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PROCEEDINGS. . .

Thirty-First Rice Technical Working Group

The Woodlands, Texas: February 26 – March 1, 2006

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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MANUAL OF OPERATING PROCEDURES

PROCEEDINGS ... THIRTY-FIRST 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 2006 Meeting

The 31st RTWG meeting was hosted by Texas and held at The Woodlands Waterway Merriott in The Woodlands, Texas, from February 26 to March 1, 2006. The Executive Committee, which coordinated the plans for the meeting, included Don Groth, Chair; Garry McCauley, Secretary; and Rick Norman, Immediate Past Chair. Geographic Representatives were Rick Cartwright (Arkansas), Randall Mutters (California), Andrew Bennett (Florida), Bill Williams (Louisiana), Tim Walker (Mississippi), Gene Stevens (Missouri), and Bob Fjellstrom (Texas). Administrative Advisors were David Boethel (Experiment Station), Mike French (Extension Service), and J. Neil Rutger (USDA-ARS). Publication Coordinators were Don Groth and Mike Salassi. The Industry Representative was Dave Jones. The Local Arrangements Chair was Anna McClung.

Location and Time of the 2008 Meeting

The Location and Time of the 2008 Meeting Committee recommended that the 32nd RTWG meeting be held by the host state California. The meeting will be held from February 18 to February 21, 2008 in San Diego, CA. The exact location will be announced at a later date.

2006 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. Rick Norman for his contributions to rice nitrogen management. The team award was presented to Drs. S. Linscombe, X. Sha, P. Bollich, R. Dunand, L. White, and D. Groth for their contributions to varietal development.

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. T.P. Croughan, J.N. Rutger, R. Talbert, and F. Turner

Publication of Proceedings

The LSU AgCenter's Rice Research Station published the proceedings of the 30th RTWG meeting. Professors Patrick Bollich and Donald Groth of Louisiana served as the Publication Coordinators for the 2004 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 32nd RTWG (2008 meeting) proceedings are included in these proceedings (pp. 201-203).

Committees for 2008

Executive:

Chair:	Garry McCauley	Texas
Secretary:	Randall Mutters	California

Geographical Representatives:

Rick Cartwright	Arkansas
Chris Greer	California
Ronald Rice	Florida
Steve Linscombe	Louisiana
Tim Walker	Mississippi
Gene Stevens	Missouri
Lee Tarpley	Texas

Immediate Past Chair:

Don Groth	Louisiana

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

2008 Local Arrangements:

Randall Mutters, Chair	California

Location and Time of 2010 Meeting:

Andy Kendig	Missouri
Gene Stevens	Missouri
Tim Walker	Mississippi

Nominations:

Rick Cartwright (Chair)	Arkansas
Chris Greer	California
Ronald Rice	Florida
Steve Linscombe	Louisiana
Tim Walker	Mississippi
Gene Stevens	Missouri
Lee Tarpley	Texas
Dave Jones	Industry

Rice Crop Germplasm:

James, Gibbons, Chair	Arkansas
Jim Correll	Arkansas
Georgia Eizenga	Arkansas
Robert Fjellstrom	USDA-ARS
Farman Jodari	California
Dwight Kanter	Mississippi
Karen Moldenhauer	Arkansas
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

2008 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:
Kent McKenzie California
Economics and Marketing:
D. Summer California
Plant Protection:
L. Godfrey California
Processing and Storage:
Z. Pan California
Rice Culture:
R. Plant California
Rice Weed Control and Growth Regulation:
A.J. Fischer California

RESOLUTIONS
31st RTWG - 2006

The 31st meeting of the RTWG held at Houston, Texas, February 26 - March 1, 2006 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 31st meeting.

1. Don Groth, RTWG Chair, and all other members of the Executive committee who organized and conducted this very successful meeting. We recognize Garry McCauley 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 Woodlands Waterway Marriot, particularly Lee Anna Shimek, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The local Arrangements committee chaired by Anna McClung for the site selection and overseeing arrangements. To Arlen Klosterboer for his time and assistance in locating and securing arrangements with the hotel. To Davee Crowell and Coleen Meitzen for conducting all aspects of registration, printing of the program, and for handling many other details of planning the meeting. To Yubin Yang and Peter Lu for design and establishment of the RTWG web site and management of online registration. To Brenda Setliff, Brandy Morace, Jack Vawter and the Eagle Lake support staff for all aspects of on site registration and set up. 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 technicians who assisted with A/V in all concurrent sessions.

5. The Panel Chairs, Shannon Pinson, Larry Falconer, Mo Way, Olga Sanford, Lee Tarpley, and Mike Chandler, and moderators for planning, arranging, and supervising the technical sessions. Special recognition is due for the efforts of the chairs, Mike Salassi, 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 Mini-Symposium and General Session speakers for sharing their knowledge and wisdom.

8. Don Groth, Mike Salassi, and the LSU AgCenter staff for editing and publishing the RTWG proceedings.

9. Rick Norman for his time and effort in creating and revising a Manual of Operating Procedures and revising the Memorandum of Agreement

10. Chuck Wilson for creating a permanent web site for the RTWG and agreeing to continue to maintain this web site.

11. The RTWG wishes to recognize RiceTec for sponsoring the social and Riviana Foods Inc. for contributions to the Awards Luncheon. Also, we wish to recognize Bayer CropScience, BASF, Dow AgroScience, Riceland Foods, Doguet Rice Milling Co., Guadalupe-Blanco River Authority, Rice Farming Magazine, and RiceCo LLC for their generous donations helped to make the 31st RTWG meeting a success.

12. Thanks to Clare Hebbard, Noel Yap, and I. Tecle for conducting a computer workshop on the use of the Gramene database.

13. Texas Department of Agriculture for the donation of "Go-Texan" souvenirs for each of the registered participants.

14. Weed Science Society of America for the loan of the easels and poster boards for the poster displays.

15. Texas Rice Improvement Association for helping with purchasing supplies for the meeting.

SPINDLETOP

RiceTec, Inc.

GUSHER

Bayer CropScience

LONESTAR

BASF
Dow AgroScience
Riceland Foods
Riviana Foods

BLUEBONNET

Doguet Rice Milling Company
Guadalupe-Blanco River Authority
Rice Farming Magazine
RiceCo LLC

Distinguished Rice Research and/or Education Award

Rick Norman

Rick Norman has spent his career increasing his understanding of soil, plant, and fertilizer N pathways to improve the ability to manage N fertilizer efficiently for rice production. Management of no other fertilizer nutrient presents a greater challenge to the rice producer than does the effective management of N fertilizer. Likewise, no other nutrient can deliver greater benefits in increased rice grain yields for effective management. With this philosophy as his foundation, his research has focused on delineation of N fertilizer response curves for new rice varieties, defining the use of new N fertilizers and management aids such as urease and nitrification inhibitors in rice, determining the influence of application time, environment, tillage, water management, stand density, and seeding method on N uptake and loss, and the development of better N management strategies for rice production through the investigation of the N balance in paddy soils utilizing the isotopic tracer N-15. He was the first to utilize the isotopic tracer N-15 to define the uptake and transformations of N fertilizer applied to rice at various growth stages. This work clearly showed farmers how and why N fertilizer applied at inappropriate times was lost and not taken up by the rice plant resulting in reduced grain yields and how well N fertilizer applied at the appropriate times was taken up and why it had such a profound impact on rice grain yields. He developed two ultraviolet spectrophotometric methods for determining nitrate and nitrite in soils that are more rapid than any other methods, but just as accurate and precise, and are currently recommend in the Soil Science Society of America 'Methods of Soil Analysis' book series. He identified the first P deficiency in rice in Arkansas, jump-starting extensive research to delineate the rates and timings of P fertilizer required for optimum rice production. He discovered that poultry litter could be used to reclaim precision graded silt loam soils that could not be reclaimed with commercial fertilizer. This research has led to national recognition as the leader in reclaiming precision grading soils and has been consulted throughout the Mid-South for advice based on his expertise. This scientist always has the rice farmer in mind as indicated by the great degree of applicability of his research to farmers' fields and the many extension recommendations that have come from his research. He has helped to educate the farmers, extension personnel, researchers, and industry on how we should best manage N fertilizer in rice so that our recommendations are sound agronomically, economically, and environmentally.

Distinguished Rice Research and/or Education Team Award

Steve Linscombe, Xueyan Sha, Pat Bollich, Richard Dunand, Larry White, and Don Groth

This research team has been responsible for the release of 17 major rice varieties in the last 14 years, including Cypress, Cocodrie, Cheniere, CL161, Bengal, Pirogue, Dellrose, and Dellmati to name just a few. Varieties released by this team have been grown on an average over 60% of the rice acreage in the southern United States for the last five years. In some states, over 90% of the rice acreage has been planted with their varieties. These varieties combine high yield, premium quality, excellent milling, good agronomic characteristics, and enhanced seedling vigor into a single package. These characteristics have helped raise Louisiana's rice yield 22% in the last seven years from 5080 lb/A in 1999 to a record 6200 lb/A in 2005. These accomplishments would not be possible except for the coordinated efforts of an effective variety development team. Besides cooperating among themselves, the team works with scientists from other state breeding programs, the U.S. Department of Agriculture-Agricultural Research Service, and with other rice researchers from around the world. Cooperative ties have been established with breeding programs and other research entities in China, Brazil, Argentina, Columbia, the Philippines, Japan, England, Uruguay, Italy, Costa Rica, Belgium, and other countries. The team also has had cooperative interactions with commercial rice development programs, including RiceTec, BASF, Bayer, and Anheiser Busch. The team has had extensive interactions with these programs, including evaluating germplasm lines, breeding materials, and varieties. In addition to cooperative ties with breeding programs, the team interacts with millers, processors, brewers, and consumer groups to ensure that potential releases meet their quality requirements. This helps ensure commercial acceptability of the variety after release to the rice farmer. This research team has played a vital role in maintaining the viability and competitiveness of the Louisiana and southern U.S. rice industries. They have been honored with the Tipton Team Research Award presented by the Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, in 2003. The members of this team are Steve Linscombe, Xueyan Sha, Pat Bollich, Richard Dunand, Larry White, and Don Groth.

Distinguished Service Award

Tim P. Croughan

Tim Croughan received his M. S. in Agronomy and Ph.D. degree in Plant Physiology both from the University of California at Davis. During his studies in California, he worked on improved salt and Aluminum tolerance in rice. He then moved to Crowley, Louisiana, in 1981 and served at the Rice Research Station. His primary duties in Louisiana have been conducting research aimed at the improvement of rice through tissue culture, anther culture, biotechnology, and mutation breeding. He has developed an extensive research program in rice and has trained several graduate students and visiting scientists in these areas of research. He is the inventor on over 60 patents that are either pending or issued in the United States and foreign countries. He received over $4 million in grant funds from state, federal, and private sector sources to support research activities. He also has over 100 publications, including journal articles, book chapters, and general audience articles. The highlight of his career was the development of the imidazolinone-resistant rice known as Clearfield Rice through mutation breeding. The varieties developed from these mutations were the first commercially-grown rice that could be sprayed with herbicides that effectively control red rice. This creation has changed rice production in Southwest Louisiana and in the rest of the mid south rice producing area, allowing farmers to control red rice, which had severely interfered with successful rice production. He has also led a project to use biotechnology approaches to control coastal erosion. Research topics included development of improved salt tolerant bullwhip, synthetic seed technology, and seed-based planting of smooth cord grass. He has been a member of the RTWG since 1982. He has served the RTWG as a member of the Local Arrangements Committee, Panel Chairman for Breeding, Genetics, and Cytology, and member of the Nomination Committee. Since 1999, he has held the position of American Cyanamid Endowed Professor of Excellence in Plant Biotechnology Molecular Biology and Crop Pest Management. This scientist retired from the LSU Agricultural Center at the end of December 2004 after 23 years of service to the Louisiana rice industry.

Distinguished Service Award

J. Neil Rutger

J. Neil Rutger has served the U.S. rice industry for 35 years: 19 years as a USDA-ARS rice geneticist on the University of California-Davis campus, 4 years as Associate Director of the MidSouth Area, and 11 years as the first Director of the Dale Bumpers National Rice Research Center.

In California, he demonstrated the usefulness of mutants in rice genetics and breeding, where he and his colleagues released the first semidwarf table rice variety in the United States, Calrose 76. He immediately used the mutant in cross-breeding to develop a second variety, M-101. Subsequently, others have used Calrose 76 as the ancestral source of semidwarfism for numerous additional varieties in California, Australia, and Egypt. As a University California Davis adjunct professor, this scientist trained 12 M.S. and 12 Ph.D. students; former students occupy rice research positions in the United States, Brazil, China, Egypt, IRRI, Korea, and Taiwan.

In Arkansas, he led the development of the Dale Bumpers National Rice Research Center, recruiting and organizing an interdisciplinary team of eight scientists. In 2003, he established the Genetic Stocks-Oryza collection, for collection and distribution of rice genetic stocks for U.S. researchers. He also developed additional useful germplasm, including 12 semidwarf mutants, two low phytic acid lines, and semidwarf basmati rice. In the last decade, he initiated an indica base-broadening program, releasing 13 indica germplasm lines for the United States. In his total career he has released 60 improved germplasm lines and genetic stocks and published over 180 papers.

This researcher is a former RTWG Chair and served as the USDA-ARS Administrative Advisor to RTWG for two decades. He was founding chair of the Rice Crop Advisory Committee, member of the National Plant Genetic Resources Board, the National Plant Germplasm Committee, and the Advisory Committee of the International Rice Germplasm Committee. He is Fellow of American Society of Agronomy, Crop Science Society of America, former ARS Scientist of the Year, recipient of the California Rice Industry Award, the RTWG Distinguished Rice Research and Education Award, the American Nuclear Society Award for Food Production, and the UCD Award of Distinction.

Distinguished Service Award

Ron Talbert

Ron Talbert taught courses at both the Undergraduate and Graduate levels and was especially active in working with graduate students as a part of the University of Arkansas' internationally recognized weed science program in graduate training. Many students who trained under him have accepted positions in rice research and extension with universities or in agro-businesses that serve the rice industry and continue to make significant contributions to rice science and education. Through the years, he and his students have done research on a wide variety of problems associated with the use of herbicides in crops. His research has been instrumental in advancing understanding of herbicide behavior in soil, factors affecting herbicide selective activity, persistence and carryover, and herbicide resistance in weeds. He was first to conduct research and monitoring programs on propanil resistant barnyardgrass, as well as quinclorac-resistant barnyardgrass in rice. His work with clomazone was important in understanding soil/herbicide interactions of this widely used herbicide in U.S. rice culture. Utilization of Command for annual grass control saved farmers over $10 million each of the first 2 years it was introduced under a Section 18 Emergency Exemption label. He has been recognized throughout his career with numerous honors and awards: including the John W. White Outstanding Team Award in 2002; the Spitze Land Grant Award from the Dale Bumpers College of Agricultural Food and Life Sciences in 1998; the Outstanding Teacher Award from the Weed Science Society of America in 1998; The Southern Weed Science Society Weed Scientist of the Year in 1991; a Recognition Award from the Arkansas State Horticultural Society in 1990; the Research Award of Merit from the U of A Gamma Sigma Delta Chapter in 1990; the Distinguished Service Award - Academia from The Southern Weed Science Society in 1990; Outstanding Achievement to the Volunteers in Overseas Cooperative Assistance from the President of the United States of America in 1989, and the Distinguished Service Award from Arkansas Agricultural Pesticide Association in 1982. He has published over 300 publications. His is currently University Professor Emeritus of Weed Science, Department of Crop, Soil, and Environmental Sciences at the University of Arkansas where he has spent his career, of 41 years, teaching and conducting research in the field of Weed Science.

Distinguished Service Award

Fred Turner

This soil scientist received his M.S. degree in flooded soil chemistry with Dr. William H. Patrick at the LSU Wetlands Biogeochemistry Institute in May 1967. In 1968, he joined the Ford Foundation's Intensive Agricultural Development Program in India. During the next 2 years, his main input was to develop soil test methods for rice production. His efforts in India laid the groundwork for a subsequent Ph.D. program which began in January 1971 at North Carolina State. His studies demonstrated that increased diffusion rate of soil P in flooded soil helped explain increased P availability to flooded rice plants. In 1974, he accepted the position as assistant professor of rice soils at the Texas A&M University Agricultural Research and Extension Center in Beaumont, Texas. His first research at Beaumont stemmed from an EPA-funded grant with Dr. Kirk Brown to evaluate run-off from flooded rice fields. Resulting data showed that flooded rice fields simulated natural wetland's ability to purify water and biodegrade chemicals applied to flooded rice fields. In other studies, he and Dr. Charlie Bollich showed that limited mesocotyl elongation in the initial semidwarf rice variety contributed to poor seedling emergence. This research helped rice breeders improve emergence of subsequent semidwarf varieties. He was also a member of the team that developed production practices which increased main crop rice yield by 25% or more in Texas. For their contribution, the team received the USDA Superior Service Award for Team Research, the Texas A&M University Distinguished Performance Award, and the RTWG Distinguished Rice Research Team Award. Serving as an adjunct professor for Rice University in association with Drs. Ron Sass and Frank Fisher, they provided an improved understanding of factors affecting methane emission from Texas rice fields. The research also led to an irrigation water management system that can eliminate methane emission without reducing rice yields. The rice production and flooded soil chemistry research led to consulting in the rice growing regions of India, Egypt, Uruguay, South Africa, Ivory Coast, Jamaica, Haiti, and Nigeria. This scientist's cooperative research has significantly improved the understanding of P chemistry and soil P test for flooded rice soils, demonstrated that the handheld SPAD chlorophyll meter could be used to estimate a rice crop's need for topdress N and established that about 50% of the variability in Texas' ratoon rice yield can be explained by the amount of reserve carbohydrates in rice stems at main crop harvest. He recognizes that his family and co-workers have contributed significantly to his successful career.

Minutes of the 31st RTWG Meeting

Opening Executive Committee Meeting

In attendance: Don Groth (Chair), Garry McCauley (Secretary), Mike Salassi (Publications Coordinator), Rick Norman, Chuck Wilson, Tim Walker, Bill Williams, Rick Cartwright, C. Michael French, Jim Hill, Cass Mutters, Pat Bollich, Dave Jones, J. Neil Rutger, Lee Tarpley and Gene Stevens.

Chair Don Groth called the meeting to order at 4:00 p.m. on February 26, 2006 at Waterway Marriott Hotel in The Woodlands, Texas.

Old Business

Don Groth announced that the minutes were published in the 2004 Proceedings and had been emailed to all Committee members. He asked for question or comments regarding the minutes. Rick Norman moved that the minutes be accepted as presented. Cass Mutters seconded the motion and the motion passed.

The financial report for the 2004 meetings had been prepared by Steve Linscombe and emailed to all members. Additional copies were passed out to members. Rick Norman reported that the contingency fund was now at $14,148.53. Gene Stevens move to accept the budget report as presented. This was seconded by Lee Tarpley and the motion passed.

Don Groth recognized Rick Norman to discuss the Manual of Operations that he had developed since the last meeting. The MOP had been circulated to all members for review prior to the meetings. Jim Hill and Don Groth suggested changes to the MOP. Neil Rutger noted that the MOP must agree with the MOA, which was last updated in 1996. He suggested that the MOA be updated to reflect the existence of the MOP and agree with it. It was pointed out by Pat Bollich that the MOP did not define the contingency fund. The level of the funds was questioned. It was noted that this was only about 15% of the cost of a meeting. Many organizations maintain a contingency fund of 50% of the cost of a meeting. The consensus was that the fund should continue to grow but evaluated at each meeting. Dave Jones suggested that the contingency fund continue to grow with no cap at present. Rick Cartwright stated that they thought of a seventh panel related to biotech had been discussed in the RiceCap meetings. If introduced, this would require further changes in the MOP and MOA. Rick Cartwright also introduced the possibility of another award category to recognize teaching or outreach. Rick Norman expanded the possibility for an applied award. It was agreed that Cartwright and Norman would evaluate these concepts and prepare a motion for the closing business meeting. Norman agreed to incorporate the approved changes and present the final version at the closing business meeting. Rick Cartwright moved that the MOP be accepted as an official document of the RTWG. It was seconded by Rick Norman and the motion passed. Neil Rutger noted the exceptional job by Rick Norman in preparing the MOP.

Don Groth recognized Chuck Wilson to discuss the potential and possibility of a permanent web site. It was suggested that links to current host states and contain a digital copy of the prior year's proceedings. The proceedings also contain the attending members. Chuck said this would present no problem. Rick Cartwright moved that RTWG accept the permanent web site with Chuck Wilson as web site coordinator. Lee Tarpley seconded the motion and the motion passed. Rick Norman moved to make the web site coordinator an ex-officio member of the Executive Committee. Don Groth seconded the motion and the motion passed.

Don Groth recognized Chuck Wilson to present his report on the evaluation of graduate student competition at the RTWG meetings. Wilson said that they found the competition not to be feasible and there were no further comments.

New Business

Don Groth announced the following awards:

- Distinguished Service Award – Tim Croughan, J. Neil Rutger, Fred Turner, and Ron Talbert
- Distinguished Rice Research and Extension Individual Award – Rick Norman
- Distinguished Rice Research and Extension Team Award – LSU Variety Development Team

Don Groth asked for inputs for the Necrology Report:

- Roy Smith – Weed Scientist – Arkansas
- Duane Mikkelsen – Soil Scientist – California
- Errol Lounsberry – Rice Producer and RTWG Supporter – Louisiana

Don Groth noted that the rice acreage in Florida was so low that a representative could not be identified and asked for suggestions. Neil Rutger noted that no action was required as outlined in the MOA.

Electronic submission and voting for awards was suggested. Chuck Wilson and Jim Hill will evaluate this for the 2008 awards.

Other business:

Lee Tarpley introduced a motion to accept papers with figures and tables for publication in the proceedings instead of one page abstracts. It was noted that tables and figures had been accepted at one time but presented an editing nightmare and had been abandoned. Cost of publishing and editing was also discussed. It was also noted that this might prevent later publication due to the rules of prior publication. Due to the many problems noted, Tarpley withdrew his motion.

Panel chairs for 2008 should be instructed to do a more complete job of editing prior to the meeting and to forwarding abstracts to the publication coordinators.

Missouri announced that they were considering hosting future meetings.

Don Groth asked if there was any further business to come before the committee. None was raised. Cass Mutters moved that the meeting close. The motion was seconded by Tim Walker and the motion passed.

Opening Business Meeting

Chair Don Groth called the meeting to order at 8:20 a.m. on February 27, 2006 at Waterway Marriott Hotel in The Woodlands, Texas. Minutes of the previous meeting were accepted unanimously without reading after Neil Rutger moved and Jim Hill seconded.

Chair Don Groth presented a summary of the opening Executive Committee meeting.

Permanent RTWG web site to be maintained by Chuck Wilson. The permanent web site will have links to the web site of the next host state. He will be an ex-officio member of the Executive Committee.

Student paper competition was considered not feasible.

First MOP developed by Rick Norman was reviewed and accepted.

MOA was revised to comply with MOP by Rick Norman and accepted.

Awards election was certified.

Electronic submission of awards and voting was evaluated. Chuck Wilson and California will evaluate the possibilities to use this for the 2008 meetings.

Chair Don Groth read the Necrology Report and asked for a moment of silence for Roy Smith, Duane Mikkelsen, and Errol Lounsberry.

