XDE-638, XDE-638 + cyhalofop-butyl, XDE-638 + quinclorac, XDE-638 + propanil, cyhalofop-butyl, or an application of propanil + quinclorac. Broadleaf signalgrass control was 84% when XDE-638 was applied alone or in combination with propanil, quinclorac, or cyhalofop-butyl MPOST fb clomazone PRE. The treatment of clomazone PRE fb propanil + quinclorac MPOST controlled broadleaf signalgrass 100%. XDE-638 applied alone or with cyhalofop-butyl MPOST fb clomazone PRE provided less than 65% hemp sesbania control. Hemp sesbania control was 100% with XDE-638 + quinclorac or propanil MPOST fb clomazone PRE. Pitted morningglory control was 36% with clomazone PRE fb XDE-638 MPOST. Applications of clomazone fb XDE-638 + propanil or quinclorac increased pitted morningglory control to 74 and 85%, respectively. There were no significant differences in yield observed among XDE-638 treatments, with yields ranging from 7010 to 7420 kg/ha.

Evaluation of Newpath Tank Mixes with Selected Herbicides for Weed Control in Rice

Williams, B.J., Copes, D.B., and Burns, A.B.

Newpath (imazethapyr) tank mixes with selected herbicides were evaluated in 2003 at the Northeast Research Station near St. Joseph, Louisiana, on a Sharkey clay soil. Imazethapyr at 0.07 kg ai/ha was applied preemergence and followed by a second application of 0.07 kg ai/ha imazethapyr at the 4- to 5-leaf rice stage. The first imazethapyr application was made alone or with 0.42 kg ai/ha clomazone, 1.12 kg ai/ha pendimethalin, 3.36 kg ai/ha thiobencarb, or 0.32 kg ai/ha quinclorac. The second imazethapyr application was made alone or tank mixed with 0.028 kg ai/ha carfentrazone, 0.042 kg ai/ha bensulfuron, 0.052 kg ai/ha halosulfuron, 0.032 kg ai/ha bensulfuron plus 0.026 kg ai/ha halosulfuron, or 0.026 kg ai/ha bispyribac. Herbicide treatments were applied, using a CO_2 pressurized backpack sprayer calibrated to deliver 140 l/ha, to plots measuring 2 x 4.5 m. Clearfield rice 'CL161' was drill-seeded at 101 kg/ha on 19-cm spacing into stale seedbeds. Plots were flushed as needed and permanent floods were established 5 weeks after planting (WAP). The experimental design for the experiments was a randomized complete block with a factorial treatment arrangement. Weed control ratings, rice injury ratings, and rice yield data were subjected to analysis of variance. Means were separated using Fisher's Protected LSD at the 5% level. Barnyardgrass (*Echinochloa crus-galli*) control 4 weeks after flood (WAF) was improved 10 to 18% when the soil application of imazethapyr was mixed with clomazone, pendimethalin, thiobencarb, or quinclorac and the second application was applied alone. When the second imazethapyr application following imazethapyr plus clomazone or thiobencarb was mixed with carfentrazone, bensulfuron, or halosulfuron barnyardgrass control was reduced 7 to 30%. Following imazethapyr plus pendimethalin with imazethapyr plus carfentrazone or bensulfuron reduced barnyardgrass control from 95 to 83 and 87%, respectively. Following imazethapyr plus quinclorac with imazethapyr plus halosulfuron or bensulfuron reduced barnyardgrass control from 88 to 77 and 78%, respectively.