The assembly was advised that the Nominations Committee was not complete and would be presented at the closing business meeting.

Don Groth asked that the Panel Chairs and committees submit materials and reports as soon as possible to accelerate the publication of the 31st RTWG Proceedings.

Garry McCauley announced the program changes since the program was publication.

Don Groth asked for a motion to adjourn the business meeting, Jim Hill moved for adjournment and Neil Rutger seconded the motion. The motion passed and Don Groth closed the meeting at 8:40 a.m. February 27, 2006.

Closing Executive Committee Meeting

In attendance: Don Groth (Chair), Garry McCauley (Secretary), Mike Salassi (Publications Coordinator), Rick Norman, Chuck Wilson, Tim Walker, Bill Williams, Rick Cartwright, C. Michael French, Jim Hill, Cass Mutters, Pat Bollich, Dave Jones, J. Neil Rutger, Lee Tarpley, and Gene Stevens.

Chair Don Groth called the meeting to order at 7:00 a.m. on March 1, 2006 at Waterway Marriott Hotel in The Woodlands, Texas.

Don Groth recognized Rich Norman to present the revised MOP and MOA incorporating comments and suggestions from the opening business meeting. A revised copy was presented to the members with changes highlighted in blue. After a review, a motion was made by Dave Jones to accept the revised MOP and MOA with a second by Neil Rutger. The motion passed.

During the opening business session, Rick Cartwright had suggested an additional award category to recognize teaching and outreach and the creation of a seventh panel for biotech researchers. He moved that these issues be tabled for further review.

Missouri representative, Gene Stevens, ask that they be put in the rotation to host the RTWG meeting. Garry McCauley suggested that they enter the rotation following California to host the 2010 meeting. Mississippi had no objections to this proposal. A motion was made by Don Groth that Missouri enter the rotation and host the 2010 meeting and it was seconded by Michael French. The motion passed. Tim Walker noted that the Mississippi representative to the 2008 local arrangements committee be replaced with a Missouri representative.

Rick Cartwright recognized Rick Norman for his work in preparing the first MOP and revisions to the MOA. Rick Norman noted that someone on the board must shoulder the responsibility of reviewing and revising the MOP and MOA prior to each meeting. Garry McCauley made a motion that the past chair be responsible for updating these documents each year since they would have the most experience regarding the RTWG operations. It was seconded by Rick Norman and the motioned passed.

Don Groth called for any unfinished business or new business to be brought before the committee. None was introduced. Rick Norman made a motion to adjourn. It was seconded by Tim Walker and the motion passed.

Closing Business Meeting

Chair Don Groth called the meeting to order at 8:30 a.m. on March 1, 2006 at the Waterway Marriott Hotel in The Woodlands, Texas.

Chair Don Groth announced that the Missouri delegation has ask and been accepted in the rotation to host the RTWG meetings. Missouri will enter the rotation after California and host the 2010 meeting. This will create a 12-year instead of a 10-year rotation.

There was one addition to the necrology report. Dr. William “Bill” Patrick a wetlands soil scientist with LSU passed away this year. There was a moment of silence for Dr. Patrick.

Chair Don Groth called for committee reports.

Tim Walker read an abbreviated edition of the Resolutions Committee Report thanking those people and organizations for their effort, participation, and support of the 31st RTWG meeting.

Don Groth presented the Publications Coordinator report. He recognized Pat Bollich for his work in editing and publishing the 2004 proceedings. Pat Bollich has been promoted and moved to administration outside of rice. Mike Salassi will replace Bollich as the Co-Publications Coordinator. Information or comments regarding the 2006 proceedings should be directed to Groth or Salassi.

The Rice Crop Germplasm committee had no report.

The Acreage Committee report was presented by Johnny Saichuk.

The Industry Committee had no report.

It was noted that recognition of Chuck Wilson for his efforts in creating a permanent web site will be added to the Resolutions.

A motion to accept the committee reports was made by Karen Moldenhauer and seconded by Chuck Rush and the motion passed.

The Nominations Committee report was presented in writing to Don Groth by Jim Hill prior to the meeting as he would not be present. Don Groth read the nominations for 2006-2008. These are:

Secretary/Program Chair: Randall “Cass” Mutters

Geographic Representatives:

Arkansas	Rick Cartwright
California	Chris Greer
Florida	Ronald Rice
Louisiana	Steve Linscombe
Mississippi	Tim Walker
Missouri	Gene Stevens
Texas	Lee Tarpley
Industry	Dave Jones

Nominations Committee:

Arkansas	Rick Cartwright
California	Chris Greer
Florida	Ronald Rice
Louisiana	Steve Linscombe
Mississippi	Tim Walker
Missouri	Gene Stevens
Texas	Lee Tarpley
Industry	Dave Jones

A motion to accept the Nominations Committee reports was made by Jason Bond and seconded by Karen Moldenhauer and the motion passed.

Don Groth thanked the Texas delegation for their hard work that went into making the 31st RTWG a success. Don Groth passed the gavel to Garry McCauley. Garry McCauley thanked Don Groth for his hard work during his four years of service to the RTWG. He presented Don a plaque recognizing his contribution to the RTWG. Don Groth thanked all those that had supported his efforts during those four years.

Garry McCauley recognized Cass Mutters as Secretary of the 2008 RTWG. Cass announced that the meetings would be in California and in the February-March time frame at a yet to be determined location.

There was no additional business for the 31st RTWG. A motion to adjourn the meeting was made by Rick Norman and seconded by Tim Walker and the motion passed. The meeting was adjourned.

SPECIAL COMMITTEE REPORTS

Nominations Committee

The Nominations Committee proposed the following individuals for membership on the 2008 RTWG Executive Committee and Nominations Committee:

Executive Committee:

Chair:	Garry McCauley
Secretary:	Randall Mutters

Geographical Representatives:

Arkansas	Rick Cartwright
California	Chris Greer
Florida	Ronald Rice
Louisiana	Steve Linscombe
Mississippi	Tim Walker
Missouri	Gene Stevens
Texas	Lee Tarpley

Nominations Committee:

Arkansas	Rick Cartwright
California	Chris Greer
Florida	Ronald Rice
Louisiana	Steve Linscombe
Mississippi	Tim Walker
Missouri	Gene Stevens
Texas	Lee Tarpley
Industry	Dave Jones

Submitted by
Jim Hill

Rice Crop Germplasm Committee

The 26th meeting of the Rice Crop Germplasm Committee met Sunday, February 26, 2006, at the Woodlands, Texas. Members in attendance were Karen Moldenhauer, Chair, Farmin Jodari, Dwight Kanter, Jim Oard, Jim Correll, James Gibbons, Georgia Eizenga, Harold Bockelman, Neil Rutger, Kay Simmons, and Mark Bohning. Others in attendance were Clarissa Maroon-Lango, Kent McKenzie, Thomas Tai, Fleet Lee, Anna McClung, Wengui Yan, David Gealy, Yulin Jia, Junda Jiang, Robert Miller, Xueyan Sha, Donn Bieghley, Kirk Johnson, Donna Mitten, Chris Deren, Jeff Oster, Carl Johnson, and Lorie Bernhardt. Minutes were approved by a motion and seconded by Kanter and Gibbons. The crop vulnerability statement was distributed with an update of seedling diseases. Kay Simmons gave the national program staff report, including proposed budget, new staffing position for GSOR at DBNRRC, international germplasm items that will be continuing in 2006, and the retirement of Dr. Stoner. Mark Bohning told of the

CGC biannual meeting to be held at Ames, Iowa, in 2006. Harold Bockleman gave an update on the list of rice germplasm accessions since March 2005 and clarified that only parents from mapping populations based on Crop Science registrations are to be included in the bank with PI numbers assigned. Dave Marshall was given special recognition for his work with rice quarantine. Clarissa Maroon-Lango of APHIS explained her role as leader of quarantine and indexing programs for sugarcane, grasses, and rice and molecular diagnostics. Plans for 2006 include processing and growing out of 200 accessions in APHIS greenhouse. Problems encountered include a continued backlog of accessions in storage at Ft. Collins and numerous cases of non-viable seed. Discussion centered on the need for viability testing, elimination of duplicate samples, and prioritizing lists. A motion was made by Rutger and seconded by Kanter to eliminate duplicates, especially when not from country of origin. A second motion was made and seconded to prioritize the accession backlog in the following order: Japan, Bangladesh, and Indonesia. Rutger reported on the Rice Genetic Stocks-Oryza (GSOR) collection based at USDA ARS DBNRRC. Requests for seed samples of eight genetic stocks and 27 Nipponbare were received in 2005. The Nipponbare is descended from T. Sasaki provided to the International Rice Gene Sequencing project. The GSOR has 24 genetic stocks for distribution. The GSOR website is:
http://www.ars.usda.gov/Main/docs.htm?docid=8320

An update on state policies for growing GM rice revealed that only California and Arkansas have laws establishing guidelines for growing rice with traits of commercial impact. Jeff Oster presented an update on incidence and control of Bakanae disease. Arkansas, Louisiana, and Missouri have restrictions on rice seed imported from California. Yan described the progress in the characterization of the core collection. The nomination committee reappointed Gibbons, Correll, and Eizenga for new 6-year terms. Woodruff was nominated and elected industry rep member, and Gibbons was nominated and elected Chair of the CGC for a 2-year term.

Submitted by
Karen Moldenhauer

Publication Coordinator/Panel Chair Committee

Publication Coordinators Don Groth and Mike Salassi met with the 2006 Panel Chairs at 2:00 p.m. on February 26, 2006, at The Woodlands Waterway Marriott in The Woodlands, Texas.

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 stated that if an oral or poster presentation was not given the abstract would not be published in the proceedings. All changes in operating procedures will be incorporated into the RTWG guidelines for preparation of abstracts in the 2006 proceedings. Proceedings should be available in both hard copy and CD format within 8 months of the meetings.

Submitted by
Don Groth and Mike Salassi

Rice Variety Acreage Committee

The Rice Technical Working Group (RTWG) Acreage Committee met on February 26, 2006. In attendance were: Chris Greer and Kent McKenzie, California; Chuck Wilson, Arkansas; Johnny Saichuk, Louisiana; Nathan Buerhing, Mississippi; Don Beighley and Bruce Beck, Missouri; Jim Stansel and Ted Wilson, Texas. Also in attendance was Pat Bollich of Louisiana.

Johnny Saichuk distributed copies of the 2004 minutes, which were accepted as presented. He also presented copies of acreage reports from all states except California for 2004 and 2005 crops.

Chuck Wilson addressed the trends he expected in Arkansas for 2006. He stated he expected acreage to decrease from 1.64 million acres in 2005 by 10 to 15 percent. Medium-grain acreage on the other hand was likely to increase by 150,000 acres because of the premium on medium-grain rice. Clearfield lines could occupy 30 percent of the Arkansas acreage in 2006. According to reports from Horizon Ag, he said there should be enough seed to plant 1 million acres in 2006 in the entire Gulf Coast region.

Kent McKenzie explained changes in the California rice industry responsible for the lack of a report from California. He indicated these changes made gathering detailed acreage by variety by county nearly impossible. He had attempted to obtain assistance from the state Farm Service Agency but was not successful. He said he has also approached the California Rice Commission without result. He further stated he hoped to be able to find another source of this information prior to the next RTWG meetings.

Johnny Saichuk said rice acreage was expected to drop by 25 to 30 percent prior to hurricanes Katrina and Rita, with Rita having made the greatest impact on Louisiana's rice area. In the aftermath of Rita, it only made decisions easier for some farmers who had not yet decided whether to grow rice in 2006. Some acres were eliminated from production because of salt contaminated soil and some farmers chose not to fight the remediation battles until the rice economic situation improved. He also stated the state's acreage would remain 98 to 99 percent long-grain. When asked about the hybrids and Clearfield varieties, he said in excess of 160,000 acres had been planted to Clearfield lines and that a steady interest in the hybrids remained especially for those who produced a ratoon crop.

Mississippi reported a likely decrease from 265,000 acres in 2005 to around 225,000 acres in 2006, a drop of 10 to 15 percent. All of Mississippi's acreage will be planted to long-grain varieties. He said the lack of purchases by Uncle Ben's had less to do with the decrease than did the price. He said the hybrids did not get a fair evaluation because hurricane Katrina caused them to shatter excessively.

Based on a steady increase in rice production over the past several years in Missouri, 2006 acreage was expected to be up according to Bruce Beck. Cocodrie acreage was declining, however, Cheniere acreage was increasing. Acreage devoted to Clearfield rice increased from 2% in 2004 to 12% in 2005. Hybrid acreage was probably greater than indicated in the filed report because he could not get good estimates by variety, especially the hybrids. Total acreage could increase or decrease by 5% next year.

Jim Stansel of Texas said an updated report had been submitted which Johnny Saichuk later confirmed. Acreage in Texas was likely to decrease again by as much as 30 percent, but he still held out hope that a 25% drop was more reasonable. Cocodrie was by far the dominant variety. The hybrids made up about 5% of the total while the Clearfield lines made up about 15%. CL131 had performed well in 2005 so was expected to increase in popularity in 2006. Ninety percent of the acreage was planted to long-grain varieties a distribution to continue.

In discussions about the long-term outlook, California reported excessive milling capacity, which was leading to either an increase in production to meet the needs of the millers or closing of mills to match production. Johnny Saichuk reported Riviana Rice Mill in Abbeville, Louisiana, had sent out an e-mail to its employees stating the mill would operate through the 2006 season then would be for sale. Kent McKenzie said there was some interest in growing specialty rice in California, especially colored bran rice. He was not sure how much would be grown and whether their production could lead to confusion about red rice. Rice production for biofuels had been explored in Texas, according to Ted Wilson, but was not economically feasible without government support. In Missouri, the Ventria Biosciences project to grow pharmaceutical rice had been stopped by Anheiser Bush and other buyers over fear of public reaction to possible contamination of their products with GMO rice. The project is not completely dead according to Bruce Beck.

The committee then adjourned the meeting.

Submitted by
Johnny Saichuk

Industry Committee

The Rice Technical Working Group Industry Committee again held a successful luncheon at the 31st RTWG meetings in The Woodlands, Texas, on Monday February 27, 2006, at The Woodlands Waterway Marriott Hotel and Convention Center. 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 of the Rice Technical Working Group meeting, 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 2006 Industry luncheon met all of these goals. The luncheon was attended by 50 guests who heard Mr. Dwight Roberts, President and CEO of the U.S. Rice Producers Association, speak about the programs the association is currently actively using to promote U.S. rice, both nationally and internationally.

The Industry Committee would like to thank Dr. Anna McClung, Chairman, Local Arrangements Committee, for her invaluable assistance in coordinating the luncheon.

The Industry Committee looks forward to again hosting a luncheon at the 32nd RTWG meetings in California in 2008.

Submitted by
Dave Jones

2004 ARKANSAS HARVESTED RICE ACREAGE SUMMARY

County/ Parish	2003 Acreage	2004 Acreage	Medium Bengal	Medium Others[2]	Long Grain CL161	CLXL8	Cocodrie	Cypress	Francis	XL 8	Wells	Others[2]
Arkansas	111,514	117,675	5,450	176	9,490	798	16,926	89	21,461	697	54,567	8,020
Ashley	15,513	14,846	0	0	2,917	0	5,818	1,020	3,604	0	1,330	156
Chicot	32,946	32,615	100	0	6,632	203	13,452	368	155	203	8,085	3,417
Clay	77,709	84,034	2,594	85	8,361	2,613	6,933	0	17,350	2,136	26,670	17,292
Craighead	78,110	83,923	12,444	149	10,594	2,554	15,251	0	8,257	320	31,599	2,755
Crittenden	36,818	41,839	356	0	5,302	80	6,045	0	1,111	0	28,458	487
Cross	105,919	106,254	6,794	185	16,646	2,894	4,516	1,440	9,611	1,283	56,389	6,486
Desha	42,992	45,784	48	0	9,495	1,668	13,742	230	1,225	234	17,868	970
Drew	15,906	17,030	422	0	9,209	0	3,188	0	1,000	423	2,290	498
Faulkner	3,190	2,844	0	0	307	0	374	0	1,568	0	596	0
Greene	61,662	69,044	5,649	0	7,293	7,911	8,674	829	15,170	3,473	19,253	792
Independence	8,634	10,896	92	0	0	0	0	0	0	0	10,804	0
Jackson	82,292	101,762	17,402	253	4,766	6,229	5,132	5	8,442	1,829	56,381	1,323
Jefferson	58,872	62,416	564	0	15,251	0	6,730	1,305	2,944	0	31,853	3,769
Lafayette	3,169	3,959	0	0	705	0	1,228	0	327	0	1,320	379
Lawrence	94,864	99,480	13,622	135	14,825	3,091	22,820	1,759	10,551	628	27,346	4,703
Lee	23,415	30,988	863	0	1,614	301	2,466	0	3,213	0	22,531	0
Lincoln	32,355	36,518	641	0	11,975	1,306	11,210	0	7,469	779	3,138	0
Lonoke	77,046	81,890	7,996	85	15,323	152	12,368	703	5,748	785	37,243	1,042
Miller	5,819	7,018	0	0	3,235	0	1,095	0	0	0	1,927	761
Mississippi	39,287	42,230	0	1	5,406	1,632	1,738	10,631	8,699	0	10,039	4,086
Monroe	51,398	54,869	2,647	0	3,003	117	17,761	0	7,558	345	21,190	2,248
Phillips	25,574	25,720	0	0	770	0	9,639	0	7,617	0	6,080	1,613
Poinsett	126,683	134,944	43,830	796	15,258	2,442	4,117	0	7,539	1,217	56,597	3,129
Prairie	57,031	68,122	10,009	9	7,564	120	14,493	0	7,015	2,494	21,336	5,082
Pulaski	4,792	6,505	1,671	0	3,352	0	154	0	0	0	1,328	0
Randolph	28,848	33,257	6,455	59	6,992	3,402	4,955	0	2,315	2,152	6,541	386
St. Francis	47,353	48,483	6,238	57	1,169	3	7,317	0	5,455	465	27,737	43
White	16,060	15,843	890	0	1,093	0	6,999	0	1,328	0	5,412	121
Woodruff	62,323	65,792	7,612	0	6,582	1,719	12,467	1,087	9,078	855	23,562	2,830
Others[3]	6,861	6,861	0	0	169	0	1,332	0	881	1,268	728	2,592
Unaccounted[4]	20,048	6,449	--	--	--	--	--	--	--	--	--	--
2004 Total		1,560,000	154,389	1,990	205,300	39,235	238,942	19,466	176,691	21,586	620,198	74,980
2004 Percent		100.00%	9.90%	0.13%	13.16%	2.52%	15.32%	1.25%	11.33%	1.38%	39.76%	4.81%
2003 Total	1,455,000		162,163	1,721	68,636	--	317,251	22,695	91,561	15,325	658,150	151,955
2003 Percent	100.00%		11.15%	0.12%	4.72%	--	21.80%	1.58%	6.29%	1.05%	45.23%	10.44%

[1] - Harvested acreage. Source: Arkansas Argicultural Statistics and FSA.

[2] - Other varieties: AB647, Adair, Alan, Banks, Bond, Cheniere, Clearfield 121, Clearfield 141, Delmatti, Dellrose, Drew, Earl, Gulfmont, Jackson, Jefferson, Koshikari, Lacassine, LaGrue, Lemont, Maybelle, Nortai, Pirogue, Rice Tec XL7, Rice Tec XP 710, Rice Tec 7015, Saber, Skybonnet, and Texmont.

[3] - Other counties: Clark, Conway, Crawford, Hot Spring, Little River, Perry, Pope, and Yell.

[4] - Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA.

2004 LOUISIANA RICE ACREAGE BY VARIETY SUMMARY

Parish	2003	2004	Medium Grain			Long Grain						
	Acreage	Acreage	Bengal	Pirogue*	Other[1]	Cheniere	Cocodrie	Cypress	CL161	Jefferson	Wells	Other[2]
Acadia	76,217	90,408	3,422	30	312	11,727	40,729	18,023	12,058	1,859	150	2,098
Allen	17,190	19,900	400	0	0	1,000	6,580	1,000	10,370	0	0	550
Avoyelles	11,384	12,725	0	0	0	1,405	4,215	6,259	766	0	0	80
Beauregard	1,901	2,147	0	0	0	100	598	274	976	0	0	199
Bossier	0	168	0	0	0	0	168	0	0	0	0	0
Caddo	0	46	0	0	0	0	46	0	0	0	0	0
Calcasieu	12,970	17,415	0	0	0	3,483	5,225	2,612	6,095	0	0	0
Caldwell	1,178	1,352	0	0	0	127	1,225	0	0	0	0	0
Cameron	12,069	14,325	0	0	0	2,993	4,297	1,996	4,670	0	0	369
Catahoula	2,500	4,682	500	223	0	35	2,348	661	388	0	200	327
Concordia	10,234	11,501	0	0	0	0	9,201	0	1,725	0	0	575
East Carroll	15,910	14,915	0	0	0	1,148	11,589	895	1,283	0	0	0
Evangeline	43,689	52,911	4,447	0	100	485	31,334	5,810	9,685	0	575	475
Franklin	921	496	0	0	0	0	496	0	0	0	0	0
Iberia	715	1,147	0	0	0	265	340	262	175	0	0	105
Iberville	214	186	0	0	0	0	186	0	0	0	0	0
Jeff Davis	75,455	85,950	850	250	300	8,730	41,830	13,470	15,350	530	1,800	2,840
Lafayette	5,319	6,366	241	0	0	833	2,901	1,179	770	140	0	302
Madison	4,711	7,412	0	0	0	0	7,412	0	0	0	0	0
Morehouse	28,795	43,734	2,800	0	43	1,000	21,657	2,000	15,234	1,000	0	0
Natchitoches	4,295	3,677	0	0	0	60	3,367	0	250	0	0	0
Ouachita	8,754	8,836	1,700	0	0	3,000	4,036	0	0	0	0	100
Pointe Coupee	2,200	2,325	75	0	0	550	950	300	50	0	0	400
Rapides	6,325	6,297	0	0	0	260	5,037	200	700	0	0	100
Red River	350	0	0	0	0	0	0	0	0	0	0	0
Richland	6,330	5,263	0	0	0	774	3,613	200	516	0	0	160
St. Landry	18,370	24,231	0	0	0	1,010	4,925	4,340	12,382	464	0	1,110
St. Martin	2,000	5,405	0	0	0	335	2,753	2,042	275	0	0	0
Tensas	2,646	954	0	0	0	0	829	0	0	0	0	125
Vermilion	67,073	83,232	2,280	800	300	15,555	25,885	20,864	15,236	0	880	1,432
West Carroll	5,785	5,749	0	0	0	0	4,029	0	1,620	0	0	100
2004 Total		533,755	16,715	1,303	1,055	54,875	247,801	82,387	110,574	3,993	3,605	11,447
2004 Percent		100.00	3.13	0.24	0.20	10.28	46.43	15.44	20.72	0.75	0.68	2.14
2003 Total	445,500		17,770	0	715	0	257,906	111,999	30,224	4,868	10,328	11,690
2003 Percent	100.00		3.99	0.00	0.16	0.00	57.89	25.14	6.78	1.09	2.32	2.62

[1] Other medium grains include XP712 and XP716; [2] Other long grains include: CL121, CLXL8, XL8, XP710, Maybelle, Francis, Della, Jasmine, Saber, and Toro-2; *Pirogue is a short grain.

2004 MISSISSIPPI RICE ACREAGE SURVEY

County	Clearfield 161	Clearfield XL8	Cheniere	Cocodrie	Cypress	Dixiebelle	Francis	Jefferson	Priscilla	Wells	Other[1]	2004 Acreage	2003 Acreage
Bolivar	19,050	1200	1800	48,750	0	500	525	225	1,950	1,125	850	75,975	74,480
Coahoma	257	0	257	8,749	0	0	257	0	129	3,217	0	12,866	12,445
DeSoto	0	0	0	2,095	0	0	0	0	0	0	0	2,095	3,200
Grenada	0	0	0	200	0	0	0	0	800	800	0	1,800	1,000
Humphreys	0	400	200	2,500	0	0	0	0	500	0	0	3,600	3,775
Issaquena	2,888	40	0	460	0	0	0	0	0	0	0	3,388	3,035
Leflore	9,000	25	800	7,400	0	0	0	0	1,550	250	0	19,025	17,000
Panola	0	0	0	2,900	100	0	0	0	250	250	0	3,500	3,300
Quitman	2,850	0	0	9,450	0	0	450	0	0	900	1,350	15,000	10,000
Sharkey	606	40	190	2,102	0	0	0	0	0	0	160	3,098	4,121
Sunflower	6,000	500	0	24,900	0	0	500	0	5,500	0	0	37,400	33,243
Tallahatchie	3,400	0	0	13,600	0	0	0	0	0	0	0	17,000	17,165
Tunica	1,200	0	700	19,000	0	0	0	0	3,500	250	0	24,650	23,500
Washington	525	750	354	6,523	2,895	1,101	1,156	1,054	9,573	8,486	0	32,417	36,061
2004 Total Acres	45,776	2,955	4,301	148,629	2,995	1,601	2,888	1,279	23,752	15,278	2,360	251,814	
2004 Percent	18.2	1.2	1.7	59.0	1.2	0.6	1.1	0.5	9.4	6.1	0.9	100	
2003 Total Acres	28,749	0	0	164,450	2,700	300	3,600	1,150	31,128	6,425	3,823		242,325
2003 Percent	11.9	0	0	67.9	1.1	0.1	1.5	0.5	12.8	2.7	1.6		100

[1] Other includes XL7, XL8, XP 710, and Lemont.

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

2004 TEXAS RICE ACREAGE BY VARIETY

			Variety Acres by County													
			Long Grains											Medium		
County	2003 Acreage	2004 Acreage	Cocodrie	Cypress	Jefferson	CL161	Francis	Cheniere	CLXL8	Saber	Dixie-belle	Wells	XP710	XL8	Bengal	Other*	Acreage Change from 2003
East Zone																	
Brazoria	10,646	15,748	12,262	394	787	787	394	0	0	0	0	0	0	0	0	1,124	47.9%
Chambers	10,937	16,024	8,642	0	0	1,427	714	2,855	714	0	0	0	0	1,672	0	0	46.5%
Galveston	781	847	847	0	0	0	0	0	0	0	0	0	0	0	0	0	8.5%
Hardin	738	762	382	0	0	76	38	152	38	0	0	0	0	76	0	0	3.3%
Jefferson	15,187	19,954	10,076	0	200	8,979	0	0	0	200	0	0	0	0	399	100	31.4%
Liberty	7,788	10,475	5,820	0	0	2,363	238	951	627	0	0	0	0	476	0	0	34.5%
Orange	0	90	0	0	0	0	0	0	0	0	0	0	0	0	90	0	200.0%
East Total	46,077	63,900	38,029	394	987	13,632	1,384	3,959	1,379	200	0	0	0	2,224	489	1,224	38.7%
Northwest (NW) Zone																	
Austin	1,684	2,313	1,506	0	320	52	0	435	0	0	0	0	0	0	0	0	37.4%
Colorado	28,572	33,273	20,807	752	1,200	3,017	511	6,662	115	0	0	0	0	208	0	0	16.5%
Harris	1,664	1,522	679	0	0	0	0	277	472	0	0	0	0	94	0	0	-8.5%
Lavaca	1,582	2,189	1,673	357	0	0	0	159	0	0	0	0	0	0	0	0	38.4%
Waller	7,300	7,868	4,608	0	0	0	0	1,927	464	0	0	0	45	371	0	453	7.8%
Wharton	46,454	53,413	33,668	5,919	2,835	5,210	639	3,648	0	0	0	491	846	157	0	0	15.0%
NW Total	87,256	100,578	62,941	7,028	4,355	8,279	1,150	13,108	1,052	0	0	491	891	830	0	453	15.3%
Southwest (SW) Zone																	
Calhoun	1,897	2,488	2,488	0	0	0	0	0	0	0	0	0	0	0	0	0	31.2%
Ft. Bend	6,525	7,933	6,875	0	0	0	0	941	0	0	0	0	0	117	0	0	21.6%
Jackson	13,510	14,734	9,573	3,332	331	700	36	496	48	0	0	36	0	182	0	0	9.1%
Matagorda	18,884	23,672	14,039	5,416	2,444	0	0	1,712	0	0	61	0	0	0	0	0	25.4%
Victoria	1,247	1,356	1,356	0	0	0	0	0	0	0	0	0	0	0	0	0	8.7%
SW Total	42,063	50,183	34,331	8,748	2,775	700	36	3,149	48	0	61	36	0	299	0	0	19.3%
Northeast (NE) Zone																	
Bowie	1,332	1,510	654	0	0	87	0	0	0	0	0	692	0	77	0	0	13.3%
Hopkins	713	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-100%
Red River	587	639	639	0	0	0	0	0	0	0	0	0	0	0	0	0	8.9%
NE Total	2,632	2,149	1293	0	0	87	0	0	0	0	0	692	0	77	0	0	-18.4%
2003 Total **2003 %**	178,028 100.0%		127,571 71.7%	17,980 10.5%	6,586 3.7%	17,476 9.8%	1,302 0.7%	 0.0%	0 0.0%	923 0.5%	536 0.3%	938 0.5%	0 0.0%	1,149 0.6%	566 0.3%	3,091 1.7%	
2004 Total **2004 %**		216,810 100.0%	136,594 63.0%	16,170 7.5%	8,117 3.7%	22,698 10.5%	2,570 1.2%	20,216 9.3%	2,478 1.1%	200 0.1%	61 0.0%	1,219 0.6%	891 0.4%	3,430 1.6%	489 0.2%	1,677 0.8%	21.8%

Compiled by Dr. Jim Stansel and Regina Tate, Texas A & M University System at Beaumont. Survey data from dryers, sales offices, agribusinesses, USDA/CFSA and County Extension Agents as appropriate. * Other varieties include Dellmati, XL7, Milagro, CL121, Sierra, Texmati Type, XP110, and Risotto.

2005 ARKANSAS HARVESTED RICE ACREAGE SUMMARY

County/ Parish	2004 Acreage	2005 Acreage	Medium Grain			Long Grain							
			Bengal	Medark	Others[2]	Banks	Cheniere	CL 161	CLXL8	Cocodrie	Francis	Wells	Others[2]
Arkansas	117,675	121,513	2,034	313	0	4,714	3,498	13,655	314	11,347	30,724	52,517	2,398
Ashley	14,846	17,211	0	0	0	0	2,144	3,917	0	6,398	444	1,790	2,517
Chicot	32,615	37,011	0	0	0	0	3,730	10,886	465	11,511	99	9,580	740
Clay	84,034	86,295	512	1,294	119	3,856	2,009	17,926	2,345	5,893	10,085	24,010	18,246
Craighead	83,923	86,637	4,377	2,687	100	3,048	13,599	17,367	2,419	5,223	4,079	30,641	3,096
Crittenden	41,839	39,534	1,043	274	0	1,251	258	7,251	0	3,000	0	26,456	2
Cross	106,254	111,433	3,252	1,677	304	8,577	1,657	30,926	3,917	4,037	7,992	46,270	2,824
Desha	45,784	50,422	0	0	0	971	4,940	14,640	2,341	8,172	3,961	14,212	1,186
Drew	17,030	19,492	0	0	0	376	1,911	5,664	906	3,162	1,532	5,498	443
Faulkner	2,844	3,256	0	85	0	0	89	464	0	230	1,860	528	0
Greene	69,044	75,440	1,592	80	389	182	4,301	16,894	3,964	7,338	12,221	22,205	6,274
Independence	10,896	13,025	0	0	0	0	0	0	0	0	0	7,474	5,552
Jackson	101,762	99,990	11,937	1,687	546	1,216	493	13,682	7,855	5,226	4,880	47,047	5,420
Jefferson	62,416	69,308	0	0	0	0	7,288	22,866	0	7,136	0	32,019	0
Lafayette	3,959	4,280	0	0	0	0	576	180	0	3,163	0	0	360
Lawrence	99,480	109,063	7,524	1,459	0	3,546	18,199	29,915	3,580	13,672	4,044	22,715	4,409
Lee	30,988	30,891	762	25	0	364	1,344	2,353	0	0	5,643	20,048	351
Lincoln	36,518	33,676	0	0	0	81	3,698	8,169	1,326	376	6,344	10,800	2,882
Lonoke	81,890	88,030	5,653	165	230	1,797	7,490	17,086	1,115	4,693	7,872	39,424	2,507
Miller	7,018	6,864	0	0	0	0	924	289	0	5,073	0	0	578
Mississippi	42,230	49,263	0	1	0	2,083	11	20,994	441	419	1,510	23,342	463
Monroe	54,869	58,581	1,217	118	109	3,046	1,603	7,873	496	9,957	12,695	20,743	724
Phillips	25,720	30,985	0	0	40	314	5,621	3,541	0	4,194	13,348	3,927	0
Poinsett	134,944	133,339	25,372	6,540	0	6,417	5,638	18,168	2,120	2,177	4,187	59,777	2,944
Prairie	68,122	72,328	4,639	1,271	0	1,842	11,541	6,409	563	12,852	8,214	20,589	4,407
Pulaski	6,505	4,718	0	0	0	104	432	986	64	271	454	2,275	133
Randolph	33,257	34,789	877	474	1,171	149	8,156	8,270	2,677	1,710	1,050	5,672	4,583
St. Francis	48,483	54,835	5,494	562	0	878	639	1,604	0	1,900	8,956	34,212	591
White	15,843	15,618	258	60	12	1,876	993	1,701	0	5,001	135	3,832	1,751
Woodruff	65,792	63,574	4,259	0	298	3,083	5,237	7,326	2,567	8,501	11,519	19,537	1,247
Others[3]	6,861	8,252	0	0	0	432	0	486	0	678	595	2362	3698
Unaccounted[4]	6,449	5,346	--	--				--	--	--	--	--	--
2005 Total		1,635,000	80,801	18,770	3,319	50,202	118,018	311,491	39,473	153,309	164,443	609,499	80,328
2005 Percent		100.00%	4.94%	1.15%	0.20%	3.07%	7.22%	19.05%	2.41%	9.38%	10.06%	37.28%	4.91%
2004 Total	1,560,000		154,389	1,444	546	2,275	18,114	20,530	39,235	238,942	176,691	620,198	287,636
2004 Percent	100.00%		9.90%	0.09%	0.04%	0.15%	1.16%	1.32%	2.52%	15.32%	11.33%	39.76%	18.44%

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

[2] - Other varieties: AB647, Ahrent , Clearfield 121, Clearfield 131, Cybonnet , Cypress, Della, Delmatti, Dellrose, Drew, Gulfmont, Jasmine 85, Jefferson, Kaybonnet, Koshi hi kari, LaGrue, Lemont, Nortai, Pirogue, Rice Tec XL7, Rice Tec XL8, Rice Tec XP 710, Rice Tec XP712, Rice Tec XP716 , Rice Tec XP 723, Rice The XP 730, Rice Tec XP 721, Saber, Spring, Texmont, and Trenasse .

[3] - Other counties: Clark, Conway, Crawford, Hot Spring, Little River, Perry, Pope, and Yell.

[4] - Unaccounted for acres is the total difference between USDA-NASS harvested acreage estimate and preliminary estimates obtained from each county FSA.

2005 LOUISIANA RICE ACREAGE SUMMARY

Parish	2004	2005	MEDIUM GRAIN				LONG GRAIN						
	Acreage	Acreage	Bengal	Pirogue	XP712	Other[1]	Cocodrie	Cypress	Wells	CL161	Jefferson	Cheniere	Other[2]
Acadia	90,608	82,563	1,040	134	350	475	15,696	7,519	158	37,973	860	16,472	1,886
Allen	19,900	17,890	0	0	0	0	4,600	60	0	7,900	0	5,000	330
Avoyelles	12,725	14,806	0	0	0	0	5,034	430	0	86	0	7,847	1,409
Beauregard	2,147	2,177	0	0	0	0	408	0	0	656	0	753	360
Bossier	168	205	0	0	0	0	205	0	0	0	0	0	0
Caddo	46	46	0	0	0	0	46	0	0	0	0	0	0
Calcasieu	17,415	15,840	0	0	0	0	4,752	0	0	6,811	0	3,960	317
Caldwell	1,352	1,400	0	0	0	0	600	0	0	800	0	0	0
Cameron	14,325	13,401	240	0	0	0	1,121	0	0	7,502	758	2,632	1,148
Catahoula	4,682	7,250	0	0	0	0	4,450	0	0	2,300	0	0	500
Concordia	11,501	14,726	0	0	0	0	8,903	0	0	4,798	0	758	267
East Carroll	14,915	15,515	0	0	0	0	6,966		0	5,383	0	3,008	158
Evangeline	52,911	49,223	1,160	150	0	0	20,680	2,200	1,000	10,580	500	10,100	2,853
Franklin	496	1,402	0	0	0	0	622	0	0	292	0	488	0
Iberia	1,147	992	0	0	0	0	0	116	0	0	0	707	169
Jeff Davis	85,950	82,210	670	160	0	0	39,000	500	300	16,480	600	19,100	5,400
Lafayette	6,366	6,477	0	0	0	0	1,566	971	0	1,969	0	1,631	340
Madison	7,412	5,412	0	0	0	0	0	0	0	0	0	0	0
Morehouse	43,734	50,213	1,000	0	0	0	28,000	0	4,000	10,000	2,000	5,213	0
Natchitoches	3,677	3,060	0	0	0	0	1,760	0	0	500	0	800	0
Ouachita	8,836	9,303	1,769	0	0	0	4,034	0	0	500	0	3,000	0
Pointe Coupee	2,325	2,123	0	0	0	0	1,260	0	0	158	0	573	132
Rapides	6,297	7,788	0	0	0	0	6,230	0	0	1,558	0	0	0
Richland	5,263	5,921	0	0	0	0	4,133	0	0	600	0	1,033	155
St. Landry	24,231	25,098	625	0	0	0	4,690	2,447	0	10,234	0	6,982	120
St. Martin	5,405	5,206	0	0	0	0	683	0	0	75	0	4,448	0
Tensas	954	1,779	0	0	0	0	1,779	0	0	0	0	0	0
Vermilion	83,232	76,361	2,126	430	0	0	15,913	9,022	185	22,576	0	24,914	1,195
West Carroll	5,749	7,003	0	0	0	0	0	0	0	7,003	0	0	0
2005 Total		525,390	8,630	874	350	475	183,131	23,265	5,643	156,734	4,718	119,419	16,739
2005 Percent		99	1.64	0.17	0.07	0.09	34.86	4.43	1.07	29.83	0.90	22.73	3.19
2004 Total	533,755		16,715	1,303	500	555	247,801	82,387	3,605	110,574	3,993	54,875	11,447
2004 Percent	100.00		3.13	0.24	0.09	0.10	46.43	15.44	0.68	20.72	0.75	10.28	2.14

*Other Medium Grains include Jupiter. **Other Long Grains include XP723, CL131, Trenasse, Ecrevisse, CLXL8, XP730, XL8, XP729, Francis, Hidalgo. ***Madison Parish did not report.

2005 MISSISSIPPI RICE ACREAGE SURVEY

County	Clearfield 161	Clearfield XL8	Cheniere	Cocodrie	Cypress	Dixiebelle	Francis	Jefferson	Priscilla	Wells	Other[1]	2005 Acreage	2004 Acreage
Bolivar	18,675	1,216	13,154	36,280	0	0	0	0	2,268	1,814	2,185	75,592	75,975
Coahoma	320	799	958	12,782	0	0	0	0	0	799	320	15,978	12,866
DeSoto	0	0	460	0	0	0	0	0	1,840	0	0	2,300	2,095
Grenada	0	0	0	500	0	0	0	0	0	0	0	500	1,800
Humphreys	500	300	1,600	1,600	0	0	0	0	0	0	0	4,000	3,600
Issaquena	2,100	40	0	624	0	0	0	0	0	0	200	2,964	3,388
Leflore	7,585	135	8,831	3,721	0	0	0	0	1,100	400	150	21,922	19,025
Panola	700	0	1,000	3,000	0	0	0	0	0	0	0	4,700	3,500
Quitman	1,508	0	2,366	10,098	0	0	1,207	0	79	412	206	15,876	15,000
Sharkey	719	80	762	716	0	100	0	0	0	0	0	2,377	3,098
Sunflower	7,511	0	8,040	18,000	0	300	1,900	0	2,500	0	0	38,251	37,400
Tallahatchie	3,810	0	7,620	5,715	0	0	953	0	952	0	0	19,050	17,000
Tunica	0	0	2,800	21,200	0	0	0	0	3,000	2,250	0	29,250	24,650
Washington	1,525	2,590	354	5,523	1,855	1,101	985	650	10,753	8,996	0	34,332	32,417
2005 Total Acres	44,953	5,160	47,945	119,759	1,855	1,501	5,045	650	22,492	14,671	3,061	267,092	
2005 Percent	16.8	1.9	18.0	44.8	0.7	0.6	1.9	0.2	8.4	5.7	1.1	100	
2004 Total Acres	45,776	2,955	4,301	148,629	2,995	1,601	2,888	1,279	23,752	15,278	2,360		251,814
2004 Percent	18.2	1.2	1.7	59.0	1.2	0.6	1.1	0.5	9.4	6.1	0.9		100

[1] Other includes : CL 131, XP 730, XL8, XP 710, XP 723, XP 721, XP 729.

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

2005 MISSOURI RICE ACREAGE

Variety	Approximate Acres	Percent of Acres Planted
Wells	84,400	40%
Francis	33,700	16%
Cheniere	33,700	16%
Cocodrie	27,400	13%
Clearfield 161	25,300	12%
Banks	2,100	1%
RTX8	2,100	1%
Cybonnet	2,100	1%

Variety data from D.J. Herzog, Manager, Riceland Foods, Corning, AR.
Acreage data from Missouri Agricultural Statistics.

2005 TEXAS RICE ACREAGE BY VARIETY SURVEY

	Variety Acres by County											
	2004	2005	Long Grains									
County	**Acreage**	**Acreage**	**Cocodrie**	**Cheniere**	**CL161**	**Cypress**	**Jefferson**	**CLXL8**	**Milagro**	**Dixiebelle**	**XP723**	**XP710**	**Other***
East Zone													
Brazoria	15,748	15,975	10,303	2,626	376	0	1,182	0	132	0	0	0	1,356
Chambers	16,024	12,792	0	1,279	7,546	0	0	1,408	2,558	0	0	0	0
Galveston	847	833	833	0	0	0	0	0	0	0	0	0	0
Hardin	762	298	298	0	0	0	0	0	0	0	0	0	0
Jefferson	19,954	19,355	4,405	5,361	6,127	0	0	2,000	0	0	84	0	1,378
Liberty	10,475	9,381	289	2,814	4,690	0	0	1,303	250	0	35	0	0
Orange	90	0	0	0	0	0	0	0	0	0	0	0	0
East Total	63,900	58,634	16,128	12,080	18,739	0	1,182	4,711	2,940	0	119	0	2,734
Northwest (NW) Zone													
Austin	2,313	2,359	1,563	667	18	0	111	0	0	0	0	0	0
Colorado	33,273	30,903	19,394	4,870	2,922	681	1,578	641	712	0	105	0	0
Harris	1,522	1,067	97	263	0	0	0	248	0	0	208	0	251
Lavaca	2,189	1,804	1,543	151	0	110	0	0	0	0	0	0	0
Waller	7,868	7,672	3,885	1,866	0	0	0	515	0	0	851	0	554
Wharton	53,413	50,678	28,788	3,565	5,003	5,157	3,120	88	818	1,201	211	1,053	1,674
NW Total	100,578	94,483	55,270	11,382	7,943	5,948	4,809	1,492	1,530	1,201	1,375	1,053	2,479
Southwest (SW) Zone													
Calhoun	2,488	2,439	2,158	0	0	0	0	0	150	0	0	0	131
Ft. Bend	7,933	6,409	5,389	839	0	0	22	0	0	0	110	0	49
Jackson	14,734	12,713	6,144	2,319	1,174	1,246	511	277	528	176	125	0	213
Matagorda	23,672	21,863	7,730	2,186	0	4,671	4,182	0	1,319	1,408	224	0	144
Victoria	1,356	1,705	1,705	0	0	0	0	0	0	0	0	0	0
SW Total	50,183	45,129	23,126	5,344	1,174	5,917	4,715	277	1,997	1,584	459	0	537
Northeast (NE) Zone													
Bowie	1,510	2,054	1,259	350	45	0	0	40	0	0	0	0	360
Hopkins	0	0	0	0	0	0	0	0	0	0	0	0	0
Red River	639	639	639	0	0	0	0	0	0	0	0	0	0
NE Total	2,149	2,693	1,898	350	45	0	0	40	0	0	0	0	360
2004 Total **2004 %**	216,810 97.9%		136,594 63.0%	20,216 9.3%	22,698 10.5%	16,170 7.5%	8,117 3.7%	2,478 1.1%	0 0.0%	61 0.0%	0.0%	891 0.4%	5,107 2.4%
2005 Total **2005 %**		200,937 100.0%	96,421 48.0%	29,155 14.5%	27,901 13.9%	11,865 5.9%	10,706 5.3%	6,520 3.2%	6,467 3.2%	2,785 1.4%	,953 1.0%	1,053 0.5%	6,110 3..0%

*Other Varieties: Cybonnet, Jasmine 85, Presidio, Sabine, Trenasse, XP733, XP712, XP716, XP721, XP732, Wells, CL131, Sierra, Francis, CLXL730, and Risotto.
Data compiled by Dr. Jim Stansel and Brandy Morace, Texas A&M University System at Beaumont.

RECOMMENDATIONS OF THE PANELS

BREEDING AND GENETICS

S. PINSON, Chair; K. MCKENZIE Chair-Elect (2008); D. BEIGHLEY, B. BLANCHE, H. BOCKELMAN, D. BRADSHAW, E. CHRISTENSEN, Q. CHU, J. COCKRELL, F. CORREA, L. DE MATTOS, H. DU, L. ESORINOS JR., P. FRANK, F. FROST, J. GIBBONS, M. GRUSAK, T. HALL, M. HINGA, S. HUNG, Y. IBRAHIM, Y. JIANG, F. JODARI, C. JOHNSON, K. JOHNSON, D. JONES, D. KANTER, C. LAY, S. LEONG, V. LIBROJO, D. MACKILL, C. MARTINEZ, A. McCLUNG, S. MOON, N. NARAYANAN, D. PARK, J. PENDERGAST, J. SAICHUK, O. SAMONTE, G. SARREAL, A. SHARMA, X. SHI, R. TABIEN, T. TAI, E. TIONGCO, H. UTOMO, M. VASCONCELOS, E. VRANCKEN, J. WANG, X. WANG, I. WENEFRIDA, B. WOODRUFF, W. YAN, 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, including consideration of the newest recommendations of the other RTWG Panels.