Barnyardgrass control 8 WAF was improved 37 to 42% when the soil application of imazethapyr was mixed with clomazone, pendimethalin, thiobencarb, or quinclorac and the second application was applied alone. Many of the reductions in barnyardgrass control observed at 4 WAF when the second application of imazethapyr was mixed with some herbicides were minimized by 8 WAF. However, some reductions in barnyardgrass control were still observed. Following imazethapyr plus clomazone or pendimethalin with imazethapyr plus carfentrazone or halosulfuron reduced barnyardgrass control 5 to 16%. Following imazethapyr plus quinclorac with imazethapyr plus halosulfuron or bensulfuron reduced barnyardgrass control from 82 to 77 and 78%, respectively. Amazon sprangletop (*Leptochloa panicoides*) control 4 WAF was improved 7 to 12% when the soil application of imazethapyr was mixed with clomazone, pendimethalin, or thiobencarb and the second application was applied alone. With the exception bensulfuron, mixing the second imazethapyr application with broadleaf herbicides did not affect sprangletop control. Annual sedge (*Cyperus compressus*) control was good to excellent when imazethapyr was applied alone or tank mixed with any of the herbicides. Mixing the soil application of imazethapyr with pendimethalin, clomazone, thiobencarb, or quinclorac did not improve hemp sesbania (*Sesbania exaltata*) control 4 or 8 WAF. Mixing the second application of imazethapyr with carfentrazone, halosulfuron, bensulfuron plus halosulfuron, or bispyribac improved sesbania control to 90% or better. Overall, imazethapyr plus pendimethalin followed by imazethapyr plus carfentrazone or halosulfuron resulted in the best barnyardgrass, sprangletop, sedge, and sesbania control. The presence and size of weeds were strongly influenced by the soil program. Thus, many of the reductions in weed control may not have been observed if second imazethapyr application timing had been modified for each soil program.

Effect of Newpath Rate and Timing on Weed Control in Rice

Burns, A.B., Williams, B.J., and Copes, D.B.

The effect of Newpath (imazethapyr) rate and timing on barnyardgrass (*Echinochloa crus-galli*) control in Clearfield rice was evaluated in 2002 and 2003 at the Northeast Research Station near St. Joseph, La. on a Sharkey clay soil. Newpath was applied at 0.15, 0.30, 0.45, 0.60, and 1.2 l/ha to 1- to 2-, 2- to 3-, 3- to 4-, 4- to 5-leaf, and 1- and 2-tiller barnyardgrass. To prevent additional barnyardgrass flushes, 1 lb ai/A pendimethalin was applied 3 days after each Newpath application. In 2002, the 2- to 3-leaf applications were made 8 days after the 1- to 2-leaf applications. The 2- to 3-leaf applications were followed by the 3- to 4-leaf applications 1 day later, and the 4- to 5-leaf applications were made the next day. The 1-tiller applications were made 4 days after the 4- to 5-leaf applications. The 2-tiller applications were made 8 days after the 1-tiller applications. Clearfield rice 'CL161' at 124 kg/ha was drill seeded in rows 19 cm apart. Permanent floods were established 4 to 5 weeks after planting. Nitrogen, in the form of prilled urea, was applied at 126 kg/ha just before permanent flood. Herbicide treatments were applied in water using a CO_2 pressurized backpack sprayer calibrated to deliver 140 l/ha plots measuring 2.1 x 4.6 m. The experimental design was a randomized complete block with a factorial treatment arrangement. Barnyardgrass control ratings were subjected to analysis of variance. Means were separated using Fisher's Protected LSD at the 5% level. Newpath application timing affected barnyardgrass control more than application rate. Overall, barnyardgrass control was best when Newpath applications were made at or before the 2- to 3-leaf stage. Control, especially at 6 and 9 weeks after treatment (WAT), declined rapidly as Newpath applications were made to increasingly larger barnyardgrass. Barnyardgrass control was 90% or better when Newpath was applied at the 1- to 2-leaf stage, regardless of Newpath rate. When Newpath applications were made at the 2- to 3-leaf stage, at least 0.3 l/ha of Newpath was required for 85% or better control. At 3 WAT, barnyardgrass control was similar when 0.15 to 0.30 l/ha Newpath was applied at the 3- to 4- and 4- to 5-leaf stages. Increasing Newpath rates to 0.45 l/ha improved barnyardgrass control 10 to 20% when applications were made at the 4- to 5-leaf stage. Barnyardgrass control 6 WAT generally increased as Newpath rate increased up to 0.45 l/ha. At least 0.60 l/ha was required for 80% barnyardgrass control 6 WAT when applied at the 4- to 5-leaf stage. After tillering, not even 1.2 l/ha Newpath resulted in better than 80% barnyardgrass control 3 WAT or 60 to 70% control 6 WAT. Results were similar in 2003. This research indicates that barnyardgrass control with Newpath is strongly influenced by application timing and applications should be made at or before 3- to 4-leaf stage.