Present research and development should be continued or new research development 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, microsatellites, and SNPs, 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 ongoing 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 for 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 oryzae)*, rice sheath blight fungus *(Rhizoctonia solani),* aggregate sheath spot fungus *(Rhizoctonia oryzae sativae)*, and 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)*, bacterial panicle blight *(Buckholderia glumae)*, bakanae *(Gibberella fujikuroi),* 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 and geneticists 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 are also 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 gametocides may facilitate these efforts. This 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.

Training of New Rice Breeders
There is concern about the shallow talent pool from which to select new breeders and geneticists to supplement and replace current and retiring U.S. rice researchers. New and specific efforts to develop and train our next generation of scientists need to be undertaken. In addition to developing rice germplasm and knowledge, all rice researchers, but especially breeders and geneticists, are encouraged to interact with the public at many levels, educating students from Kindergarten through Ph.D. levels about these fields of research and encouraging students to enter them. Interest in molecular genetics is currently high. That, combined with the fact that rice has served as a genetic model for other crops, the geneticist pool is presently larger than the pool for breeders. But it is believed that the model crop advantages are already waning. Interaction with K-12 students, teachers, science curriculum coordinators, and advisors is strongly urged as a means to encourage students to select pre-breeding fields of study for their B.S. Interaction with B.S. students will be required to encourage them to continue their studies with higher degrees to become knowledgeable breeders and geneticists. In addition to genetics knowledge, breeders must know both the theoretical issues of field design and the practical issues of field set-up and must have an understanding of environmental interactions and genotype response. Students from the B.S. through the Ph.D. levels should be encouraged to gain both laboratory and field training. Changes in college degree requirements may be required.

ECONOMICS AND MARKETING

L. FALCONER, Chair; D. SUMNER, Chair-Elect (2008); N. CHILDS, B. PAGANOS, B. WATKINS, H. BRYANT, A. DURAND, R. MANE, E. CHAVEZ, J. THOMPSON, J. HILL, S. DEVILLIER, J. HIGNIGHT, L. POZDNYAKOVA, M. SALASSI, and E. WAILES, 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 of 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 United States 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 periodically 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 2008 should be forwarded by December 20, 2007 to Larry Falconer at Texas A&M University.

PLANT PROTECTION

M. WAY, Chair; L. GODFREY, Chair-Elect (2008); F.E. NWILENE, J.P. KRAUSZ, D.S. PARK, P.A. BOLLICH, M.C. RUSH, R. NANDAKUMAR, M. STOUT, J. HAMM, F. REAY-JONES, F.N. LEE, S. BROOKS, F. CONNEA. C. PARSONS, L. SCHMIDT, K. JOHNSON, L. ANDERSON, E. TIONGCO, J. OARD, R. PORTER, L. ESPINO, R. MILLER, E. SUTTON, Y. JIA, J. BERNHARDT, B. CASTRO, J. OLSON, S. LAWLER, L. ALDRICH, T.J. MUIR, S. DEVILLIER, F. FROST, J. OSTER, and D. GROTH, Participants.

Diseases

The principal objectives of basic and applied rice disease research in the United States include more complete understanding of molecular mechanisms of pathogenesis of the pathogen, host resistance to rice pathogens, and the ultimate control of the diseases. Ultimately, an effective and integrated disease management program relying on resistance, cultural practices, and chemical control based on cooperative research with scientists in agronomy, entomology, and weed science should be striven for. If future advances are made in the understanding and application in biological or molecular-genetic control aspects, these factors should be developed and included in the program.

Major yield and quality diseases in the United States causing damage to the rice crop each year currently include sheath blight, caused by *Thanatephorus cucumeris* (A.B. Frank) Donk (anamorph: *Rhizoctonia solani* Kühn); stem rot caused by *Magnaporthe salvinii* (Cattaneo) R. Krause & Webster (synanamorphs: *Sclerotium oryzae* Cattaneo, *Nakataea sigmoidae* (Cavara) K. Hara); blast caused by *Pyricularia grisea* Sacc. = *P. oryzae* Cavara (teleomorph: *Magnaporthe grisea* (Hebert) Barr); kernel smut caused by *Tilletia barclayana* (Bref.) Sacc. & Syd. in Sacc. = *Neovossia horrida* (Takah.) Padwick & A. Khan; and bacterial panicle blight caused by *Burkholderia glumae* Kurita & Tabei. Seed rot and seedling diseases continue to be major stand establishment problems in both water- and dry-seeded systems, especially with the trend to earlier planting dates. In water-seeded systems, *Achlya* and *Pythium* spp. are important while *Pythium*, *Rhizoctonia* and possibly *Bipolaris*, *Fusarium* and other fungi have been considered important in dry-seeded rice in the South. The role of seedborne *Pyricularia* and *Burkholderia* in stand establishment and later epidemics should continue to be investigated. Straighthead, a physiological disease, remains a major problem in certain areas.

Diseases that are more locally important include narrow brown leaf spot caused by *Cercospora janseana* (Racib.) O. Const. = *C. oryzae* Miyake (teleomorph: *Sphaerulina oryzina* K. Hara); aggregate sheath spot caused by *Ceratobasidium oryzae-sativae* Gunnell & Webster (anamorph: *Rhizoctonia oryzae-sativae* (Sawada) Mordue); brown spot caused by *Cochliobolus miyabeanus* (Ito & Kuribayashi) Drechs. ex Dastur (anamorph: *Bipolaris oryzae* (Breda de Haan) Shoemaker); false smut caused by *Ustilaginoidea virens* (Cooke) Takah.; crown sheath rot caused by *Gaeumannomyces graminis* (Sacc.) Arx & D. Olivier; and bakanae caused by *Gibberella fujikuroi* Sawada Wollenworth *(anamorph: Fusarium fujikuroi* Nirenberg = *F. moniliforme* J. Sheld.). White tip, a nematode disease of rice caused by *Aphelenchoides besseyi* Christie, remains an economic constraint to rice exports in the southern United States although direct yield and quality losses in the field remain minor. Peck of rice, caused by a poorly defined complex of fungi and possibly other microbes in concert with rice stinkbug feeding, remains a problem in certain areas and years.

Currently, minor diseases include leaf scald caused by *Microdochium oryzae* (Hashioka & Yokogi) Samuels & I.C. Hallett = *Rhynchosporium oryzae* Hashioka & Yokogi; sheath rot caused by *Sarocladium oryzae* (Sawada) W. Gams & D. Hawksworth = *Acrocylindrium oryzae* Sawada; stackburn disease caused by *Alternaria padwickii* (Ganguly) M.B. Ellis; sheath spot caused by *Rhizoctonia oryzae* Ryker & Gooch; and leaf smut caused by *Entyloma oryzae* Syd. & P. Syd. A minor and confusing strain of *Xanthomonas* caused symptoms on rice in the early 1990s in part of Texas and Louisiana. Originally identified as a weakly virulent strain of *Xanthomonas oryzae* Ishiyama pv. *oryzae* Swings, the cause of bacterial leaf blight in other parts of the world, recent information suggests this strain differs from XOO. More definitive molecular research is needed to separate these strains.

Miscellaneous diseases and problems of currently unknown cause are scattered in the rice growing regions of the United States and include an unidentified crown rotting disease, forms of hydrogen sulfide toxicity (autumn decline), eyespot disease, sheath blotch, white leaf streak, undefined leaf bronzing, and various grain-spotting problems.

Areas in which research should be continued or initiated concerning the following:

1. Systematic and coordinated field monitoring and diagnostics should be established and continued long-term in the various rice states to detect new pathogens or changes in existing ones. Yearly surveys should be conducted to support existing and future research and extension programs, including breeding efforts.

2. The cooperative testing and breeding program with rice breeders should be continued for the development of improved disease-resistant rice varieties. Newly released varieties should be fully evaluated for reaction to the recent field isolates. In addition, screening programs should endeavor to locate new germplasm with high degrees of resistance to major and developing diseases while susceptibility to other problems should be monitored. Straighthead testing should continue and cooperative regional or area testing should be encouraged.

3. A comprehensive testing program focused on new and existing chemical therapeutic control options should be continued with regional coordination encouraged. A better understanding of efficacy and economic return under realistic field conditions should be emphasized in the future, in addition to inoculated efficacy trials. The discovery and development of improved scouting and detection methods, and decision thresholds should be continued. Measurement of crop loss to various diseases under different conditions should be encouraged.

4. Genetic and chemical control options should be researched for early planted rice to improve the reliability of stand establishment and survival each year.

5. Research on the molecular genetics of host/parasite interactions including molecular characterization of the pathogen isolates and their interaction mechanisms with rice in U.S. rice and the use of molecular genetics and biotechnology including genetic engineering, molecular assisted breeding, and biotechnology based tools to improve disease control should be a high priority.

6. Research on the effects of cultural practices on disease incidence and severity and the interaction of rice soil fertility (mineral nutrition) and other soil factors in disease severity should be continued and increased.

7. Given the failure of the current system of importation and quarantine of rice germplasm to allow rapid and orderly dissemination and usage of exotic rice germplasm for U.S. breeding programs, additional funding should be sought to research and implement a more workable but safe system. While existing federal quarantine procedures are effective and warranted, the United States needs to fund enough personnel and

facilities to make them practical – a situation that does not currently exist.

8. Molecular characterization of virulent blast isolates IE1k in commercial fields and on the weakly virulent bacterial strains, originally reported as XOO in Texas and Louisiana, should be conducted to characterize and identify them.

9. Additional disease research should be conducted on hybrid rice, niche varieties, and organic systems to provide workable management recommendations for current and future producers.

10. Cooperative research on the interaction of disease with water stress (limited irrigation water), salt, and other environmental stress should be encouraged as these problems increase in certain areas.

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, *Diatraea saccharalis* (Fabricius), *Eoreuma loftini* (Dyar), and *Chilo plejadellus* Zincken; rice leaf miner, *Hydrellia griseola* (Fallen); South American rice miner, *Hydrellia wirthi* Korytkowski; armyworm, *Pseudaletia unipuncta* (Haworth); fall armyworm, *Spodoptera frugiperda* (JE Smith); chinch bug, *Blissus leucopterus leucopterus* (Say); various species of leaf- and plant hoppers; numerous grasshopper species (Locustidae and Tettigoniidae); midge larvae (Chironomidae); greenbug, *Schizaphis graminum* (Rondani); bird cherry-oat aphid, *Rhopalosiphum padi* (Linnaeus.); rice root aphid, *Rhopalosiphum rufiabdominalis* Sasaki; western yellowstriped armyworm, *Spodoptera praefica* (Grote); yellow sugarcane aphid, *Sipha flava* (Forbes); and an exotic stink bug, *Oebalus ypsilongriseus* (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 clarkii* (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 nontarget 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

O. SANFORD, Chair; Z. PAN, Chair-Elect (2008); J. KENDALL, C. GRIMM, F. SHIH, M. FITZERALD, T. SIEBENMORGEN, R. BAUTISTA, D. HIMMELSBACH, and C. EARP, Participants.

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 post-harvest 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 the 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 evaluations of perspective new varieties for processing quality.

Study the correlations of ‘functional amylose’ to processing and cooking properties.

Determine basic relationship 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.

Study the genetic mechanisms controlling amounts and compositions of components which might have significant economical and nutritional value (e.g., oil, brain, phytochemicals etc).

Characterize bioactive components in varieties in regards to physicochemical and functional properties. Measure the amount 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

L. TARPLEY, Chair; R. PLANT, Chair-Elect (2008); P. BOLLICH, J. BOND, N. BUEHRING, J. BUSHONG, R. DeLONG, B. GOLDEN, D. HAGLER, J. HILL, D. JONES, R. LOEPPERT, R. NORMAN, M. REITER, J. ROSS, B. SCHMID, N. SLATON, D. STEPHENSON, T. WALKER, C.O. WILSON, 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, seeding date, and other factors necessary to characterize BMPs for various cultivars of interest.

Evaluate the use of harvest aid chemicals in rice production.

Develop cultural practices to minimize potential detrimental environmental impacts on rice quality.

Fertilizers and Soils
Develop a greater understanding of the chemical, physical, and physicochemical 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, continuous-flood, and alternative 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 System 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

J.M. CHANDLER, Chair; A.J. FISCHER, Chair-Elect (2008); N. FALKENBERG, W.D. NANSON, S. WILLINGHAM, K. SMITH, N. BURGOS, V. SHIRVAIN, B. WILLIAMS, A. KENDIG, R. TALBERT, D. GEALY, H. BLACK, L. SCHMIDT, and L. ESTORNINOS JR., Participants.

The overall objective of the Rice Weed Control and Growth Regulation Panel's recommendations is to develop integrated 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
Evaluate weed control systems for prevention and management of herbicide-resistant weeds.

Mechanisms of resistance.

Evaluate new chemicals for the control of weeds in rice.

Facilitate label clearance and continued registration for rice herbicides.

Evaluate varietal tolerance to herbicides in cooperation with plant breeders.

Study new and existing herbicides for their fit in conservation tillage in rice-based cropping systems.

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 herbicide-resistant rice weed control systems.

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

Weed Biology and Ecology

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, gene flow, molecular biology, and population genetics.

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 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.

Evaluate rice cultivars for weed suppressive traits.

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:
Opportunities and Risks Associated with Transgenic Crops
Moderator: A. McClung

Genetic Engineering and Traditional Breeding- What is the Difference?

Ronald, P.

Controversy continues to swirl around genetic engineering. To evaluate the potential risks and benefits, it is essential to fully understand the science behind the GE process, a modern form of genetic modification that is, in some important respects, distinctly different from traditional breeding. Can we use this new genetic information to improve sustainable agricultural farming practices? Are there necessary conflicts between modern genetic research and traditional farming? If so, how can we address these problems? I propose a set of criteria based on sustainable agricultural practices that can be used to evaluate food choices and help move the debate on genetic engineering forward. I suggest that varieties and/or farming practices should seek to:

- Provide safe and nutritious food;
- Reduce negative environmental inputs (e.g. pesticides);
- Provide healthful conditions for farm workers;
- Be profitable for farmers;
- Foster ecological farming practices;
- Benefit the local community; and
- Improve the lives of the poor and malnourished

I hope that such a framework will help farmers and consumers evaluate the ethical and safety issues that inevitably accompany new scientific breakthroughs such as genetic engineering.

Golden Rice: Developments in Its Biotechnology, Safety, and Nutritional Evaluation

Grusak, M.A., Tang, G., and Russell, R.M.

Golden Rice is a transgenic product that was developed to enable the synthesis of beta-carotene in rice grains. Beta-carotene is a yellow-orange carotenoid that can serve as a precursor for vitamin A. Vitamin A deficiency (VAD) is a significant nutritional concern, especially in developing countries where rice is eaten as a staple food crop. Recent estimates indicate that over 250 million people are suffering from VAD. The main cause of VAD is inadequate dietary intake of vitamin A (animal products) or pro-vitamin A carotenoids (plant sources). Low income families throughout the developing world consume limited amounts of animal foods and infrequent amounts of colored fruits and vegetables. For those areas of the world where rice is a staple caloric food source, it was hoped that Golden Rice technology could increase the dietary supply of carotenoids, and diminish the incidence of VAD.

The original proof-of-concept version of Golden Rice succeeded in the synthesis and accumulation of beta-carotene and other carotenoids in the endosperm, with total carotenoids reaching 1.6 ug/g DW. More recently, scientists at Syngenta developed a new transgene construct in which a maize gene for phytoene synthase replaced the original daffodil gene. This new product, now known as Golden Rice 2, has resulted in grain carotenoid concentrations as high as 37 ug/g DW, with beta-carotene representing as much as 84% of the total carotenoids. At these levels, it is estimated that 50% of a 1- to 3-year-old child's RDA for vitamin A (300 ug) could be met with 72 grams of dry rice (a child's typical portion is 60 grams of rice, and this amount is usually eaten more than once a day). This estimate assumes a 12:1 factor for the conversion of beta-carotene to vitamin A.

Although Golden Rice technology works, there are still other issues that need to be addressed. What is the safety of the transgenic product as a human food source? What is the nutritional value of beta-carotene when delivered in a rice endosperm food matrix? And, what means are available to transfer this technology to elite cultivars throughout the world? A number of approaches have been used to assess any adverse impacts of transgenic products, including animal-based allergenicity studies, in silico analyses of the allergenicity of predicted peptide fragments from the expressed proteins, safety evaluation of marker genes, and an evaluation of the risk of toxic intake of the synthesized product. In this presentation, we will discuss how these approaches have been used in the case of Golden Rice.

An evaluation of the nutritional value of Golden Rice is currently under investigation using stable isotope technologies. Beta-carotene is a long-chain hydrocarbon that can be readily labeled with deuterium, a non-radioactive, stable isotope of hydrogen. We are growing Golden Rice in hydroponic media that contains heavy water (deuterium oxide) and have successfully labeled beta-carotene in the grains for use in clinical feeding trials in China. We will provide an overview of these studies, including how they will be conducted and the type of information we hope to gain. We also will discuss the requirements that must be met (e.g., Internal Review Board approval) to establish and ensure safety and informed consent for this type of clinical trial.

Finally, there are several efforts underway to move Golden Rice technology into diverse rice lines throughout the world. The Golden Rice Humanitarian Board (www.goldenrice.org) has primary oversight for this undertaking, through the collaboration of national and international breeding programs and breeding centers and various international research projects. We will provide an overview of the current activities in this area and the types of approaches being used to move nutritionally enhanced rice into the consumer arena.

Regulatory Oversight of Transgenes in Crop Plants – the United States and Abroad

Mitten, D.H. and Scott, A.

The regulatory oversight of agricultural biotechnology is well established in many nations. As early adopters of the technology, the United States, Canada, and Argentina have supported commercial development with coordinated frameworks based upon existing legislation for food, feed, and environmental safety. In nations where new legislation is enacted, the progress for commercial application has been slower. New legislation has been drafted to recognize issues raised by public acceptance discussions (e.g. EU and Brazil) or to conform to the Cartagena BioSafety Protocol – Convention of Biological Diversity (BSP) (e.g. Japan, Korea, and Mexico), even when previous legislation was in place. An example is Japan, engaged in the re-registration of products previously approved. In addition, there are some ratifying nations that do not have a regulatory process in place, have yet made provision for the BSP, and are faced with existing trade patterns that may not be in compliance with the BSP. The landscape of regulation is diverse and complex. There are national, regional, and international laws and treaties that must be considered in the development of regulatory oversight frameworks.

To provide a context for the regulations in place today, a review of the ISAAA reports on adoption of agricultural biotechnology is offered. In 1996, the first products of ag biotechnology were being grown by farmers in Canada and the United States. By 1999, the global production of biotech crops was 40 million hectares, and a growing gap between the number of products approved for commercial use in North America and Europe was creating strain on trade between these regions. As the EU implemented its new regulations in Spring 2004, worldwide production of biotech agricultural crops reached 80 million hectares.

In a broad sense, there are two schools of thought for the oversight of transgenes in crop plants. The U.S.-style is based upon the premise that any oversight required to ensure the environmental and safety assessment on the new biotech crop can be conducted under the existing laws and using the existing risk evaluation criteria, and then it can be determined if the biotech crop presents any additional concerns as compared with its non-biotech counterpart. The more cautious EU-style takes into account the possibility that "unknown and unanticipated" risks may not be identified by the risk assessment, and thus, post-market monitoring and consumer-based product labeling are necessary to protect the public interest. Post-market monitoring and product labeling may be required in the United States when the risk assessment warrants. The development of the two schools of regulatory oversight are said to be influenced by the confidence the public has in their respective governmental agencies. The resulting escalating requirements for generating the safety data package and the post-market responsibilities have driven the price for a product registration in the EU to be more than 10 million dollars, a prohibitive cost for products benefiting smaller markets.

For the industrial nations, agricultural biotechnology for commodity crops has provided productivity enhancements. Insect-resistant and herbicide-tolerant soybean, canola, cotton, and corn have been registered and are widely grown. The slower introduction of biotechnology into other crops, like wheat and rice, has been influenced by market (domestic and export) and trade considerations. However, for nations with developing economies, the products of agricultural biotechnology are becoming increasingly viewed as contributing to the goal for a secure food supply through increased domestic production. In these nations, the food and feed derived from ag biotech crops is supported by the governments and accepted by the consumers. As an example, Bt rice is being developed by a number of public institutions. The nation of Iran reports commercial scale planting of Bt rice in 2005 following government review and approval. Commercial approvals for China's first biotech rice are anticipated in 2006 and include transgenes for Xa21 and Bt. It is anticipated that biotech rice will be approved in the Philippines within two years of a successful commercial launch in China.

The advancement of biotech rice in Asia demonstrates that when domestic supply and food security are important, registrations for domestic use are being accomplished and new products are being locally grown. Many of these products developed by national research programs are not intended for export to nations with more demanding registration requirements. What will happen when these products do not stay at home? We leave this topic for the next decade.

Decommodified Crops: The Case of GM Traits in Emerging Markets

Gardner, J.C.

Among the many outcomes of the industrial era of the 19^{th} and 20^{th} centuries, one of the most profound was the commodification of agricultural goods. No longer a local good, the advent of generic, largely unprocessed, agricultural goods, such as with corn, wheat, milk, as well as meat products, created a currency for financial markets that could be traded through time and space. Trade, regulatory, and economic policy have been built around the concepts inherent in agricultural goods that meet the uniform and consistent standards of the commodity.

Among the many 21^{st} century challenges in agricultural and food systems, one of the more pervasive is the ability to cope with the decommodification of agricultural goods. The most notable criteria suggested to differentiate agricultural goods include geography (through country of origin labeling), production methods (such as the USDA's certified organic program), and genetics (such as certified Angus beef). An emerging criteria for differentiating crops has been the presence of a transgene, rendering the resulting commodity crop distinguished from the traditional as being genetically modified (GM) or identified as a genetically-modified organism (GMO).

Soybeans, corn, and cotton were among the first commodity crops differentiated by the presence of a transgene, nearly all inserted to render the host plant some advantage over production pests which added value for the crop producer. GM soybean and corn have been discriminated in some international trade situations, usually discounted or not allowed as compared with the synonymous non-GM commodity. Rice is among the first crops with the potential to distinguish GM versions with traits targeting added value for the consumer. Enhanced vitamin content and plant-made pharmaceuticals are but two of the market-ready types of rice developed to date.

History clearly indicates that the burden of successful decommodification rests with the innovator and has followed a consistent pattern. First, a system of identity preservation must be developed. The USDA has required the segregation of one crop type from another at every stage from production and processing to distribution. They have required a certification process performed through audits and site visits which provide independent third-party verification of the segregation. Second, a regulatory framework must be established to verify and allow claims (if any) of the decommodified crop's benefit. Lastly, based on the balance of costs/benefits, trade and economic policies are established that are ultimately driven by consumer demand.

Given the new classes of rice targeted at consumer benefits, coupled with the worldwide production and consumption patterns, it appears the decommodification of rice is attracting an unprecedented amount of public attention. Political intervention is certain; both in the regulatory framework and cost/benefit analyses as GM rice is introduced in Asia and the United States. Each case will be unique, but all will be instructive as we continue the future challenge of decommodifying agricultural crops for the benefit of both producers and consumers.

Abstracts of Presentation of the General Session
Moderator: D. Groth

Renewable Fuels: New Policies, New Opportunities, and Economic Realities for Rice

Outlaw, J.

The Energy Policy Act of 2005, signed into law by President Bush on August 8, provides substantial incentives for the development and use of renewable fuels. There will be opportunities for agricultural producers to get involved in energy production by growing feed stocks, capturing wind and solar energy, and/or utilizing agricultural wastes to generate electricity. While there is a general sense of excitement regarding renewable fuels, a closer look at the economics for rice producers indicates the need for improved technology.

Water Issues in U.S. Rice Production

Evett, S.

In the United States, rice is produced in eastern Arkansas, California, northeast and southern Louisiana, the upper Gulf Coast of Texas, the Delta area of Mississippi, the Boot Heel of Missouri, and southern Florida. Rice grown in the United States is almost entirely paddy rice, which consumes from 1 to 4 acre-feet of water, depending on location. Water resources used for rice vary widely among the states. Water for rice production in Arkansas (49% of U.S. production) is largely from wells penetrating the Alluvial aquifer; while that in California (22% of U.S. production) is mostly surface water from snow melt. Over the years, rice production has become increasingly water efficient with production now ranging from 2000 to 6000 pounds per acre-foot of water. Increasing competition for water resources with other users, declining water resources in many states, and environmental issues are forces for change in rice farming in all parts of the United States.

What Does the Rice Genome Sequence Mean for Rice Improvement?

McCouch, S.R.

The availability of rice genome sequence creates many new challenges for the rice breeding and genetics community. It brings new people into the field of rice research, it allows new questions about basic biology to be addressed using rice as a model organism, and it paves the way for novel applications in rice improvement. To take advantage of the possibilities that the sequence represents requires enhanced flexibility and a desire for engagement on the part of the entire rice research and production communities. The promise of sequencing the rice genome was always to generate knowledge that could be translated into improved productivity, into higher quality products using more economically and environmentally sustainable production systems. Even when all the pieces are in place, it takes energy, intelligence, and commitment to align and integrate them into a coherent whole, especially one that is greater than the sum of the parts. The parts themselves are fascinating and worthy of study, and there are those who will focus an entire career on characterizing and understanding the pieces. There are emerging dictionaries of rice genes and proteins that tell us what each one does and how it works. Along with the dictionaries are manuals showing how different genes and proteins interact inside a living system. Learning to use this kind of information to assemble or re-assemble the parts into new rice varieties or new production systems will capture the imagination of many, and the ability to integrate and synthesize parts into working “whole” systems with novel features will catalyze many new enterprises. There will be those who have no interest in rice, but find its sequence intriguing because it lends insight into the mysteries of evolution or the cryptic syntax of genes. The challenge confronting us all is to share the knowledge that we derive from the rice genome sequence, to use that knowledge to build better rice plants and more sustainable production systems, and ultimately to improve the lives of people with whom we interact.

Abstracts of Papers on Breeding and Genetics
Panel Chair: S.R.M. Pinson

Medium-Grain Breeding in Louisiana

Blanche, S.B., Linscombe, S.D., and Sha, X.

Rice is an important plant commodity in Louisiana, behind only forestry and sugarcane, with a total value of $323,988,839. In 2004, approximately 1496 Louisiana growers farmed rice on 215,845 ha producing a total yield of 141,603 mt. Historically, three grain types of rice (long, medium, and short) have been grown in the U.S. with the majority of acreage being planted with long- and medium-grain cultivars. Since 1959, U.S. medium-grain rice acreage has been between 21 and 50% of the total rice acreage and averaged 26% from 1995 to 2004. In the years 1991 to 2003, U.S. medium-grain production varied from a high of 556,136 mt in 1991 to a low of 19,272 mt in 2001.

Between 1990 and 2003, the average yield of medium-grain rice in Louisiana has increased from 5322 to 6475 kg/ha and the average medium-grain yield for the United States (excluding California) during the same time period has increased from 5557 to 7052 kg/ha. Although the advancement of rice production technology played an important role in these yield increases, the majority can be attributed to the new varieties developed by the LSU Agricultural Center at the Rice Research Station.

Rice growers in Louisiana and other southern states face many challenges, such as high input costs, variable pest pressure, conservation issues, and tight regulation of pesticide use. Advances in yield potential and host-plant disease resistance, made possible by a dedicated focus on improved medium-grain varieties, can offset some of these challenges and allow growers to increase profits, reduce production costs, and meet conservation goals.

Blast (caused by *Pyricularia grisea* Sacc.), bacterial panicle blight (caused by *Burkholderia glumae*), and sheath blight (caused by *Rhizoctonia solani* Kühn) are major diseases that pose a constant threat to rice production in Louisiana. Since climactic conditions in southwest Louisiana are favorable for the development of these diseases, improved resistance to blast, sheath blight, and bacterial panicle blight has been, and will continue to be, a major goal of the breeding program. Marker-assisted selection and anther culture are used to accelerate the identification of improved medium-grain cultivars with blast resistance.

Conventional breeding techniques using the pedigree selection method are used to accomplish the program objectives. About 70 crosses (single crosses, backcrosses, and three-way crosses) are made each year at the Rice Research Station to combine desired characteristics to meet the objectives of the breeding program. Approximately 10,000 progeny rows are maintained yearly for medium-grain variety development, and segregating generations are advanced at the Rice Research Station and at the winter nursery facilities at Lajas, Puerto Rico. Yield potential and grain quality are always the most important traits followed by short stature, lodging resistance, disease (blast, sheath blight, and bacterial panicle blight) resistance, earliness, seedling vigor, ratoon yield, and many others.

Lines advanced to the early yield trials are evaluated by Dr. Don Groth and the Rice Pathology Project for reactions to major rice pathogens under artificial inoculation conditions. Promising lines from the preliminary yield test are advanced to the Uniform Regional Nursery (URN) and/or Commercial Advanced (CA) test. The CA test is carried out at the Rice Research Station at Crowley and at seven other locations across the diverse Louisiana rice growing environment. Performance in the CA and URN is studied as a measure of adaptation and stability. Promising advanced lines are evaluated for susceptibility to the physiological disorder straight head (conducted by Dr. Jason Bond and the Rice Agronomy Project) and resistance to sheath blight, leaf and neck blast, and bacterial panicle blight (conducted by the Rice Pathology Project and the Plant Pathology and Crop Physiology Department, Dr. M.C. Rush). Lines having release potential are evaluated for nitrogen fertilizer requirements (conducted by the Rice Agronomy Project). Production and maintenance of breeder and foundation seeds is handled by Larry White and the Foundation Seed Program at the Rice Research Station.

The Indica Revolution. I. Improving Tropical Germplasm for the United States

Rutger, J.N., Bryant, R.J., Lee, F.N., Bernhardt, J.L., Gibbons, J.W., and Yan, W.

The indica revolution in the United States began in the late 1960s with the introgression of the semidwarf gene from IR8 into California japonicas, through crossing and repeated backcrossing to the California parents, resulting in the release of M9 in 1978. Similarly PI 331581, which was Bluebelle*6/TN1, introduced from IRRI in 1968, was a donor for still more crossing to southern U.S. germplasm which led to Bellemont and Lemont in 1983 and 1985, respectively. A blip along the way was the release in 1979 of the first indica cultivar in the United States, LA 110 from the cross TN1/H4 in Louisiana. At the time of its release, LA 110 was dubbed an "industrial" rice as its grain quality did not meet U.S. standards, and it soon disappeared from production. An indica cultivar which has persisted, and indeed is the only true indica cultivar in the U.S. today, is Jasmine 85, an aromatic selection from IRRI that was released in Texas in 1998.

Exciting yield increases of indicas over tropical japonicas began to be observed in the late 1980s and 1990s. For example, in Arkansas, three indica cultivars yielded 23% more, in 11 days less, than three leading tropical japonica cultivars. However, the grain quality of the indica cultivars was not suitable for U.S. markets. Thus, the stage was set for an indica base-broadening approach, using Zhe 733 from China as a source of early maturity, and six late maturing IRRI germplasm lines as sources of grain quality similar to U.S. long grains. From this effort, nine improved indica germplasms, indica-1 to indica-9, possessing intermediate amylose levels and maturity similar to U.S. cultivars, were released in 2005. Although comparable in maturity, grain dimensions, and amylose content, these first nine lines had weaker straw and lower milling yields than desired. The next step was to induce early flowering mutants in the IRRI lines. Four early flowering germplasms, indica-10 to indica-13, resulted. These mutant germplasms were 15 to 29 days earlier than the parents, about a week later than local long grains, had intermediate amylose as did their parents, and had competitive milling yields. Another indica, the highly blast-resistant but late maturing indica cultivar Oryzica llanos cinco (OL 5) from Colombia, was mutagenized to select for early flowering. Selection was highly successful, resulting in 21 mutants that ranged from 12 to 33 days earlier than the OL 5 parent. The mutants retained the resistance of the OL 5 parent to six blast races. The 21 mutants have been narrowed down to three lines, indica-14 to indica-16, that have high milling yield and grain yield similar to local cultivars. Appropriate intercrosses between the IRRI and OL 5 mutants have been made in order to recombine the desired features of each, thereby setting the stage for further adaptation of tropical indica germplasm to U.S. environments.

The Indica Revolution. II. Improving Chinese Germplasm for the United States

Yan, W., Bryant, R.J., Gibbons, J.W., Lee, F.N., Bernhardt, J.L., and Rutger, J.N.

In the USDA rice collection, 85% of the Chinese accessions were introduced before 1977 when yield in China was 3.64 t/ha. Rice yield in China is almost double nowadays (6.27 t/ha in 2002). Hence, it is desirable to update Chinese germplasm in our collection and introduce advanced rice cultivars from China. Over 200 Chinese lines, mostly indicas, were introduced in 1996 in exchange for 50 U.S. cultivars. Indica lines GP-2, 4594, R 312, 4597, 4612, Taizhongxian 255, 4641, and Shufeng 121 were observed to have yield advantages from 20 to 40% over U.S. cultivars in 2000. However, they were either too high or too low in amylose content for the grain types, and most of them were tall and lodging susceptible.

Line 4484, which had 20% amylose similar to U.S. long grains and yielded 16% more than U.S. long grains, was entered into the Uniform Rice Nursery (URN) in 2002. This line yielded the same as Francis in both 2002 and 2003, and 16% more than Francis in the 2004 URN. For example, it had a total grain yield (main + ratoon) of 12,500 kg/ha and ranked second after hybrid XL 8 in the 2004 Louisiana URN. Line 4484 was 112 cm tall and lodged 34 and 52%, respectively, in 2002 and 2003, which explained lower yields in those years of URN. This line had head rice yield similar to Francis but with Toro-type cooking quality of 18% amylose.

In 2004, entry 4484-1693, selected from the M4 generation of 4484 seed irradiated at 300 Gy, was 10 cm shorter in height and 4% higher in amylose than the parent 4484. This change decreased lodging risk and made it a typical long grain in cooking quality while its yield potential was maintained. Similarly, entry Shufeng 121-1655, selected from the M5 generation of Shufeng 121 irradiated at 250 Gy, had an increase of amylose and a decrease of plant height as compared with its parent. Molecular marker analysis revealed heterozygous alleles associated with amylose content in parent line 4484. A study is being conducted to clarify whether the amylose change was due to heterozygosity or mutation.

These Chinese indicas including their selections had broad spectrum disease resistance. For example, both 4484-1693 and Shufeng 121-1655 were uniformly rated 0 for all blast races, including IB-33, IE-1K and BC3-1, the new races to which most cultivars having the *Pi-ta* resistance gene are susceptible. None of the known genes for resistance to blast, i.e., *Pi-ta*, *Pi-b*, *Pi-k* and *Pi-z,* were found in molecular marker analysis for five plants of 4484-1693 and three plants of Shufeng 121-1655. These results indicated a new source(s) of resistance, and the novel gene(s) will add genetic diversity for resistance and make the resistance more durable. In addition, parent line 4484 was rated 3 for sheath blight, 0 for narrow brown leaf spot, 4 for brown spot, 0 for leaf smut, and 2 for panicle blight in URN tests.

New sources of disease resistance are extremely rare. Most prospecting for new genes is done on wild *Oryza* relatives or very poorly adapted accessions of germplasm, which often are less desirable in yield, milling and general fitness. Poorly adapted cultivars are very difficult to use in breeding. However, line 4484-1693 and Shufeng 121-1655 are high quality cultivars possessing not only novel blast resistance, but high yield and acceptable milling and cooking traits as well. Therefore, they can be rapidly introgressed into breeding programs to provide needed resistance, while enhancing agronomic traits.

Utilization of Wild Rice Species at CIAT to Broaden the Genetic Base of Cultivated Rice in Latin America

Martínez, C.P., Borrero, J., Carabali, S.J., Sanabria, Y., Delgado, D., Correa, F., Lorieux, M., and Tohme, J.

Wild species are valued as a unique source of genetic variation; however, they have rarely being used for the genetic improvement of quantitative traits. Since 1994, the CIAT Rice Project in close partnership with CIAT Biotechnology Unit has been characterizing and utilizing wild rice species to broaden the genetic base of cultivated rice in Latin America. The strategies in place make use of molecular maps in combination with backcrossing to elite breeding lines or commercial varieties to develop populations that are used to identify and transfer QTLs associated with traits of agronomic importance to cultivated rice. Recent progress in this area will be reviewed and presented in this paper.

Data that will be presented suggest that several traits of agronomic importance, including yield and yield components and tolerance to biotic and abiotic stresses, have been transferred from *O. rufipogon* (IRGC105491), *O. glaberrima* (IRGC103544), and *O. barthii* (IRGC104119) to improved cultivars. Breeding implications will be discussed.

On the other hand, samples of wild rice populations collected in two sites in Colombia were classified as *O. latifolia*, a tetraploid species carrying the CCDD genome. Preliminary evaluations suggest that these accessions carry resistance to all rice blast lineages found in our “hot spot” Santa Rosa, as well as resistance to rice hoja blanca virus and *Tagosodes orysicola*.

Status of Development of Lowland NERICA Rice in West Africa

Sié, M., Séré, Y., Sanyang, S., Narteh, L., Dogbe, A., Coulibaly, M.M., Sido, A., Cissé, F., Drammeh, B., and Futakuchi, K.

In Africa, there are two major cultivated rice species *Oryza sativa* L. and *O. glaberrima* Steud. *Oryza sativa* L. originated from Asian and introduced into Africa by the Portuguese around 1500 A.D. It has high yield potential but is susceptible to the stresses of African ecologies. *O. sativa* is divided into two groups Indica and Japonica. *O. glaberrima* Steud. is an African indigenous species that originated in the central Niger delta and spread towards Gambia, Casamance, and the Sokoto basin. It has been cultivated for 3500 years and is adapted to African environments but prone to lodging and grain shattering. It possesses good genetic qualities and is resistant to major rice diseases. In Burkina Faso, there are three major types of rice ecology systems with irrigated rice accounting for 70% of the acreage but only 48% of the production. In efforts to expand the biodiversity of our rice, we undertook interspecific hybridization between the African traditional rice, *O. glaberrima,* and the Asian rice, *O. sativa,* with the support of the West Africa Rice Development Association (WARDA). After the success of the upland interspecific varieties, WARDA initiated other *O. glaberrima* X *O. sativa* crossings directed toward developing lowland cultivars. The objective was to combine the characteristics of *O. sativa* associated with high yield potential with the *O. glaberrima* resistance to the major constraints in the sub-region. After the screening and the evaluation of the first progenies, the selected material was sent to three countries, Burkina Faso, Togo, and Mali in order to continue the selection process. Thus, about 740 interspecific lines were evaluated in these countries. This study showed the emergence of a new set of interspecific lines adapted to lowlands that the national research programs will be able to use in various tests for satisfying farmers needs. Four of these new lowland NERICA are already released in Burkina faso and two in Mali.

Linkage Disequilibrium and Mapping Association of Yield and Disease Traits in Rice

Agrama, H.A., Eizenga, G.C., Yan, W., and Lee, F.N.

Rice (*Oryza sativa* L.) genetic mapping often involves the development, genotyping, and phenotyping of doubled haploid, recombinant inbred, or advanced backcross populations derived from a cross between somewhat diverse parents. This type of mapping population shows extreme disequilibrium between linked loci. Population-based genetic association studies are another approach available for mapping the relevant genes and identifying the variants that control economically important traits. The objective of this research was to use blast-resistant rice accessions to determine the utility of population structure analysis, linkage disequilibrium (LD), and mapping association of yield and blast [*Magnaporthe grisea* (T.T. Herbert) Yaegashi & Udagawa] traits in evaluating rice germplasm.

One hundred twenty simple sequence repeat (SSR) markers located across the 12 rice chromosomes were selected from the core set of 189 markers for use in this study. Associations between SSR markers and phenotypic traits were investigated in a collection of 103 rice accessions. Ninety-two of these accessions were introduced from seven countries, including five regions of China and the remaining 11 were U.S. cultivars. All accessions were evaluated for the complex traits yield, kernel width, kernel length, kernel length/width ratio, 1000-kernel weight, and blast in replicated trials. Regression of these traits on individual marker data using TASSEL software disclosed marker-trait associations.

The SSR markers were highly polymorphic across all germplasm accessions. To infer population structure and assign ancestries, a mode-based clustering algorithm implemented in the program *Structure* v2.1 was used. Population structure analysis identified eight main clusters at $K = 7$ and these clusters generally corresponded to the major geographic regions that the accessions originated from, including the U.S. cultivars. The accessions were classified by UPGMA and algorithm neighbor joining tree based on the genetic similarity matrix. Diversity clustering of all genotypes generally agreed with the population structure classification. In the structure of several populations, individuals had partial membership in multiple clusters. These accessions might have a complex breeding history involving intercrossing and introgression between germplasm groups, overlaid with strong selection pressure for agronomic and quality characteristics.

Linkage disequilibrium patterns and distributions are of fundamental importance for genome-wide mapping associations. Linkage disequilibrium between pairs of SSR loci was estimated using the squared allele-frequency correlation (r^2). Between linked markers, LD decreased in centiMorgans (cM) with decreased distance between loci. A considerable drop in LD decay values between 15 to 20 cM was observed, suggesting that it should be possible to achieve resolution down to the 15 cM level. Association between markers and traits was examined using significance of marker-trait correlations in comparison with associations found in other QTL studies. Many of the associated markers were located in regions where earlier QTL were found. The decline of LD within relatively short distances in the genome makes fine mapping yield and blast traits possible.

Population structure and diversity analyses will enhance rice breeding programs by allowing breeders to choose parents from a wide variety of backgrounds for incorporation into their breeding programs. These results indicate association mapping approaches in rice are a viable alternative to classical QTL approaches using mapping populations. The application of association mapping to rice breeding appears to be a promising approach to overcome the limitations of conventional linkage mapping.

Crude Protein Content and Phenotypic Characteristics of High Protein Lines

Wenefrida, I., Linscombe, S.D., and Utomo, H.S.

Improved nutritional quality of rice will bring positive implications to the health of a great portion of the world's population since rice is a staple food for over three billion people. A total of 612 lines have been recovered from *in vitro* screening and other methods aimed to improve protein or lysine content in rice. These high protein entries were planted in replicated plots at the Rice Research Station's South Farm near Crowley, LA, in the summer of 2005. The seeding rate of approximately 50 seeds per 6-foot (1.8 m) row was applied. Plants were grown under standard cultural practices with a recommended rate of nitrogen fertilization. The objectives of this study were to determine total protein content and evaluate their phenotypic performance under field conditions.

Total crude protein content was determined using Bradford's method. Currently, 163 entries have been analyzed for their total crude protein content. They included 30 entries derived from Francis, 45 from Wells, 23 from Cypress, 20 from Cocodrie, 10 from the indica IR64, and 35 from the japonica Nipponbare. Out of 163 lines, 129 lines showed a significant increase in their total crude protein content, ranging from 5 to 96%.

Protein lines were planted in replicated plots, with three replicates and two blocks. Phenotypic evaluation was carried out on a number of important traits, including sterility, grain size, chalkiness, panicle number, and row grain yield. Two hundred twelve lines exhibited partial sterility, ranging from mild to severe. The remaining lines were fertile with no apparent differences with their respective original parental lines. Lines with the highest protein content were fertile, with grain morphology closely resembling the parental lines.

Molecular Markers for Milling Yield in Southern U.S. Long-Grain Rice

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

Milling yield, defined as the percentage of whole rice kernels recovered after de-hulling rough rice, is a critically important trait in rice, with poor milling cultivars being rejected by rice growers. Milling yield is a complex trait comprised of component traits, each of which is under the control of numerous loci. Breeding for improved milling yield is difficult because of the numerous sub-component traits and their quantitative inheritance and the impact of pre- and post-harvest environments on the grain. A population of 137 F_{11} progeny lines derived from a Cypress X Panda cross was developed for mapping quantitative trait loci (QTLs) associated with milling yield. Cypress is a long-grain cultivar having intermediate amylose content and is well-known for high and stable milling yield (whole kernel percentage ~ 64%) over a wide range of harvest moisture levels. Panda is also a long-grain cultivar but has low amylose content and is characterized by low milling yield (whole kernel percentage ~ 52%). Important component traits contributing to the final milling yield were identified by regression analysis. Subsequent QTL analysis was used to identify molecular markers linked directly to milling yield and/or to the component traits.

Samples were milled using standard milling techniques beginning with 125 g of rough rice. Grain recovered after each step of the processing was weighed and data for brown rice (BR), total milled rice (TR), and whole milled rice (WR) were recorded. The whole kernel recovery was determined as the proportion of whole milled grains to the total milled rice (WR/TR). Kernel lengths and widths were measured on 100 - 150 kernels per family for both brown and milled rice using a winSEEDLE (2005a Pro) color image analysis system, and the broken and full length brown rice kernels were counted. The color analysis feature of the system allowed development of a new method for quantifying the area of chalkiness on a per kernel basis. Kernel thickness was measured with a digital micrometer on 20 kernels. The apparent amylose content was measured using standard procedures.

A genetic linkage map of the population was created with JoinMap 3.0 using genotypic data from 532 amplified fragment length polymorphism (AFLP) and 39 SSR markers across the 137 lines. AFLP markers clustered in regions heterogeneous between the parents, and 442 AFLP markers were placed onto the 12 chromosome pairs of rice using SSR markers of known location as anchors. The remaining 90 AFLP markers were linked into 13 relatively small groups for which the genomic location remains unknown at this time

Using simple regression, the proportion of brokens in the brown rice after de-hulling and before milling (PB = Pre-broken), explained 59.2% of the variance (R^2) in WR/TR, indicating this is an excellent predictor of milling yield. Chalkiness in brown rice explained 19.2% of the variance in PB while apparent amylose explained 9.6% of the variance. BR explained 67.9% of the variance in TR but was unrelated to WR and WR/TR. TR explained 14.1% of the variance in WR. Chalk and apparent amylose explained 20.4 and 14.8% of the variance in WR/TR, respectively. Moreover, length, width and thickness accounted for only for 0.3, 2.6, and 0.5% of the variance in WR/TR, respectively, indicating that grain shape in this long-grain cross had little impact on milling yield.