Evaluation of Clincher Tank Mixes with Selected Herbicides for Weed Control in Rice

Copes, D.B., Williams, B.J., and Burns, A.B.

Clincher (cyhalofop) tank mixes with selected herbicides were evaluated in 2003 at the Northeast Research Station near St. Joseph, Louisiana, on a Sharkey clay soil. One water-seeded study and two dry-seeded studies were conducted. The treatments were 0.27 kg ai/ha cyhalofop plus 0.028 kg ai/ha carfentrazone, 0.14 kg ai/ha acifluorfen, 0.85 kg/ha bentazon, acifluorfen + bentazon, 0.042 kg ai/ha bensulfuron, 0.033 kg ai/ha halosulfuron, 0.032 kg ai/ha bensulfuron + 0.013 kg ai/ha halosulfuron, or 0.04 kg ai/ha penoxsulam in the water seeded trail. Cyhalofop plus each tank mix partner was applied at the 1- to 2-leaf rice stage. A second 0.25 kg ai/ha cyhalofop application was made at the 4- to 5-leaf rice stage. The treatments in the first dry-seeded trial were 0.25 kg ai/ha cyhalofop applied when rice was at the 2- to 3-leaf stage followed by (fb) a second application of 0.27 kg ai/ha cyhalofop at the 4- to 5-leaf stage. Carfentrazone at 0.028 kg ai/ha, 0.21 kg ai/ha triclopyr, 0.022 kg ai/ha bispyribac, or 0.042 kg ai/ha bensulfuron was tank mixed with cyhalofop at either the first or second timing. The treatments in the other dry-seeded trial were 0.21 kg ai/ha cyhalofop applied when rice was at the 2- to 3-leaf stage fb a second application of 0.31 kg ai/ha cyhalofop at the 4- 5-leaf stage. The first cyhalofop application was made alone or with 1.12 kg ai/ha pendimethalin, 0.42 kg ai/ha clomazone, 0.32 kg ai/ha quinclorac, or 3.36 kg ai/ha thiobencarb. The second cyhalofop application was made alone or tank mixed with carfentrazone at 0.028 kg ai/ha, 0.21 kg ai/ha triclopyr, 0.022 kg ai/ha bispyribac, or 0.042 kg ai/ha bensulfuron. Herbicide treatments were applied, using CO_2 pressurized backpack sprayer calibrated to deliver 140 l/ha, to plots measuring 2 x 4.5 m. 'Cocodrie' was drill seeded at 101 kg/ha on a 19-cm spacing in dry-seeded rice and broadcast at 170 kg/ha in water-seeded rice. After draining the seeding flood, plots were flushed weekly and flooded 4 weeks after planting in the water-seeded rice trial. In the dry-seeded trials, plots were flushed as needed and flooded 5 weeks after planting. The experimental design was a randomized complete block with a factorial treatment arrangement. Weed control ratings, rice injury ratings, and rice yield data were subjected to analysis of variance. Means were separated using Fisher's Protected LSD at the 5% level. At the 1- to 2-leaf stage, barnyardgrass (*Echinochloa crus-galli*) control was reduced from 95% to 88 and 82% in water-seeded rice when cyhalofop was applied with bensulfuron and halosulfuron, respectively. There was no difference in barnyardgrass control fb the second cyhalofop application. Cyhalofop plus bentazon, bensulfuron, or penoxsulam did a good job of controlling ducksalad (*Heteranthera limosa*). Cyhalofop plus halosulfuron, carfentrazone, and acifluorfen did not control ducksalad. Cyhalofop plus carfentrazone controlled purple ammania (*Ammannia coccinea*) 70 to 80%. Cyhalofop plus acifluorfen, bentazon, bensulfuron, halosulfuron, or penoxsulam did a good job of controlling purple ammania. In dry-seeded rice, applying cyhalofop plus carfentrazone, triclopyr, or bensulfuron at the 2- to 3-leaf stage reduced barnyardgrass control from 85% to 80, 78, and 67%, respectively. After the second cyhalofop application there was no reduction in control when cyhalofop was mixed with carfentrazone. Cyhalofop plus bispyribac did an excellent job of controlling barnyardgrass. Cyhalofop plus carfentrazone, triclopyr, bispyribac, or bensulfuron applied at the 2- to 3-leaf stage did an excellent job of controlling hemp sesbania (*Sesbania exaltata*), rice flatsedge (*Cyperus iria*), spreading dayflower (*Commelina diffusa*), and eclipta (*Eclipta prostrate*) in dry-seeded rice. Occasionally, tank mixing cyhalofop with a residual herbicide at the 2- to 3-leaf timing reduced the antagonism between cyhalofop and broadleaf herbicides at the 4- to 5-leaf timing. Barnyardgrass control was 90% or better when cyhalofop plus clomazone or pendimethalin at the 2- to 3-leaf stage was fb cyhalofop plus carfentrazone, triclopyr, bispyribac, or bensulfuron at the 4- to 5-leaf stage. Barnyardgrass control was not as consistent when cyhalofop was mixed with thiobencarb or quinclorac. Amazon sprangletop (*Leptochloa panicoides*) control was excellent when cyhalofop was mixed with a residual herbicide and followed by cyhalofop plus the broadleaf herbicides. Surprisingly, applying cyhalofop plus pendimethalin, clomazone, thiobencarb, or quinclorac reduced broadleaf weed control in many cases. Differences in control were largely due to the differences in the ability of residual herbicides to provide some level of broadleaf control, which resulted in some weeds being larger or absent when the second application was made. Palmleaf morninnglory (*Ipomoea wrightii*) and tall waterhemp (*Amaranthus tuberculatus*) control was excellent when cyhalofop was mixed with a residual herbicide and fb cyhalofop plus any of the broadleaf herbicides. Overall, in water-seeded rice, these data suggest that cyhalofop tank mixes with carfentrazone, acifluorfen, bentazon, bispyribac, bensulfuron, halosulfuron, or penoxsulam are possible when a second cyhalofop application is planned. Despite some success, these data suggest that the antagonism between cyhalofop and broadleaf herbicides cannot be minimized simply by making the applications earlier.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2006 MEETING