Significant QTLs were identified for BR, TR, TR/BR, WR and WR/TR, with *qBR-3*, *qTR-2, qTR-3*, *qTR/BR-2*, *qWR-6,* and *qWR/TR-6* explaining 23.5, 14.6, 12.2, 13.8, 13.7, and 14.7% of their phenotypic variances, respectively. Multiple significant QTLs for length, width, thickness, and chalkiness were also identified. The percentage of phenotypic variance explained by the single largest contributing QTL for these traits was 22.4, 16.3, 21.2, and 12.6%, respectively. The *Waxy* locus (*qWR/TR-6*: RM190) was directly associated with 14.7% of the variance in WR/TR. RM190 was also the largest contributing locus to the variance in PB, explaining up to 15.4%. As a next step, we will perform QTL mapping within RM190 genotypic classes to identify additional loci with significant effects on WR/TR and PB.

In conclusion, we have determined that chalkiness and, surprisingly, amylose content had a significant impact on milling yield in this long-grain cross. We are converting the AFLP markers associated with chalkiness in this population into micro-satellite (SSR) markers for testing and verification in U.S. rice breeding programs. Although grain shape components did not have a major impact on milling in this cross, we also identified significant QTLs for grain length, width, and thickness that may be useful in breeding programs. Moreover, we determined that PB is a simple and efficient means of evaluating progeny for milling yield potential. We are continuing our investigation to identify additional markers for milling yield in southern U.S. long-grain rice.

Genotypic and Phenotypic Assessment of the NSGC Rice Core Collection for Amylose Content and Alkali Spreading Value

Fjellstrom, R., Yan, W., Chen, M.H., Bryant, R., Bockelman, H., and McClung, A.M.

The USDA-ARS National Small Grains Collection (NSGC) of *Oryza* germplasm currently contains over 20,000 rice accessions. A core subset of roughly 1600 accessions was made in 2001 to represent the genetic spectrum of the rice germplasm collection. Core collections are being established for many species to enhance the efficiency of identifying new and useful source materials and, consequently, reduce costs in identifying desirable genes. The NSGC rice core, derived from some 100 countries, was grown in Stuttgart, AR, during 2002 for phenotypic and genotypic evaluation.

Cooking quality is one of the most important traits in rice, with the two foremost components being amylose content and gelatinization temperature. Detailed biochemical and genetic studies have shown that the rice *Waxy* gene, which encodes the granule bound starch synthase enzyme, controls grain amylose content. Comprehensive studies have also shown that the *Alk* gene, which encodes the soluble starch synthase IIa enzyme, controls starch gelatinization temperature (frequently measured as alkali spreading value, or ASV) by regulating starch amylopectin chain lengths.

In this research, over 1600 accessions of the USDA rice core collection were phenotyped for amylose content and ASV. These accessions were also genotyped for two SNP (i.e., single nucleotide polymorphism) markers associated with amylose content (exon 1 and exon 6), one SNP marker associated with starch pasting (RVA) properties (exon 10), and an intragenic microsatellite (RM 190), all in the rice *Waxy* gene, as well as two SNP markers in the *Alk* gene associated with ASV.

Fourteen alleles for the *Waxy* microsatellite marker were identified, six of which were rare, each being found in less than 1% of the accessions. Accessions with 8, 10, 11, or 12 CT repeats in the *Waxy* microsatellite marker all had high (>22%) amylose content, while each of the few accessions with 14, 21, or 22 CT repeats had intermediate (20-22%) amylose content. Accessions having 13, 15, 16, 17, 18, 19, and 20 CT repeats had either low (4-19%), intermediate, or high amylose content, such that these microsatellite alleles were not highly correlated with any one amylose content level. We found that the SNPs at exon 1 or 6 of the *Waxy* gene were better indicators of amylose content than microsatellite alleles. Jodon, L-202, and Cocodrie are examples of cultivars having the same *Waxy* microsatellite allele as cultivars like Cypress, Lemont, and Jefferson but they have significantly higher amylose content. Our results indicate that allelic variation at exon 6 in these cultivars results in increased amylose content but reduced RVA paste viscosity. Although amylose content explains some of the variation in starch pasting properties, a SNP in exon 10 of the *Waxy* gene appears to significantly affect RVA measurements independent of amylose content. One allele of this SNP is associated with a distinct RVA curve that is indicative of superior processing and parboiling quality. These results demonstrate that although the RM190 marker, which is a microsatellite in the non-coding region of the *Waxy* gene, is useful for predicting cooking quality in a narrow germplasm base, allelic variation in other coding regions of *Waxy* have been identified that offer greater accuracy in prediction of rice cooking and processing quality. We have also seen that there is no single SNP or mutation shared among ‘waxy’ (glutinous) rice accessions that have no measurable amylose. Other researchers have demonstrated that a wide variety of mutations in the *Waxy* gene can abolish granule bound starch synthase enzyme activity, resulting in no amylose being produced

Over 60% of the accessions had the same alleles at the two *Alk* gene SNP sites which were associated with intermediate or high ASV. However, mutations shown at either of the two SNPs resulted in ASV readings indicating low gelatinization temperatures in the core accessions. Thirty percent of the accessions possessed a SNP mutation commonly found in medium and small grain U.S. germplasm and 9% of the accessions had a SNP mutation found primarily in northeast Asian germplasm. A small number of accessions had low gelatinization temperatures with neither SNP mutation, suggesting the presence of other genes affecting amylopectin properties besides the specific *Alk* gene SNPs assayed.

Our results demonstrate that molecular marker evaluation provides a valuable method for characterizing world germplasm that is not skewed by environmental error, reveals sample heterogeneity that may be obscured in phenotypic evaluation, and clearly identifies novel alleles within a continuous spectrum of phenotypes.

High Silencing Frequency of the Rice *RCg2* Promoter

Shi, X.Y., Jiang, Y.M., Wang, T., Lee, Y.H., and Hall T.C.

The *RCg2* promoter, identified in a search for root-specific genes to combat the rice water weevil (RWW), has proven to be silenced at high frequency (~90%). To identify key elements contributing to the root-preferential expression of *RCg2* and the high frequency of silencing observed in transgenic (YXB) lines, several *RCg2* promoter deletion constructs were designed. These include 5' deletions MC1, MC2, MC4, MC7, and MC8 and internal deletions MC5, MC11, MC12, and MC13. The promoter constructs were fused to the *gus* reporter gene and used for *Agrobacterium*-mediated transformation of rice. Transformants resistant to 50 mg/L hygromycin were analyzed by genomic DNA blots and histochemical GUS staining. The frequency with which silencing was encountered in populations of the deletion mutants was used to characterize the effects of the various promoter elements.

Sequence analysis predicted the presence of many elements, including miRNAs, miniature inverted repeat transposable elements (MITEs), and other repetitive regions. A comparison of GUS spatial distribution and expression levels provided insight to the contributions of these elements to promoter activity. Related studies in our lab have shown that MITEs can positively affect transcription but also increase the incidence of silencing.

The large number of independent transformants studied (363) gives credibility to the deduced positive and negative regulatory elements. The region -272 to -214 includes elements with features similar to those of highly repetitive sequences, to HSA miRNA from *Homo sapiens* and the conserved region of the MITE *mJanus*, and was found to be a negative regulatory region. Deletion of the region from -406 to -208 (the MC11 promoter) revealed that it was also a negative element as, of 36 independent transformants, 33% expressed GUS. A third, major, negative regulatory region was identified: that between -328 and -268, which corresponds with a medium repetitive sequence. Evidence for strong positive element(s) between -729 and -328 is derived from the finding for MC1 that 55% (of 33 independent transformants) express, whereas no expressors (of 16 independent transformants) were recovered for MC4.

Analysis of the *RCg2* coding sequence suggests that it is a lipid transfer protein. The complexity of its promoter regulation, together with its high frequency of silencing, suggests that it may play an essential role in rice growth and development.

New Source of Imidazolinones Resistance in Rice

Livore, A.B., Prina, A.R., Birk, I., and Singh, B.

According to a farmer survey, the major constraints to rice production are weeds. Grasses, sedges and weedy rice ("red rice") have been the major groups of species that possess high fitness to the same environments where rice is grown. These weeds have become globally distributed and are difficult to control in rice crops. Red rice belongs to the same species as cultivated rice (*Oryza sativa L.*). The genetic similarity of red rice and commercial rice has made herbicidal control of red rice difficult.

Imidazolinone herbicides bind to AHAS enzyme at specific binding sites. By inhibiting AHAS activity, this family of herbicides prevents further growth and development of susceptible plants including many weed species.

A single nucleotide change in one or more conserved DNA regions elicits herbicide resistance. A mutation was induced by chemical treatment and a nucleotide substitution that confers herbicide resistance was found.

Three rice plants were found that had increased tolerance to the imidazolinone herbicide as compared with a wild-type variety of the rice plant and wherein the plants comprise one or more AHAS nucleic acids encoding a variant AHAS protein comprising an alanine to threonine substitution as compared with a wild-type AHAS protein.

A treatment of 2X imidazolinone herbicides, Arsenal (Imazapyr 75 g ai/ha) and Cadre (Imazapic 24 g ai/ha) in a water solution with a non-ionic surfactant (Citowet) at the rate of 0.25% (v/v) was applied at the 4- to 5-leaf stage of the rice plants. No phytotoxic symptoms were observed in any of the populations derived from the three putative resistant plants. The populations outyielded the check plot treated with a regular grass herbicide. No segregants were observed and a highly homogenous population either in agronomic and tolerance traits was produced from each plant.

Genomic DNA was extracted from leaves of greenhouse grown seedlings from wild-type and variant IMINTA 1, IMINTA 4, and IMINTA 5 rice lines and the AHAS gene was amplified by PCR. The PCR product was sequenced using standard protocols. Sequence analysis revealed a single base pair change in the coding region of the AHAS gene that caused an amino acid change from Alanine at amino acid 96 in the wild-type line to Threonine 96 in the mutant lines. This mutation corresponds to an amino acid change at Alanine122 in the *Arabidopsis* AHAS sequence to Threonine 122.

IRGA 417 was used as original cultivar to induce mutations. Crosses between IRGA 417 and IMINTA 4, were made and the F_1 and F_2 were grown in the greenhouse to study the inheritance of the resistant gene. Preliminary results of inheritance studies showed dominant gene effect. F_3 segregation studies are being carried out to check the dominant gene hypothesis.

An imidazolinone-resistant rice cultivar was registered and commercially released under the name PUITA INTA-CL in 2005, for the Argentine rice production system.

Variations in IR8 Rice Cultivar Released as Milagro Filipino in Mexico after 39 Years

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

A series of plantings and seed increases in farmers' fields can change the population, even in a highly self-pollinated crop like rice. IR8 was released in Mexico in 1967 as Milagro Filipino and after 39 years, the recent population may be distinguishable from the original population due to accumulation of variation.

Forty-four panicles from a seed production plot were planted one panicle to a row and evaluated for two years. Several phenotypic variations were noted during the first year, thus a replicated test of 11 diverse lines and IR8 from the gene bank was conducted. Significant differences were noted in plant height, maturity, length and width of flag leaf, 1000-seed weight, and length and width of grain. Awning of seed and different colors of milled grain were also noted. At least five lines had variation within rows and only two lines were comparable with IR8 in several traits. Initial DNA analysis of the lines will be presented.

Improving Blast Resistance for Upland Rice in Colombia: A Challenging Task

Correa-Victoria, F.J. and Martinez, C.P.

Rice blast disease caused by *Pyricularia 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 frequently defeated by the pathogen shortly after cultivar release; exceptions include Colombian commercial cultivars Oryzica Llanos 5, released in 1989, and Fedearroz 50, released in 1998. High pathogen variation, as described by infection phenotypes or "races" on a series of differentials, is often reported as the main cause of resistance breakdown. One strategy to improve the durability of blast resistance is to "pyramid" resistance genes by crossing rice varieties with complementary genes to provide multigenic resistance against the total spectrum of blast races in a rice-growing region. To do this effectively requires: 1) characterization of the genetic structure of the pathogen, including the composition, distribution and frequency of the avirulences that underlie race variation; 2) identification and incorporation of resistance gene combinations into commercial rice cultivars; and 3) the continuous evaluation and selection of breeding lines under high disease pressure and pathogen diversity. The development of molecular genetic markers has allowed major advances in all aspects of this strategy.

DNA fingerprinting establishes that the genetic structure of the pathogen throughout the Americas consists of historically identifiable, clonal lineages. Each lineage may express many races, and some may have a broad spectrum of virulence among related commercial cultivars. But, most lineages have defined cultivar-specificities, and most importantly, all lineages characterized thus far have a corporate genetic weakness. At least one of the known rice blast resistance genes is effective against all isolates of the same lineage. This suggests an evolutionary (phylogenetic) association of avirulence genes and genetic lineages in the pathogen. This association can only come about if these avirulence genes have an important function in pathogen and are strongly associated with pathogenic fitness. As a major consequence, pyramiding the resistance genes corresponding to all of the lineage-wide avirulence genotypes in a local pathogen population could be most relevant in breeding for durable resistance. Unfortunately, pyramiding genes is difficult using just conventional greenhouse or field screening procedures. Here too, advances in molecular marker technology, such as development of closely linked molecular markers, have made it possible to pyramid major genes into one genotype and to simultaneously select several other complex characters like quantitative trait loci (QTLs) that contribute to resistance expression. Convenient and cost-effective molecular markers such as microsatellites (SSR) seem to be promising for the identification of blast resistance genes and for pyramiding them into rice commercial varieties. These markers are now available through the published high-density linkage map of rice or public database (www.gramene.org).

The rice blast project at CIAT serves as a model for using molecular markers to both develop and carry out a breeding strategy for the development of durable blast resistance. We have analyzed the genetic structure of blast pathogen populations extensively using MGR-DNA and rep-PCR fingerprinting techniques and studied the avirulence gene diversity using a set of rice differentials with known resistance genes. The blast pathogen in Colombia has high levels of race variability but exhibits few genetic lineages. The complexity of the pathogen described as many races has been simplified into just six genetic families, named SRL-1 to SRL-6, which are mainly compatible with indica types of rice, and one genetic lineage, named A-7, that is compatible mainly with japonica type. Together, Colombian rice blast lineages exhibit a broad spectrum of virulence and, collectively, they defeat all known blast resistance genes. However, some resistance genes are effective against all members of each lineage and complements of such genes, in theory, should exclude all lineages.

Despite 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. The resistance of Oryzica Llanos 5 has been durable and has remained stable under field conditions for more than 14 years. Genetic studies have indicated the presence of at least four major genes controlling the resistance to some blast isolates. Based on the presence of avirulence genes in our blast populations we have inferred that Oryzica Llanos 5 carries at least eight major genes. The genetic basis of the high level of durable resistance to rice blast in Oryzica Llanos 5 is being characterized in two Recombinant Inbred Lines (RILs) from a cross between the susceptible cultivar Fanny and Oryzica Llanos 5. As a whole, the observed durable resistance in Oryzica Llanos 5 seems to be the result of a combination of quantitative and qualitative resistance genes.

Benefits and Practical Challenges in Applying DNA Markers into an Actual Rice Breeding Program

Utomo, H.S., Linscombe, S.D., and Sha, X.

DNA marker technology provides the opportunity to improve conventional breeding programs. SSR markers linked to blast resistant genes *Pi-ta2* and *Pi-z* were used to combine these genes during line development. Multi-way crosses were made among the *Pi-ta2* and *Pi-z* source lines and 32 breeding lines, including major cultivars. The presence of markers for both blast-resistant genes was confirmed, a total of 412 F_2 plants from multi-way crosses were grown in the greenhouse. The $F_{2:3}$ plants were planted in 4300 rows and evaluated for agronomic traits. Hundreds of $F_{2:4}$ lines both showing good agronomic potential and possessing the two blast genes were selected. The marker approach has demonstrated its versatility to speed up the breeding process through utilization of the greenhouse throughout the seasons followed by normal field evaluations.

A majority of agronomic traits important to rice breeders are polygenic in nature and exhibit continuous phenotypic variation (QTL). This is the greatest challenge for marker application in cultivar development. Despite current success in polygene mapping, the application of DNA markers to dissect these complex traits remains a problem. Most QTL mapping strategies require tremendous up-front cost, time, and labor. Association mapping based on linkage disequilibrium (LD) was conducted to alleviate this problem. The resulting marker-trait association can directly be used in the actual breeding cycles of crop improvement. Core entries of 140 lines representing breeding germplasm, cultivars, exotic germplasm, elite line, and URN entries were used in the LD mapping. Population structure was estimated based on 18 unlinked microsatellite markers. Associations of 64 SSR loci with kernel size and weight were analyzed through a mixed-effects model in which marker tested was considered as a fixed factor and subpopulation a random factor. Significant markers for kernel weight and size were detected on six and five locations, respectively. These alleles were potentially useful for selection.

Reverse QTL mapping was conducted on an F_2 population aimed to fine map kernel weight and size. A rough mapping analysis was performed on 80 F_2 plants. Information obtained was then used to screen 1120 F_2 plants to select for QTL isogenic recombinants. The isogenic recombinants were subjected to fine mapping and the results will be discussed. Fine mapping will allow marker-trait association not to become lost during the breeding process.

Advances in Marker-Assisted Selection for Rice Blast Resistance

Boyett, V.A., Gibbons, J.W., Moldenhauer K.A.K., Jia, Y., McClung, A.M., and Fjellstrom, R.G.

Marker-Assisted Selection (MAS) is being used in U.S. rice breeding programs to enhance development of rice cultivars with improved genetic resistance to rice blast disease. Because there is a continuous threat of race shifts within the *Magnaporthe grisea* populations found in southern U.S. rice fields, which can lead to a breakdown in host plant resistance, it is important to identify, introgress, and pyramid additional sources of resistance into new cultivars. Using molecular marker technology to accomplish these goals can accelerate the breeding process, as it is more efficient for identifying major gene resistance and can be performed without regard to environmental influences or confounding phenotypic traits.

As a result of research performed by the molecular genetics programs of the USDA-ARS/TAES in Beaumont, TX, and USDA-ARS in Stuttgart, AR, several major resistance genes to rice blast have been mapped and DNA markers have been developed for public use. *Pi-ta* confers resistance to races IB1, IB49, IB54, IB45, IH1, IG1, IC17, and IE1, but not IE1K. However, *Pi-b* and *Pi-z* confer resistance to IE1K as well as several of the same races as *Pi-ta*. *Pi-k*^{h}, *Pi-k*^{s}, *Pi-LEAH*, *Pi-i*, and *Pi-d* also confer resistance to some of the races covered by *Pi-ta*, *Pi-b*, and *Pi-z*. By pyramiding overlapping resistance genes into an improved cultivar, phenotypic resistance may be maintained even if one source of genetic resistance breaks down.

Markers are available for the above resistance genes except *Pi-d*, which is reported to be linked to *Pi-k*^{h}. Most are microsatellite markers, but both the microsatellite markers OSM 89, RM 155, and RM 7102 and the SNLP markers YL 155 and YL 183 are available for analyzing *Pi-ta* alleles. Presence of *Pi-b* alleles can be determined by using RMs 138, 166, 266, and 208. *Pi-z* alleles are detected by the microsatellites AP3540, AP5413, AP5659-3, RM 527, or RM 6836. RMs 144, 224, and 1233 differentiate *Pi-k* alleles, and *Pi-i* is analyzed with RM 3855.

In the UA RREC breeding program, testing usually begins using a SNLP marker for *Pi-ta* in the F_3 generation. Leaf tissue is sampled for genomic DNA using a high-throughput DNA extraction. PCR is performed with fluorescent-labeled forward primers, and the resulting PCR products are detected with an Applied Biosystems 3730 DNA Analyzer and analyzed with GeneMapper software. After the first round of MAS, progeny of parents that may also possess *Pi-b* or *Pi-z* resistance undergo another series of marker analyses for these additional genes.

Thousands of samples have been processed for MAS in the UA RREC program, eliminating on average about 40% of the test material. By increasing the efficiency of early rounds of selection for blast resistance, the breeders gain confidence in the selected materials and can quickly cease investing resources in material that would otherwise never perform to the breeders' standards.

Genotypic and Phenotypic Assessment of the NSGC Core Collection of Rice for Resistance to *Pyricularia grisea*

McClung, A.M., Yan, W., Jia, Y., Lee, F., Marchetti, M.A., and Fjellstrom., R.G.

Currently, the USDA ARS National Small Grains Collection (NSGC) of rice consists of over 18,000 accessions that have been collected from 115 countries. Although, the first accessions were entered into the rice collection in 1904, over 40% of the accessions were introduced during the 1970s, predominantly from Asia. Data on 27 traits are curated on the Germplasm Resource Information Network website (www.ars-grin.gov/npgs) for the accessions. However, only 2% of the collection has been evaluated for resistance to blast disease caused by *Pyricularia grisea.* Because it is difficult to collect meaningful data over such a large set of material, a "core" subset of the collection has been developed. The NSGC core collection is comprised of some 1800 accessions that represent about 10% of the whole collection. Over the last several years, progress has been made in developing molecular markers that are closely linked to major *Pi-* blast resistance genes. These have been successfully used as selectable markers in U.S. cultivar development programs. The objective of this study was to characterize the rice core collection for resistance to blast disease using phenotypic and genotypic assessment.

Some 1600 accessions of the core collection were evaluated for resistance to blast using a mixture of races in inoculated blast nurseries and for their reaction to seven individual races of blast that are found in the United States: IB33, IB1, IB49, IH1, IG1, IC17, and IE1k. In addition, the accessions were scored for molecular markers that are associated with major blast resistance genes: *Pi-ta*^{2}*, Pi-b, Pi-z,* and *Pi-k.* A total of 1160 accessions evaluated for their reaction to all seven races of blast. Two accessions, T442-57 (PI 406577) from Thailand and Blakka Tere Thelma (PI 369804) from Suriname, were observed to be resistant to all races of blast. These cultivars likely have multiple resistant genes, some of which are unknown in U.S. germplasm. In addition, 1% of the collection was found to have resistance to race IB33, for which there is no known resistance in the United States.

Genotypic analysis of the accessions, indicated that over 30% were heterozygous at one or more loci, suggesting that these are mixtures or landraces. Twelve percent of the core collection was observed to possess the *Pi-ta*^{2} allele which provides broad spectrum resistance to many races of blast found in the United States. However, over 60% of the accessions having *Pi-ta*^{2} were susceptible to one or more of these races. This suggests that there may be variability at this locus for resistance to specific races of blast. In addition, 11% of the accessions which possessed the *Pi-ta*^{2} gene, but lacked other Pi-genes, were resistant to IE-1k which generally causes a susceptible reaction when *Pi-ta*^{2} is present. This indicates that other novel resistance genes may be present in this germplasm. For the accessions that were genotyped using markers for the *Pi-z* and *Pi-b* genes, about 10% of the collection had resistant genotypes. However, 10 or more marker alleles were identified for these genes, indicating wide genetic diversity at these loci.

Using both molecular markers and phenotypic reactions to blast, inoculations have demonstrated that the core collection offers new sources of resistance to blast disease that can be exploited in U.S. breeding programs. Molecular markers are useful for determining if multiple known genes are present in the resistant germplasm or if new genes or alleles should be expected. This information is valuable for breeders to know how to best utilize the germplasm in crossing programs.

Molecular Mechanisms of Blast Resistance Gene *Pi-ta* Mediated Defense Response

Jia, Y., Lin, M., Jia, M.H., and Gubrij, K.