Beginning with the Proceedings for the 24th Rice Technical Working Group meetings, Desktop Publishing software was chosen as a means for expediting the post-meeting publication process. To accomplish this move, Microsoft Word (Windows) has been identified as the preferred word processing software to be used. If individuals do not have access to MS Word, submission of materials in ASCII format (DOS compatibility is essential) is acceptable. **Each electronic file should include: 1) title of materials, 2) corresponding RTWG panel, 3) corresponding author's name, daytime telephone number, e-mail address, and 4) computer format** (i.e., MS Word and version number). These criteria apply uniformly to 1) presented paper abstracts, 2) poster abstracts, 3) symposia abstracts, 4) panel recommendations, and 5) list of panel participants. More details with respect to each of these items follow below.

As soon as a web page is established by the host state, a link will be provided to the Rice Research Station web page where current submission instructions will be maintained.

Presented Paper, Poster, and Symposia Abstracts

To be published in the printed proceedings, presented paper, poster, and symposia abstracts for the 31st RTWG meetings must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the proceedings.

1. Both a paper copy and an electronic file are required. Hard copy and electronic file are to be submitted to the respective panel chairs 2 ½ months prior to the 31st RTWG meeting in 2006, or earlier as stated in the Call for Papers issued by the 31st RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2006 RTWG meeting and their email and mailing addresses are presented on page 206. In case of other questions or in the absence of being able to access the Call for Papers, contact:

   Dr. Don Groth
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   1373 Caffey Road
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2. Margins: Set 1-inch for side margins; 1-inch top margin; and 1-inch bottom margin. Use a ragged right margin (do not full justify) and do not use hard carriage returns except at the end of paragraphs.