A better understanding the *Pi-ta* gene-mediated defense response will allow the development of novel strategies to control rice blast disease and obtain the new knowledge on molecular mechanisms of the gene-for-gene theory. The *Pi-ta* gene in rice prevents the infections of *Magnaporthe grisea* races containing the corresponding avirulence gene *AVR-Pita*. Pi-ta is a putative cytoplasmic receptor that appears to directly recognize the elicitor molecule from *M. grisea*. *AVR-Pita* is predicted to encode the cognate elicitor molecule. Upon a direct recognition, a sophisticated multifaceted rapid defense response occurs in preventing further blast infection.

Katy contains the *Pi-ta gene* conferring resistance to *M. grisea* races IB-49, IC-17, IE-1, IG-1, and IH-1. To study the components in the *Pi-ta* gene-mediated signal pathways, a genetic screen identified five Katy blast susceptible mutants induced by fast neutrons. Preliminary analysis suggests that two of these mutants contain the *Pi-t*a gene, and three of the mutants have altered within the *Pi-ta* gene. All five mutants were susceptible to above-mentioned races. The *pi-ta* alleles in these mutants are being analyzed and further genetic analysis is being performed to determine the novel loci that are involved in the *Pi-ta* mediated defense pathways.

As an alternative approach, a yeast two-hybrid screen was used to identify potential interaction proteins in the *Pi-ta* pathway. Both the Pi-ta protein and AVR-Pita protein were fused in frame with GAL 4 DNA binding protein to screen a two-hybrid library made from mRNA isolated after Katy was inoculated with a *M. grisea* race containing *AVR-Pita*. An AVR-Pita interacting protein, termed AVI3, a putative transcription factor, was identified and further characterized. This gene is located on rice chromosome 1 and is induced by the fungal elicitor in rice suspension cells. Progress in analysis of the role of *AVI 3* in *Pi-ta*-mediated signal pathways is reported.

Antagonistic Interaction of Ethylene and Abscisic Acid Signaling Modulates Disease Resistance and Abiotic Stress Tolerance in Rice

Zhou, X., Bailey, T.A., and Yang, Y.

Ethylene (ET) and abscisic acid (ABA) appear to act antagonistically to regulate rice disease resistance and abiotic stress tolerance. Exogenous application of ET was previously reported to enhance rice resistance to the blast fungus, *Magnaporthe grisea*. In this study, we have shown that exogenous ABA treatment decreases endogenous ET levels in rice plants and increases host susceptibility to *M. grisea*. Furthermore, two rice genes, *OsEIN2b* and *OsMPK5*, were found to mediate the antagonism between ET and ABA signaling pathways and play an important role in rice disease resistance and abiotic stress tolerance.

In *Arabidopsis*, *EIN2* encodes a central component of ethylene signaling pathway. We isolated the full-length cDNA of a rice *EIN2* orthologue (*OsEIN2b*) and generated *OsEIN2b* suppression lines using the double-stranded RNA interference (RNAi) approach. The *OsEIN2b* suppression lines did not have a significant change in the levels of endogenous ET or ABA but exhibited insensitivity to ET and hypersensitivity to ABA. Suppression of *OsEIN2b* also negatively affected seed germination, tiller formation, and flowering of the transgenic lines. In comparison with control plants, the *OsEIN2b* suppression lines showed increased susceptibility to the fungal (*M. grisea*) and bacterial (*Burkholderia glumae*) infection as well as decreased induction of ET-responsive defense genes. Interestingly, the same transgenic lines were much more tolerant to cold and salt treatments and exhibited increased induction of ABA-responsive stress genes. These results demonstrate that *OsEIN2b* positively regulates ET signaling and disease resistance but negatively modulates ABA signaling and abiotic stress tolerance.

The *OsMPK5* gene encodes an ABA-inducible mitogen-activated protein kinase (MAPK) in rice. Suppression of *OsMPK5* in transgenic rice via RNAi significantly reduced the level of endogenous ABA but increased the level of endogenous ET. The *OsMPK5* suppression lines also exhibited decreased sensitivity to ABA, constitutive activation of defense genes, and enhanced resistance to *M. grisea* and *B. glumae*. By contrast, over expression of *OsMPK5* in transgenic rice led to a significant increase of endogenous ABA level and enhanced tolerance to drought, salinity, or cold treatments. Therefore, *OsMPK5* positively regulates endogenous ABA level and abiotic stress tolerance but negatively modulates endogenous ET level and disease resistance.

TraitMill: A Versatile Platform for Plant Functional Genomics

Vrancken, E.J.M., Frankard, V., Reuzeau, C., Sanz, A., Hatzfeld, Y., de Wolf, J., Lievens, K., Wilde, V., van de Camp, W., and Peerbolte, R.

The advent of the "omics" sciences in the last decade has raised the expectation that better understanding of gene function will lead to the creation of new plant varieties with improved agronomic performance. To meet this challenge, CropDesign has developed TraitMill, a platform that allows assessing the effect of alleles on agronomically valuable traits of rice such as growth rate, leaf biomass, root biomass, heading time, seed yield, and harvest index. TraitMill is thus designed to identify new targets for crop improvement and to deliver comprehensive and quantitative data on individual allele effects.

Plant evaluation in the TraitMill is performed in a highly controlled greenhouse environment that can be adapted to either provide optimal growing conditions or to inflict stresses such as drought stress or nutrient deprivation stress. Rice plants are grown on a conveyor belt system and most plant handlings are performed by robots. Agronomic parameters are extracted from digital images using various segmentation algorithms. Once plants are mature, seeds are harvested and processed through automated equipment for cleaning, counting, and weighing of the seeds. All data are downloaded in a central relational database and automated statistical algorithms are deployed to compare the performance of the plants.

Over 1000 different plant-based transgenes have been tested in the TraitMill, and statistically significant effects on yield components have been observed for dozens of transgenes. Our results not only point to the clear impact that single genes can have on quantitative traits but also prove the relevance of genetic engineering approaches for improving yield and yield stability components and for generating additional genetic diversity.

Development of Molecular Strategies to Control Rice Sheath Blight Disease

Jia, Y., Singh, P., Jia, M., Wang, G., Wamishe, Y., and Zhu, L.

This oral presentation also was given and can be found in the **Abstracts of Papers on Plant Protection** section.

Bringing Quantitative Traits under Breeder Control by Combining QTL Mapping with Candidate Gene Approaches: A Case Study of Rice Sheath Blight Resistance

Pinson, S.R.M., Jia, Y., Oard, J.H., Fjellstrom, R.G., Jia, M.H., Hulbert, S., Liu, K., and Nelson, J.C.

It is inherently difficult to collect reliable phenotypic data on quantitative traits where the individual genetic effect of the multiple genes is generally less than the environmental effect(s), and the genes themselves may interact, producing a genetic-background effect. The difficulty in obtaining reliable phenotypic data for these traits is one reason breeders highly desire molecular tags to facilitate marker-assisted selection for quantitative trait loci (QTLs). Molecular gene-tags are identified through statistical correlation between phenotype and molecular markers. Accurate and precise data on QTL locations are also difficult to achieve without first obtaining reliable phenotypic data. Unfortunately, the same factors that make it desirable to know the precise chromosomal location, or even know the molecular sequence of a QTL also make this information inherently difficult to determine. While several major genes have been cloned and sequenced in rice, we know the DNA sequence of very few QTLs not just in rice but in any species.

Tens of thousands of QTLs have been mapped in plants, with new QTLs being reported each month. As of January 2006, Gramene (www.gramene.org) cited more than 7500 QTLs for rice alone. Some of Gramene's QTL listings are redundant in that a locus identified in the same population observed over multiple replications/locations gets a separate listing in the database. This is intentional and allows the information in Gramene to also reflect the replication or confidence levels of each QTL. Even so, of the thousands of QTLs mapped in all plants, only a handful has been fine mapped and cloned. For example, just one of the several QTLs for fruit sugar content in tomato has been cloned. The same for tomato fruit shape and weight. QTLs cloned from *Arabidopsis* include one for insect resistance controlled by aliphatic glucosinolate structure profiles, one for root morphology, and two QTLs for flowering time. Only heading time QTLs have been cloned from rice, but four have been cloned to date (*Se1*, *Hd3a*, α*CK2*, and *Ehd1),* all by researchers in Japan. Nearly all plant QTLs sequenced and cloned to date were identified through positional cloning, which generally proceeds along the following steps: 1) Putative identification and mapping of QTLs to large (10 – 20 cM) chromosomal regions; 2) QTL verification – often from agreement between independent mapping studies; 3) Fine mapping (≤5 cM) – often within near-isogenic lines (NILs) where the QTL is now 'Mendelized'; 4) After location to a sufficiently small genomic region, the region can be sequenced and analyzed for gene features such as start and stop codons or similarity to genes reported from other species; and 5) Gene sequence verification - often via transformation. Progressing from phenotype to genotype in this manner is known as forward genetics. It is also possible to conduct 'reverse genetics' where one starts with a base sequence then identifies the gene's function or affected phenotype.

The NRI Rice Coordinated Applied Genomics Program (a.k.a. RiceCAP; http://www.uark.edu/ua/ricecap/) is a multi-disciplinary, multi-state research project aimed at building within the U.S. rice community the "machinery" and experience-base required for developing and using molecular markers to facilitate marker-assisted selection (MAS) of QTLs. RiceCAP focuses on two quantitative rice traits, grain milling quality, and sheath blight resistance (SBR). This paper focuses on the SBR-QTL tagging effort to facilitate MAS. RiceCAP includes both forward and reverse genetics studies, with additional markers for the forward genetics efforts being identified through reverse genetics (candidate genes, expression differences), and with the putative genes identified via reverse genetics being verified and prioritized for further analysis with the forward genetics results. SBR was selected for RiceCAP efforts because seven QTLs had already been verified through agreement between two or all of the three of the prior SBR mapping studies, the last of which used a set of recombinant inbred lines (RILs) from Lemont/TeQing developed by USDA/TAES, Beaumont, TX. A set of nearly 300 TeQing-into-Lemont introgression lines (TILs) created at IRRI serves as a source of NILs in which to study the QTLs isolated (Mendelized) in some TILs, and in various QTL combinations within other TILs.

The three prior SBR-QTL studies all used RFLP molecular maps. Fortunately, the Lemont/TeQing RIL RFLP map had included many anchor probes, which were probes selected by the rice research community to provide a solid framework for comparing maps – between species and between types of maps such as from genetic cM maps to BAC clones to gene sequence base-pair maps. This allowed use of the CMap option in Gramene (www.gramene.org) to conduct *in silico* identification of microsatellite markers within the chromosomal regions reportedly containing SBR-QTLs. Use of the PCR-based markers allowed for cost-efficient characterization of the TILs. After molecular and phenotypic evaluation of the TILs, only one of the Mendelized SBR-QTLs proved to be reliably detected using inoculated field-plot data. This SBR-QTL is located near the centromere on chromosome 12 where a cluster of blast resistance genes and several resistance gene analogues (RGSs) also map. The Lemont/TeQing RIL SB and RFLP marker data were reanalyzed using WinQTL Cartographer V2.0. No epistasis was detected among the SBR-QTLs, so the inability to detect the individual QTLs after isolation appeared to be due to limits in the phenotypic evaluation method to detect such small individual gene effects. RiceCAP also included efforts to develop improved methods for evaluating SBR, including a micro-chamber method where seedlings were inoculated and grown under 2-L plastic bottles. The SBR-QTL on chromosome 12 was again the only SBR-QTL reliably detected after Mendelization. Expression studies comparing untreated with *Rhizoctonia solani* (causal org. of sheath blight disease) treated disease resistant varieties have identified hundreds of mRNA and proteins whose expression is putatively associated with host resistance. Some of the pathogen-induced gene sequences are in chromosomal regions containing SBR-QTLs and may provide a novel "disease resistance phenotype" that can be used to fine-map QTLs not detectable using the whole-plant SBR evaluation methods.

Discovery of Genomic DNA Polymorphisms using Oligonucleotide Arrays

Leong, S.A., Tian, S., and Splinter-BonDurant, S.

As part of a Mcknight CCRU project on finger millet and the NRI Rice Coordinated Applied Genomics Program (RiceCAP), we are trying to use oligonucleotide microarray technology as a means of rapidly discovering single feature polymorphisms (SFPs) that can be used as DNA-based markers for genetic mapping. Studies with Arabidopsis have demonstrated the feasibility of using Affymetrix oligonucleotide arrays for the discovery of SFPs for mapping of QTLs. Can this technology be extended to more complex grass genomes? To investigate this possibility, we have conducted a blast analysis of the two available rice genome sequences from indica line 93-11 and japonica line Nipponbare against the Affymetrix rice array probe set, which is largely based on the sequence of Nipponbare, to discover the number of electronic polymorphisms present in each genome sequence. A total of 170,256 putative single feature polymorphisms were identified in the 93-11 genome, indicating that the chip approach should be fruitful. Following a protocol previously used with Arabidopsis genomic DNA (www.naturalvariation.org), rice genomic DNA target was prepared by random priming. The method has been optimized by examining the conditions of labeling, temperature, and extent of incubation, use of hexamer and octamer primers, alteration of the ratio of biotinylated dCTP to dCTP, and methods of post synthesis processing of the labeled target. In addition, the amount of labeled target added to the hybridization at different temperatures was altered to test for probe saturation. Pilot hybridizations were conducted with labeled genomes of the two rice genotypes 93-11 and Nipponbare. Analysis of this preliminary, un-replicated data using several data normalization methods showed that a percentage of the putative SFPs can be reliably detected when perfect match, mismatch, and single copy probe hybridization data were considered. Increased signal to noise was observed by increasing the total amount of labeled target and the temperature of hybridization indicating that probe saturation was not achieved with the standard protocol used for Arabidopsis (www.naturalvariation.org). This work sets the stage for application of this technology to the discovery of single feature polymorphisms that can be used for genetic mapping of quantitative resistance to blast in finger millet, as well as resistance to sheath blight and milling quality and yield in rice.

Evolutionarily Expansion and Divergence of the Stress Tolerance Gene Families, *OsDREB1* and *OsWAK*, in Wild and Cultivated Rice Genomes

Lemaux, P.G., Zhang, S., Gu, Y.Q., Singh, J., and He, Z.H.

Developing new strategies to protect cultivated rice against biotic and abiotic stresses is of critical importance due to climatic changes and the need for increased productivity without increased environmental damage. The *Oryza* genus includes 21 wild rice species, two cultivated rice species (*O. sativa* and *O. glaberrima*), and a variety of landraces. Allelic variation within cultivated rice species and between cultivated and wild rice species offers a rich source of genetic variation. Our studies looked at genetic variation in two gene families, *OsDREB1* and *OsWAKs*, associated with biotic and abiotic stress tolerance with the goal of identifying markers and genes potentially useful for improving this important crop species.

Wild rice germplasm has high levels of genetic variation and is a valuable resource to broaden the gene pool of cultivated rice for improved traits, like abiotic stress tolerance. One focus of our efforts is on mining allelic variation in wild rice species and landraces for Dehydration-Responsive Element Binding (*OsDREB1*) transcription factors, known to regulate genes responsible for drought, salt, and cold tolerance in many plant species. Our long-term goal is to isolate, characterize, and utilize alleles/paralogs in wild rice species and landraces, using *OsDREB1A* and *OsDREB1B* probes from *O. sativa*, to identify wild rice BACs containing alleles.

Preliminary results indicate the success of this approach in identifying *OsDREB1* alleles from BAC clones of the FF genome wild rice species, *O. brachyantha.* Sequence data from a single BAC, containing both *OsDREB1A* and *OsDREB1B* alleles, demonstrates that diversification of coding and regulatory sequences has occurred between the cultivated and wild species. Expression analysis of the cloned alleles under abiotic stress conditions also indicates diversification in the wild species relative to *O. sativa*. Through this reverse genetics approach, we are gaining insights into how and what natural variation of *OsDREB1* is involved in abiotic stress tolerance. The approach might provide potentially beneficial alleles for improving abiotic stress tolerance in cultivated rice and other crop species.

Another focus of our research is on the wall-associated kinase (*WAK*) gene family, which plays important roles in pathogen resistance, heavy-metal stress tolerance, and cell expansion in the model dicot plant species, *Arabidopsis.* Although 26 *WAK* and *WAK-like* (*WAKL*) genes were identified in *Arabidopsis,* 125 *OsWAK* gene family members were found in *japonica* rice through a reiterative database search and reannotation of the sequenced *O. sativa* genome. Phylogenetic analyses of rice, *Arabidopsis* and barley OsWAKs showed that this gene family expanded in rice due to lineage-specific expansion in monocots; localized gene duplications appear to be the primary event responsible for the expansion, resulting in *OsWAKs* clustering.

A recent study looking at the history of rice genome duplications indicated that massive individual gene duplications are ongoing and provide a robust source of raw material for the creation of new genes and gene functions. The identification of the large number of *OsWAKs* provides the necessary genomic information for further in-depth studies of function and evolutionary expansion. Preliminary studies indicate that the majority of *OsWAKs* are expressed, based on cDNA, EST, tiling microarray, and RT-PCR analyses. Utilizing siRNA and overexpression of specific gene family members in transgenic cultivated rice, our current efforts are focused on further characterizing the role of these genes in biotic and abiotic stress tolerance in rice.

Utilizing the rich resources of the recently sequenced *O. sativa* genomes, BAC libraries of 12 wild rice species and recently developed analytical and technical tools, it is possible to more accurately describe rice and to investigate the secrets that its genome holds. While the information we have obtained is intellectually intriguing, we believe that the practical lessons it will reveal will lead to improvements in the ability of rice to resist biotic and abiotic challenges.

Mapping *R*-Genes in Rice Wild Relatives (*Oryza* spp.)

Eizenga, G.C., Agrama, H.A., and Lee, F.N.

Rice sheath blight caused by *Rhizoctonia solani* Kühn and leaf blast caused by *Magnaporthe grisea* (T.T. Herbert) Yaegashi & Udagawa are major fungal diseases of cultivated rice (*Oryza sativa* L.). Rice wild relatives (*Oryza* spp.) are the source of several resistance (*R*-) genes, including those for blast and sheath blight resistance. Simple sequence repeat (SSR) markers were used to genotype rice accessions and determine the relatedness between the accessions. Recently, methodology to identify associations between DNA markers and specific traits was developed, and it should be possible to use this methodology to identify *R*-genes in *Oryza* spp. accessions. The objectives of this research were to 1) determine the genetic distance between three groups of *Oryza* accessions (*Oryza* spp., blast resistant *O. sativa* accessions, and U.S. rice cultivars) with SSR markers; 2) identify marker-trait associations between the SSR markers and disease reactions; and 3) compare the marker-trait associations identified between the three groups to further define novel *R*-genes.

Oryza spp. accessions were obtained from IRRI or are available from the U.S. rice germplasm collection (GRIN) (http://www.ars-grin.gov/npgs/). The blast-resistant *O. sativa* accessions are being introduced into the GRIN system. Seed of the U.S. cultivars are available through GRIN or from the appropriate breeding program.

Pathogenicity tests of *M. grisea* and *R. solani* were adapted from standard procedures. Genomic DNA was extracted from leaf tissue for amplification of PCR-based SSR primers. A total of 176 SSR markers were visualized by fluorescent-labeled products, processed by an ABI Prism 3700 DNA Analyzer, and data analyzed with GeneScan 3.6/Genotyper 2.6 software. The distance between each two genotypes was calculated using Rogers' distance (RD). Unweighted Pair-Group Method using Arithmetic Average (UPGMA) clustering was calculated based on the RD estimate pairs of genotypes matrix. Genetic distance and cluster analysis were conducted using the software program *PowerMarker*. Associations between the SSR markers and disease resistance traits also were delineated using *PowerMarker*.

The genetic distance between the three groups, *Oryza* spp. accessions, newly introduced, blast resistant *O. sativa* accessions, and U.S. rice cultivars, delineated the U.S. cultivars in one cluster with sub-clusters representing the parentage. The *Oryza* spp. group was represented by *O. alta*, *O. australiensis*, *O. barthii*, *O. glumaepatula*, *O. latifolia*, *O. meridionalis*, *O. nivara*, *O. officinalis,* and *O. rufipogon*. The close relationship between many accessions of *O. barthii*, *O. nivara* and *O. rufipogon* was readily apparent. One cluster of *O. glaberrima* and its ancestral species, *O. barthii*, was identified. The *O. sativa* ancestral species, *O. nivara* and *O. rufipogon,* are grouped together in several clusters. The *Oryza* spp. and *O. sativa* groups are distinct except for one *O. rufipogon* included in the 'Tox' lines obtained from Ivory Coast. It should be noted that this *O. rufipogon* accession originated in Cameroon. A cluster of *O. sativa* accessions originating from China also was identified.

In order to identify possible new *R*-genes, associations between the aforementioned SSR markers and disease ratings were determined within each of the three groups. Preliminary results identified 28 marker-disease trait associations in the *Oryza* spp. group, 44 associations in the blast resistant *O. sativa* group, and 21 associations in the group of U.S. cultivars. Most likely, more associations were identified in the *O. sativa* group because these accessions were identified as blast resistant in the field. There is little overlap between the associations of the three groups, suggesting a number of *R*-genes are present in these accessions. Approximately 34 chromosomal regions which do not have known blast (*Pi-*) resistance genes were identified by these marker-trait associations. These regions will be investigated further to identify novel *R*-genes in both the *Oryza* spp. and *O. sativa* accessions. Only five associations with sheath blight were identified, and these are in regions of previously identified sheath blight QTLs.

Using blast-resistant *O. nivara* accessions, mapping populations are being developed from crosses with susceptible U.S. rice lines for fine mapping and identification of novel *R*-genes. In addition, disease-resistant backcross progenies obtained from these mapping populations will be made available to rice breeding programs.

A Comparison of Regression and Multivariate Models for Marker-Trait Associations Among Inbred Lines of Rice

Zhang, N., Zhang, W., and Oard, J.H.

Traditional quantitative trait loci (QTL) mapping techniques are commonly used to identify loci or intervals linked to traits of interest, but power and precision are often lacking. Association mapping is said to be more precise with savings in time and expense. To detect the association between molecular markers and traits, linkage disequilibrium mapping, case-control test, logistic regression, and analysis of variance with general linear model have been used. We evaluated the potential of discriminate analysis (DA) for discovery of candidate microsatellite markers associated with 12 economically important traits in a large population of unrelated U.S. and Asian inbred lines of rice. Associated marker alleles detected by DA mapped within the same genetic intervals when compared with previous traditional QTL mapping experiments that evaluated progeny derived from various controlled crosses. With the same dataset, we also compared different modern regression approaches for selecting molecular markers associated with agronomic traits. These methods included forward stepwise regression, least angle regression (LAR), and Least Absolute Shrinkage and Selection Operator (LASSO) selection R2, and cross validation data were used as criteria for optimal selection of both additive and epistatic models. The results indicate that the regression models were at least as effective, if not more in some cases, as the multivariate DA approach for predicting strength of association between microsatellite markers and complex agronomic traits among inbred lines of rice.

Development of Rice Mutant Populations for Forward and Reverse Genetics

Tai, T.H., Colowit, P.M., Cooper, J.L., and Comai, L.

With the sequencing of the rice genome, more attention is now being placed on determining the function of the 30,000 to 40,000 predicted genes. Mutant populations of rice represent one of the most important resources for functional gene analysis. Several groups around the world have or are in the process of developing mutant populations using a wide variety of mutagenic agents (e.g. transposons, T-DNAs, Tos17, irradiation, chemical) as well as different cultivars of rice. Availability of these resources has been instrumental in the identification and characterization of many important genes in rice.