3. Type: Do not use any word processing format codes to indicate boldface, etc. **Use 10 point Times New Roman font**.

4. Heading:
   a. Title: Center and type in caps and lower case.
   b. Authors: Center name(s) and type in caps and lower case with last name first, then first and middle initials, with no space between the initials (e.g., Groth, D.E.).
   c. Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

5. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

6. Content is limited to one page.
    a. Include a statement of rationale for the study.
    b. Briefly outline methods used.
    c. Summarize results.

7. **Tables and figures are not allowed**.

8. **Literature citations are not allowed**.

9. **Use the metric system of units**. English units may be shown in parentheses.

10. **When scientific names are used, *italicize* them -- do not underline.**

Special Instructions to Panel Chairs

Each panel chair is responsible for collecting all of his/her panel abstracts prior to the 31st RTWG meetings. The appropriate due date will be identified in the Call for Papers for the 31st RTWG meetings. **Each panel chair is responsible for assembling his/her panel abstracts into one common MS Word file that is consistent with the above guidelines, with the abstracts appearing in the order presented. Paper abstracts will be presented first and poster abstracts second. A Table of Contents should be included with each panel section. Panel chairs are responsible for editing all abstracts for their panel.** A common file should be developed prior to the beginning of the 31st RTWG meeting and submitted to D.E. Groth or M.E. Salassi, RTWG Publications Coordinators, to accommodate preliminary preparation of the proceedings prior to the meeting. These materials will be merged in the final proceedings in the format submitted. Final editing will be done by the Publication Coordinators, Rice Research Station secretarial staff, and the incoming Chair.

In addition, panel chairs are to prepare and submit both a paper copy and MS Word computer file version of the (1) final Panel Recommendations and (2) a list of panel participants by the conclusion of the meetings. A copy of the previous recommendations and panel participants will be provided to each panel chair prior to the meetings.

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GUIDELINES FOR RTWG AWARDS

1.0 The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

1.1 The Distinguished Rice Research and/or Education Award

1.1a Individual category – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one or more of the following: (1) significant and original basic and/or applied research, (2) creative reasoning and skill in obtaining significant advances in education programs, public relations, or administrative skills - which advance the science, motivate progress and promise technical advances in the rice industry.

1.1b. Team category – Same as the individual category, except that one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

1.2 The Distinguished Service Award - Awards to be made to designated individuals who have given distinguished long-term service to the rice industry in areas of research, education, international agriculture, administration, and industrial rice technology. Although the award is intended to recognize contributions of a long duration, usually upon retirement from active service, significant contributions over a period of several years shall be considered as a basis of recognition.

2.0 The Awards Committee shall consist of the Executive Committee.

3.0 The duties of the Awards Committee are as follows:

3.1 To solicit nominations for the awards in advance of the biennial meeting of the RTWG. Awards Committee Members cannot nominate or write letters of support for an individual or team for the RTWG awards.

3.2 To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority vote. The Awards Committee Chair (same as the Executive Committee Chair) can only vote in case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

3.3 The Awards Committee shall arrange for a suitable presentation at the Biennial RTWG Meeting.

3.4 The Awards Committee shall select appropriate certificates for presentation to the recipients of the Awards.

4.0 Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three (3) recommendation letters. Fifteen (15) complete copies of each nomination must be submitted. A one-page summary of accomplishments should also be included with each nomination. This summary will be published in the RTWG Proceedings for each award participant.

4.1 Nominees for awards should be staff personnel of Universities or State Agricultural Experiment Stations, State Cooperative Extension personnel, cooperating agencies of the United States Department of Agriculture, or participating rice industry groups.

4.2 A member of an organization, described in 4.1, may nominate or co-nominate two persons.

4.3 Nominations are to be sent to the Awards Committee for appropriate committee consideration.

4.4 The deadline for receipt of nominations shall be three months preceding the biennial meeting.

4.5 Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

Past RTWG Award Recipients

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients
1972	D.F. Houston	L.B. Ellis	None
Davis, CA	R.D. Lewis	H.M. Beachell	
	N.E. Jodon	C.R. Adair	
	E.M. Cralley	W.C. Dachtler	
1974	J.G. Atkins	R.A. Bieber	None
Fayetteville, AR	N.S. Evatt	J.T. Hogan	
	M.D. Miller	B.F. Oliver	
	T. Wassermand		
1976	D.H. Bowman	T.H. Johnston	None
Lake Charles, LA	R.F. Chandler	M.C. Kik	
	J.N. Efferson	X. McNeal	
	J.P. Gaines		
1978	J.W. Sorenson, Jr.	D.T. Mullins	R.K. Webster
College Station, TX	R. Stelly		
1980	M.L. Peterson	W.R. Morrison	B.D. Webb
Davis, CA	L.E. Crane	F.T. Wratten	

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			Arkansas 'Get the Red Out' Team	
1982 Hot Springs, AR	C.C. Bowling J.P. Craigmiles	L. Drew	R.J. Smith, Jr. F.L. Baldwin	B.A. Huey
1984	M.D. Morse	E.A. Sonnier	California Rice Varietal Improvement Team	
Lafayette, LA	L.C. Hill	D.L. Calderwood	H.L. Carnahan	J.N. Rutger
			C.W. Johnson	S.T. Tseng
			J.E. Hill	J.F. Williams
			C.M. Wick	S.C. Scardaci
			D. M. Brandon	
1986	D.S. Mikkelsen	J.B. Baker	Texas Rice Breeding and Production Team	
Houston, TX			C.N. Bollich	B.D. Webb
			M.A. Marchetti	G.N. McCauley
			J.E. Scott	J.W. Stansel
			F.T. Turner	A.D. Klosterboer
			E.F. Eastin	M.O. Way
			N.G. Whitney	M.E. Rister

Continued.

Past RTWG Award Recipients
(continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1988	M.D. Androus	H.L. Carnahan	Arkansas DD-50 Team	
Davis, CA	S.H. Holder	B.A. Huey	N.R. Boston	G.L. Davis
	M.D. Faulkner	W.R. Grant	F.N. Lee	N.P. Tugwell
	C.H. Hu	F.J. Williams	D.A. Downey	G.L. Greaser
			T.H. Johnson	G. Rench
			B.R. Wells	M.S. Flynn
			B.A. Huey	T.C. Keisling
			R.J. Smith	F.J. Williams
			D. Johnson	
1990	H.R. Caffey	B.R. Jackson	None	
Biloxi, MS	O.R. Kunze			
1992	C.N. Bollich	A.A. Grigarick	J.W. Stansel	
Little Rock, AR	B.D. Webb	C.M. Wick		
1994	S.H. Crawford	K. Grubenman	M.C. Rush	
New Orleans, LA	J.V. Halick	R.N. Sharp		
	R.J. Smith			

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1996 San Antonio, TX	P. Seilhan	K. Tipton	D.M. Brandon	
1998 Reno, NV	G. Templeton S.-T. Tseng	B. Wells	S.D. Linscombe	
			Advances in Rice Nutrition Team	
2000 Biloxi, MS	D.M. Brandon J.W. Stansel	R.K. Webster	P.K. Bollich R.J. Norman	C.E. Wilson
			Bacterial Panicle Blight Discovery Team	
2002 Little Rock, AR	F.L. Baldwin R.H. Dilday	M.A. Marchetti J.F. Robinson	M.C. Rush	D.E. Groth A.K.M. Shahjahan
			Individual	
			K.A.K. Moldenhauer	
			Discovery Characterization and utilization of Novel Blast Resistance Genes Team	
2004 New Orleans, LA	P.K. Bollich A.D. Klosterboer F.N. Lee W.H. Brown	J.A. Musick J.E. Street J.F. Williams S.L. Wright	F.N. Lee A.K. Moldenhauer	M.A. Marchetti
			Individual	
			R.D. Cartwright	

RICE TECHNICAL WORKING GROUP HISTORY

Meeting	Year	Location	Chair	Secretary	Publication Coordinator(s)
1st	1950	New Orleans, Louisiana	A.M. Altschul		
2nd	1951	Stuttgart, Arkansas	A.M. Altschul		
3rd	1951	Crowley, Louisiana	A.M. Altschul		
4th	1953	Beaumont, Texas	W.C. Davis		
5th	No meeting was held.				
6th	1954	New Orleans, Louisiana	W.V. Hukill		
7th*	1956	Albany, California	H.T. Barr	W.C. Dachtler	--
8th	1958	Stuttgart, Arkansas	W.C. Dachtler	--	--
9th	1960	Lafayette, Louisiana	D.C. Finfrock	H.M. Beachell	--
10th	1962	Houston, Texas	H.M. Beachell	F.J. Williams	--
10th	1964	Davis, California	F.J. Williams	J.T. Hogan	--
11th	1966	Little Rock, Arkansas	J.T. Hogan	D.S. Mikkelsen	--
12th	1968	New Orleans, Louisiana	M.D. Miller	T.H. Johnston	--
13th	1970	Beaumont, Texas	T.H. Johnston	C.C. Bowling	--
14th	1972	Davis, California	C.C. Bowling	M.D. Miller	J.W. Sorenson*
15th	1974	Fayetteville, Arkansas	M.D. Miller	T. Mullins	J.W. Sorenson
16th	1976	Lake Charles, Louisiana	T. Mullins	M.D. Faulkner	J.W. Sorenson
17th	1978	College Station, Texas	M.D. Faulkner	C.N. Bollich	O.R. Kunze
18th	1980	Davis, California	C.N. Bollich	J.N. Rutger	O.R. Kunze
19th	1982	Hot Springs, Arkansas	J.N. Rutger	B.R. Wells	O.R. Kunze
20th	1984	Lafayette, Louisiana	B.R. Wells	D.M. Brandon	O.R. Kunze
21st	1986	Houston, Texas	D.M. Brandon	B.D. Webb	O.R. Kunze
22nd	1988	Davis, California	B.D. Webb	A.A. Grigarick	O.R. Kunze
23rd	1990	Biloxi, Mississippi	A.A. Grigarick	J.E. Street	O.R. Kunze
24th	1992	Little Rock, Arkansas	J.E. Street	J.F. Robinson	M.E. Rister
25th	1994	New Orleans, Louisiana	J.F. Robinson	P.K. Bollich	M.E. Rister
26th	1996	San Antonio, Texas	P.K. Bollich	M.O. Way	M.E. Rister M.L. Waller

Continued.

RICE TECHNICAL WORKING GROUP HISTORY
(Continued)

Meeting	Year	Location	Chair	Secretary	Publication Coordinator(s)
27th	1998	Reno, Nevada	M.O. Way	J.E. Hill	M.E. Rister M.L. Waller
28th	2000	Biloxi, Mississippi	J.E. Hill	M.E. Kurtz	P.K. Bollich D.E. Groth
29th	2002	Little Rock, Arkansas	M.E. Kurtz	R.J. Norman	P.K. Bollich D.E. Groth
30th	2004	New Orleans, Louisiana	R.J. Norman	D.E. Groth	P.K. Bollich D.E. Groth

- 1972 was the first year that an official Publication Coordinator position existed within the RTWG. Prior to that, the Secretary assembled and coordinated the publication of the meeting proceedings.

The previous Memorandum of Agreement is published in the 22nd RTWG Proceedings in 1988. The following is a revised Memorandum of Agreement accepted by the 26th RTWG membership in 1996.

REVISED MEMORANDUM OF AGREEMENT
FEBRUARY, 1996

INFORMAL UNDERSTANDING

among

THE STATE AGRICULTURAL EXPERIMENT STATIONS

and

THE STATE AGRICULTURAL EXTENSION SERVICES

of

ARKANSAS, CALIFORNIA, FLORIDA, LOUISIANA, MISSISSIPPI,
MISSOURI, AND TEXAS

and

THE AGRICULTURAL RESEARCH SERVICE,
THE ECONOMIC RESEARCH SERVICE,
THE COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

and

OTHER PARTICIPATING AGENCIES

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

and

COOPERATING RICE INDUSTRY AGENCIES

Subject: Research and extension pertaining to the production, utilization, and marketing of rice and authorization of a Rice Technical Working Group.

It is the purpose of this memorandum of agreement to provide a continuing means for the exchange of information, cooperative planning, and periodic review of all phases of rice research and extension being carried on by State Agricultural Experiment Stations, State Agricultural Extension Services, the United States Department of Agriculture, and participating rice industry groups. It is believed this purpose can best be achieved through a conference held at least biennially at the worker level of those currently engaged in rice research and extension. Details of the cooperation in the several States are provided in formal Memoranda of Understanding and/or appropriate Supplements executed for the respective state.

The agencies represented in this memorandum mutually agree that overall suggestions of cooperative review and planning of rice research and extension in the several rice producing states and the United States Department of Agriculture shall be developed by a Rice Technical Working Group (henceforth designated RTWG), composed of all personnel actively engaged in rice investigations and extension in each of the agencies, as well as participating rice industry groups.

It is further agreed that there shall be a minimum of three Administrative Advisors to the RTWG to represent the major agencies involved, including:

1) A director of an Agricultural Experiment Station from a major rice-growing state elected by the Station Directors of the rice-growing states,

2) A director of a State cooperative Extension Service from a major rice-growing state elected by the Extension Directors rice-growing states, and

3) A USDA Administrative Advisor from ARS named by the Administrator of Agricultural Research Service.

The RTWG shall convene at least biennially to review results and to develop proposals and suggested plans for future work. It is understood that the actual activities in research and extension will be determined by the respective administrative authorities and subject to legal and fund authorizations of the respective agencies.

Interim affairs of the RTWG, including preparation and distribution of the reports of meetings, plans, and agenda for future meetings, functional assignments of committees, and notification of State, Federal and industry workers will be transacted by the officers (chair and secretary), subject to consultation with the remainder of the Executive Committee.

The Executive Committee shall consist of 15 members:

Officers (2):

Chair -- presides at meetings of the RTWG and of the Executive Committee and otherwise provides leadership.

Secretary/Program Chair -- (normally moves up to Chair).

Geographic Representatives (7):

One active rice worker in state or federal agencies from each of the major rice states -- Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas.

These Geographic Representatives will be responsible for keeping all governmental rice workers and administrators in their respective geographic areas informed of the activities of the RTWG.

Immediate Past Chair -- provides guidance to incoming chair to facilitate smooth transition between biennial meetings.

Administrative Advisor (one from each category) (3):

State Agricultural Experiment Station
State Agricultural Extension Service
USDA - Agricultural Research Service

Publication Coordinator -- serves to handle matters related to publication of the RTWG Proceedings. (Currently, this position is served by two individuals acting as co-publication coordinators. Only one of these individuals will have a vote on the Executive Committee.)

Industry Representative -- to be elected by industry personnel participating in the biennial meeting of the RTWG; represents all aspects of the U.S. rice industry and serves as liaison with other rice industry personnel; and is responsible for keeping all interested rice industry personnel informed of the activities of the RTWG.

The Officers, Geographic Representatives, and the Publication Coordinator of the Executive Committee shall be elected on the first day of each biennial meeting to serve through the close of the next regular biennial meeting.

A Panel Chair or Panel Chair and Co-Chair, at least one of whom will be an active rice worker in state or federal agencies, shall be elected by each of the active subject matter panels. Such election shall take place by the end of each biennial meeting and Panel Chairs will serve as members of the Program Committee for the next biennial meeting. Each Panel Chair will be responsible for developing the panel program in close cooperation with the Secretary-Program Chair and for seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective panel sessions.

Participation in the panel discussions including presentation of rice research finding by rice industry representatives and by representatives from National or International Institutes is encouraged.

At the end of each biennial meeting, after all financial obligations are met, remaining funds collected to support the programs or activities of the RTWG will be transferred to the newly elected secretary. The secretary will have the option of depositing these funds in his or her local Agricultural Experiment Station or University Foundation account designating them as RTWG funds. The secretary may choose to have the local arrangements chair deposit said funds in station or foundation accounts in the state where the next meeting will be held. In instances where USDA or industry personnel are elected to serve as RTWG secretary, either the local arrangements chair or the state representative in the state where the next meeting is to be held will be designated by the RTWG secretary to receive and deposit funds in station or foundation accounts.

This type of memorandum among the interested state and federal agencies provides for voluntary cooperation of the several interested states and agencies.

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