Mutant populations are typically used for either forward or reverse genetics approaches. In forward genetics, populations are screened for a particular mutant phenotype of interest under conditions that enable detection of that phenotype. Once mutants of interest are detected, they are used to isolate the gene that has been mutated. How this is accomplished is dependent on the nature of the mutagenic agent may involve map-based cloning or isolation of DNA sequences flanking insertional agents such as transposons or T-DNAs.

Reverse genetics is another approach dependent on the availability of mutant populations. In this case, the gene of interest is known and the mutant populations are screened at the DNA level to identify mutants with alterations in the gene. Once these are identified, the corresponding plants (or typically their progeny) are then characterized to determine what phenotype the mutation in the gene of interest causes.

Recently, a novel method for detecting mutated genes was developed called targeting induced local lesions in genomes (TILLING). TILLING facilitates the identification of point mutations in genes of interest. Since point mutations are more subtle changes that may alter but not completely inactivate a gene, they are often of more interest than mutations causing larger lesions or disruptions of genes such as the insertion of transposons or T-DNAs. Here, we report our progress in developing chemically-mutagenized populations of the rice cultivar Nipponbare, our preliminary analysis of the feasibility of the TILLING approach using these materials, and our efforts to identify useful mutants using forward genetic screens.

Molecular Characterization of Rice Recombinant Inbred Line Population Derived from a *Japonica-indica* Cross

Liu, G., Bernhardt, J., Jia, M.H., Wamishe, Y., and Jia, Y.

Recombinant inbred line (RIL) populations of rice represent a permanent genetic source usable for the construction of molecular genetic linkage maps and map-based identification of quantitative trait loci (QTL). The objective of this study was to characterize a population of 269 $F_{10\text{-}11}$ RILs from a cross between Kaybonnet *lpa*1-1 (KBNT*lpa*) and Zhe733 using 109 polymorphic simple sequence repeat (SSR) markers. SSR markers (107) were mapped on 12 rice chromosomes representing a total of 1016.3 c*M* of genetic map. Ten markers (9.2%) on chromosomes 3, 6, 7, and 11 favored ($\chi^2 = 34.0–189.7$, $P \leq 0.01$) Zhe733 alleles, and three markers (2.7%) on chromosome 6 favored ($\chi^2 = 37.7–46.6$, $P \leq 0.01$) KBNT*lpa* alleles. Twenty-six RILs (10.2%) were skewed ($\chi^2 > 15.7$, $P \leq 0.01$) towards Zhe733. The average frequencies of overall genome heterozygous and non-parental alleles per RIL were 1.3% (0.0%-38.9%) and 0.4% (0.0%-15.0%), respectively. Thirteen heterozygous RILs at more than five marker loci and nine RILs with more than five non-parental alleles were identified representing 5.1 and 3.5% of the population, respectively, consisting of 255 RILs. Two hundred thirty-five RILs were clustered into seven sub-groups based on Nei's genetic distance. These results demonstrate that the KBNT*lpa*×Zhe733 $F_{10\text{-}11}$ RIL population is an excellent mapping population characterized by low frequencies of heterozygosity and non-parental alleles and by low percentages of skewed markers and RILs.

Abstracts of Posters on Breeding and Genetics
Panel Chair: S.R.M. Pinson

Twenty-Five Years of Progress in the Arkansas Rice Breeding Program

Griffith, A.L., Blocker, M.M., Moldenhauer, K.A.K., Gibbons, J.W., Gibbons, J.H., and Wilson, Jr., C.E.

In the past 25 years, yields of long-grain rice cultivars have dramatically increased due in large part to cultivar improvement and somewhat to management techniques. Harvested acres have increased by 28% since 1980 due to more modern and efficient harvesting equipment and the ongoing success of the Arkansas breeding program. In the early eighties, there were only three public rice breeders in the south. Now, 25 years later, there are at least seven breeders. This helps the progress dramatically. In the late seventies and early eighties, the average yields were 95 to 100 bu/A verses today at 150 bu/A (153.6 in 2004 and 148.9 in 2005). In 1969, Starbonnet replaced Bluebonnet as the most popular rice cultivar and remained the number one cultivar through 1984. In 1985, yields again increased several bushels per acre. Newbonnet and Lemont were released in 1983, and in 1985, Newbonnet replaced Starbonnet as the most widely grown cultivar. In 1984, Starbonnet, Lebonnet, and Labelle were planted on 80.7% of the state's acres. In 1985, these three cultivars were planted on less than 13% of the state's acreage. In comparison, Newbonnet acreage increased from 5.1% in 1984 to almost 61.2% in 1985. During the 1990s, cultivars like Bengal, Cypress, Drew, Kaybonnet, and LaGrue increased the overall state average yields. In 1999, a new cultivar was released that took the state by storm. Wells has been on approximately 40% of the acreage for the last 4 years and will continue to be a major player in the upcoming years. Development of technology and the ongoing effort of the Arkansas breeding program to develop superior rice cultivars will help Arkansas producers remain competitive in the future.

Selection for Stable High Income Grossing Rice Genotypes

Samonte, S.O.P.B, Wilson, L.T., McClung, A.M., and Tabien, R.E.

Rice breeders aim to develop new cultivars with high grain yield, resistance to stresses, and acceptable grain quality. On the other hand, rice producers aim for maximum income. The objective of this study was to determine the direct effect of whole and total milled rice percentages on gross income using path analysis and to determine the genotypes that produce stable and high expected gross income using GGE biplot analysis.

Data from the Uniform Rice Regional Nursery trials on main crop grain yield and the percentages of whole and total milled rice from 47 long-grain genotypes that were grown at each of five locations (AR, LA, MO, MS, and TX) during each of three cropping seasons (2001 to 2003) were used in this study. Gross income of each genotype was estimated based on rough rice grain yield, milling yield percentages, market prices of milled rice, and direct and counter-cyclical payments. Path analysis was used to estimate the path coefficients (p) of the direct effect of grain yield and the percentages of whole and total milled rice on rough rice gross income. Genotype and genotype x environment interaction (GGE) biplot analysis was used to identify the highest yielding and highest income grossing genotype(s) for each location.

Grain yield had the highest positive direct effect on gross income ($p = 0.87$). Whole ($p = 0.35$) and total ($p = 0.14$) milled rice percentages also had significant positive direct effects on gross income. Grain yield was not correlated with either whole or total milled rice percentages. These indicated that for a genotype to have high gross income, it must have high grain yield and high percentages of whole and total milled rice.

The highest yielding genotype was not the highest income grossing genotype in nine out of 13 environments (location-season combinations) based on GGE biplot analysis. RU0103184 was the highest income grossing genotype in six of 13 environments and was the consistent highest income grosser at LA. RU0003178 was the highest income grossing genotype in four of 13 environments and was the highest income grosser at MS for 2 years. In both AR and TX, the highest income grosser varied across years. These were RU0003178 in 2001, RU0001188 in 2002, and RU0103184 in 2003. This study demonstrated the importance and method of estimating rough rice gross income and including it in GGE biplot analysis that identifies the highest income grossing genotype for a specific location.

Development of Medium-Grain Rice Cultivars with High Yield Potential and Superior Quality for the Southern United States

Sha, X. and Linscombe, S.D.

In the United States, cultivated rice is grouped into long-, medium-, short-grain, and specialty market classes, primarily based on the grain shape or dimension, along with the cooking quality. Long-grain rice is almost exclusively grown in the southern states, while medium- and short-grain rice is largely grown in California. Traditionally, southern states, such as Louisiana and Arkansas, also had large medium-grain acreage. However, this acreage has declined during the last decade. Rapid improvement on long-grain rice yield and the low commodity price of medium-grain rice may have contributed to the decline. Compared with long-grain rice, medium-grain rice has a narrower genetic background, poor seedling vigor, prolonged grain filling period, and is more susceptible to rice pests, such as blast, panicle blight, and stinkbugs. Current breeding effort has been placed on the further improvement of yield potential while maintaining the superior milling and cooking quality, as well as the improvement of disease resistance, especially blast resistance, by introducing major resistance genes from long-grain cultivars. Marker-assisted selection has been applied for qualitative traits, such as blast resistance and cooking types, in the early generations.

Breeding Aromatic Long-Grain Rice Cultivars for the Southern United States

Sha, X., Linscombe, S.D., and Theunissen, S.

The demand for aromatic rice has dramatically increased over the past two decades in the United States. The three major types of aromatic rice, in the order of importance, are Jasmine, Basmati, and Della types. Most of the aromatic Jasmine and elongating Basmati rice in the U.S. market is imported from other countries and the volume of such imports is increasing every year. Imported aromatic rice makes up 12% of domestic food rice consumption. At present, only the Della-type and very limited quantities of the Jasmine- and Basmati-type aromatic rice are being grown in southern rice growing states. There are few adapted cultivars available in the United States. However, specialty characteristics, such as aroma, flavor, and appearance, of these domestically produced Jasmine and Basmati rice do not match those of imported rice. Development of improved special purpose rice cultivars adapted to the southern U.S. environment with competitive grain and milling yields, superior specialty characteristics that match those of imported rice, and pest resistance will help the U.S. rice industry to obtain a sizable portion of this fast growing, high value aromatic rice market, both domestically and internationally.

The Combined Use of Anther Culture and Marker-Assisted Selection Enhances Breeding Efficiency in Rice

Jiang, J., Boyett, V.A., Gibbons, J.W., Moldenhauer, K.A.K., and Lee, F.N.

Breeding efficiency is, to a large extent, determined by accurate selection of desirable progenies created by hybridization and rapid fixation of desired characters for further cultivar development trials. To accelerate the development of improved rice cultivars with desirable cooking quality and novel blast resistance, marker-assisted selection (MAS) and anther culture techniques were incorporated into the Rice Breeding Program of the University of Arkansas Rice Research & Extension Center at Stuttgart.

Coupled with a greenhouse pathogenicity assay and field phenotypic selection, DNA markers greatly facilitated selection of desirable progenies for anther culture and their derived doubled haploids (DHs). In 2002-2003, by using RM190, a microsatellite marker associated with apparent amylose content of milled rice and a co-dominant PCR marker to detect the presence of blast resistant *Pi-ta* allele, 167 (14%) progenies were stringently selected from a total of 1,189 F_1s of 16 triple crosses for efficient production of 3,400 DHs, thus saving tremendous resource and time. DNA markers were also efficiently used in identification/selection of DH lines with desired blast resistance and cooking quality. Using MAS and anther culture, we succeeded in the introgression of new blast resistance (not *Pi-ta*) from exotic *indica* germplasm such as Zhe733, Yangzi 95, Jing 185-7, and Jasmine 85 into U.S. quality breeding lines. In 2003-2004, numerous DH lines with resistance to the devastating blast races IE-1k, IE-1k-Banks, and IB-33 were recovered in less than 2 years from anther culture, marker-assisted selection to greenhouse pathogenicity assay.

The potential for combined use of MAS and anther culture to enhance breeding efficiency was evident. However, MAS and anther culture are employed to complement but not to replace the proven successful conventional breeding program, due to the considerable genotypic effect on DH production and limitations with DNA markers.

Method for Streamlining Marker-Assisted Breeding: From Field Sampling to Marker Analysis

Utomo, H.S., Wenefrida, I., Nash, J., and Linscombe, S.D.

Genomics and the marker-assisted breeding will undoubtedly benefit crop improvement. However, the relative ease, speed, and cost to conduct marker analysis on a practical scale remain a problem. Using microsatellite markers, we have devised a procedure to streamline marker-assisted selection that is both simple and economical from sample collection in the field to DNA extraction, PCR amplification, and marker analysis. A snap of leaf tip was placed in a 96-sample holder. Several leaf holders containing hundreds of samples can be carried in a pocket. Samples were collected while evaluating other desirable traits. Once brought to the lab, the leaf samples could be processed immediately or later. One person could extract about 800 DNA samples a day. Depending on the PCR block, 192 to 768 PCR reactions could be performed a day. One person could generate 400 data markers per day using the dual PAG electrophoresis unit. The average cost to generate marker data was 34¢, 1¢ for DNA extraction, 29¢ for PCR reaction, and 4¢ for gel electrophoresis. Multiplexing brought the cost down further. The overall procedure requires an up-front cost of less than $15,000 for equipment. This low-cost, high throughput marker application will benefit breeding programs.

Development and Application of PCR-Based Assays for High Throughput Screening of Aromatic and Herbicide-Resistant Rice

Kadaru, S.B., Yadav, A.S., and Oard, J.H.

Fragrance is an important desirable trait for cooking quality of premium-value Jasmine and Basmati rice cultivars, associated with the level of 2-acetyle-1-pyrroline controlled by a recessive locus (*fgr*) on chromosome 8 that encodes for betaine aldehyde dehydrogenase (*BAD2*). We present here the design and application of PCR-based SNP markers using rice genomic template DNA in exon 7 of the *BAD2* gene. The approach developed during this study represents a relative high-throughput, cost effective, reproducible, and facile protocol using a three-primer system that unequivocally distinguished alleles of the *BAD2* gene among 22 rice fragrant and non-fragrant rice lines. Our PCR-based method is an effective option to facilitate rapid marker-assisted screening of fragrant and non-fragrant homozygous or heterozygous genotypes in cultivar improvement programs.

Outcrossing or gene flow is a major concern in herbicide-resistant crop management such as the Clearfield rice technology. Recent studies have shown that the acetohydroxyacid synthase (AHAS/ALS) gene that confers resistance to the imazethapyr (Newpath) herbicide can be transferred from the rice cultivar CL161 via cross pollination under field conditions to weedy red rice. We report here a DNA-based method that involves design and application of allele-specific primers using PCR assays to distinguish herbicide-susceptible and resistant AHAS alleles in either homozygous or heterozygous genotypes produced from natural outcrosses between CL161 and red rice. The PCR-based assay is simple, rapid, inexpensive, reproducible, and only requires standard PCR and electrophoresis instruments that can be applied toward marker-assisted selection, outcrossing evaluation, and effective weed management strategies for the Clearfield crop system.

Genetic Relationships Determined Among Rice Cultivars Based on Expressed Sequence Tags and Microsatellite Markers

Ndjiondjop, M.N., Kassa, S., Mamadou, C., Hirochi, T., Baboucarr, M., Mande, S., and Jones, M.

Fourteen rice cultivars have been widely used in breeding programs at WARDA. They represent the two cultivated rice species and their interspecific hybrids. The genetic similarity or distance and relationship among these cultivars are largely unknown but of great interest for breeding programs. *Oryza sativa* was represented by a total of six genotypes with three *O. sativa subsp. indica* (Wita12, IR64, and Tos145-19) and three *O. sativa* subsp. *japonica* (WAB 56-104, WAB 181-18, and WAB 56-50) cultivars. *O. glaberrima* consisted of a total of four landraces adapted to both lowland (Tog 5681 and Tog 71062) and upland (CG 14 and CG 20) conditions. The four NERICAs (NERICA 1, NERICA 4, NERICA 5, and NERICA 6) are interspecific hybrids between *O. glaberrima* and *O. sativa*. *O. longistaminata* and Nipponbare were included in this study for comparative purpose. The former is a wild species and has good potential for future breeding programs as a donor parent for some useful traits (e.g., resistance to bacterial leaf blight and perennial trait) while the latter is a universal model cultivar for the International Rice Genome Sequencing Project.

The genetic relationship among 16 rice cultivars was investigated using 83 EST and 174 SSR markers. Similarity among the 16 cultivars varied from 21.9 to 91.2% for SSRs and 30.9 to 98.8% for ESTs. The extent of similarity of the four NERICA's with their donor (CG 14) and recurrent (WAB 56-104) parents ranged from 26.8 to 46.8% and 80.4 to 92.7%, respectively. Genetic similarity within the four NERICAs was the lowest between NERICA 1 and NERICA 6 (76.7 to 86.4%), which is in agreement with differences in agronomic traits. Cluster and principal component analyses performed on both marker types revealed three major groups for the cultivated rice species: the *glaberrima* group, *indica* group, and NERICA and *japonica* group. The wild species, *O. longistaminata*, appeared to be close to the *glaberrima* than the other groups. Sixty-four markers (22 EST and 42 SSR) were sufficient to clearly separate the 16 cultivars into their respective group. Matrices correspondence tests demonstrated the presence of greater correspondence between the phenograms derived from SSRs and ESTs ($r = 0.96$).

The New Interspecific Cultivars of Rice for Lowland Ecology

Sié, M., Séré, Y., Narteh, L., Dogbe, S., Coulibaly, M., Ndjiondjop, M., Zadji, L., Sido, A., Cissé, F., Hema, D., Drammeh, B., and Futakuchi, K.

Three important types of rice cultivation are practiced in West Africa: upland rice cultivation, irrigated rice cultivation with total water control, and lowland rice cultivation.

Within the framework of increasing the biodiversity base, WARDA, in more of its intraspecific creations, made several interspecific crosses between *Oryza sativa japonica* and *O. glaberrima* aimed at development of upland rice and between *O. glaberrima and O. sativa indica* for irrigated rice. The interspecific upland types called NERICA are well known and diffused in West Africa. It is not the same for the interspecific lines adapted to lowland-irrigated conditions.

This requires the continuation of the tests of these new lines in this agroecological zone to, in the short term, propose to rice producers materials adapted to all the toposequence (valley fringe, valley bottom, and irrigated). The Western and Central Rice Research Network (ROCARIZ) supported this program of development of interspecific germplasm adapted to lowland and irrigated ecologies held by the WARDA breeding task force. Its financial support made possible the selection of the lines. Now WARDA-The Africa Rice Center has named 60 new NERICAs adapted to both irrigated and rainfed lowland ecology.

Rice Identity Testing Using DNA Marker Analysis of Processed or Archived Rice Tissue and Rice-Ingredient Foods

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

The highly regarded reputation of USA rice in the world marketplace rice has been achieved by delivering rice and rice products that meet rigorous standards of uniformity and quality. In this regard, seed dealers, farmers, millers, and processors are concerned that the rice seed they are handling is correctly identified and true to type. Since the composition of food products is also of significant importance to consumers and the food industry, the detection of unexpected genes or unwanted transgenes in rice products can be critical as well.

DNA markers analyzed with the polymerase chain reaction (PCR) provide an effective analytical means to assay the identity and uniformity of rice products and a useful way to detect the presence of undesired genes in rice products. Since no single DNA marker can correctly identify a cultivar, we have devised a panel of 12 simple sequence repeat (SSR) DNA markers that can successfully ‘fingerprint’ most, if not all, USA rice cultivars.

Initially, these fingerprinting markers were successfully utilized using DNA extracted from grain or fresh leaf tissue, which are common sources of tissue from seed dealers and farmers, who can frequently inquire about cultivar identity and purity. Since post-harvest rice industry members increasingly request the identification of possible cultivars making up rice products found in the global marketplace, we wanted to find out how well these markers perform with DNA extracted from an assortment of rice products.

Six fingerprinting markers were tested on DNA from a wide variety of rice tissues and rice-containing foods, which included: milled, parboiled, instantized, crisped, and puffed rice; rice flour, bread, milk, ‘cakes,’ noodles, and vinegar; rice as an ingredient in soup (testing both grains and broth), baby food, beer, chocolate candy bars, and ready-to-eat pudding; cooked rice in frozen food meals; rice seed stored for 10 to 50 years; as well as recent to 78-year old herbarium leaf samples, hulls, pollen, and archaeological remains. A majority of the products tested were comprised of rice from known cultivars in order to test marker accuracy. Also tested were known mixtures of whole grain or flour in order to test sensitivity of detecting mixtures of rice products using markers.

In most cases, standard DNA extraction techniques and PCR conditions produced results for all the SSR markers tested from the various DNA sources. In some cases where DNA was isolated from highly processed (e.g., parboiled rice) or aged samples (e.g., >200-year old excavated single-seed samples), whole genome amplification techniques were used prior to PCR in order to obtain marker results. DNA marker fingerprint results routinely matched those expected from the specific cultivar-sourced materials. DNA marker mixtures were repeatedly detected when as little as a 1:49 mixture ratio was present in the tested samples.

Our results show that: DNA markers can be accurately obtained from a surprisingly wide variety of rice tissues and foods containing rice; whole genome amplification techniques can be used to successfully obtain marker information with DNA isolated from highly degraded samples; and marker techniques are capable of detecting trace amounts of DNA (e.g., transgenes) that may be unexpectedly introduced into rice grain or flour. This technology is useful for identity preservation from the production field to delivery to the consumer.

Five-Year Estimates of Reciprocal Outcrossing Between Rice and Red Rice Using Phenotyping and DNA Fingerprinting

Estorninos, Jr., L.E., Gealy, D.R., and Black, H.L.

Observations of nearly synchronous flowering of cultivated rice and weedy red rice have increased interest in the dynamics of reciprocal outcrossing between these two *Oryza sativa* plant types. At Stuttgart, AR, we are continuing our efforts to evaluate outcrossing rates between numerous, diverse rice cultivars, and red rice types. We selected pairs of cultivated rice and red rice due to their overlapping flowering periods. Isolated outcrossing plots were drill-seeded in the field with a nine-row planter from 2000 to 2004. Rows (18 cm apart) were planted either to rice or to red rice in the arrangement of two rows rice: one row red rice: three rows rice: one row red rice: two rows rice. Red rice was planted at one-third the density of rice to minimize the suppression of rice growth. The experimental design was a randomized complete block with three replications. Plots typically consisted of two side-by-side drill strips (~4-m wide) that were 5-m long but were only one drill strip wide (2 m) in 2000 and 2001. Red rice (via bagged panicles) and rice rows were harvested separately and seeds were composited by plant type each year. In 2005, 700,000 of the seeds produced in 2000 to 2004 were drill-seeded into long screening plots from which about 460,000 seedlings emerged to be evaluated for the presence of rice-red rice F_1 hybrids. Hybrids were detected by observing specific combinations of phenotypic traits of plants growing in rice and red rice rows (e.g. leaf pubescence, leaf and stem colorations, presence and coloration of awns, days to flowering, hull colors, and plant heights). Typical F_1 hybrids produced from pairs of blackhull awned red rice types and long-grain rice have purple-colored lower stems, and/or pink awns, and normal flowering patterns, while those from strawhull awnless red rice types produced hybrids with normal green stems, no awns, and extremely delayed flowering periods. Seedlings derived from red rice that had been paired with herbicide (imazethapyr)-resistant rice in the outcrossing plots were sprayed three times with commercial rates of imazethapyr to screen for herbicide-resistant hybrids.

With red rice as the pollen donor to non-herbicide-resistant rice, the highest outcrossing rate was from AR#8 blackhull red rice to Kaybonnet rice in 2004 (0.79%) and the lowest rate was from AR11-D red rice to Starbonnet rice in 2001 (0.02%). With red rice as the pollen donor to herbicide-resistant rice, outcrossing ranged from 0.06% (CL121/Stuttgart straw red rice) in 2004 to 0.32% (CLXL8/Stuttgart straw red rice), also in 2004. With non-herbicide-resistant rice as the pollen donor, the highest outcrossing rate was from Starbonnet rice to AR11-D red rice in 2001 (0.35%) and the lowest rate was from Starbonnet to Stuttgart black red rice in 2004 (0.01%). With herbicide-resistant rice as the pollen donor, the highest outcrossing was from CL161 rice to Stuttgart strawhull red rice in 2002 (0.17%) and the lowest rate was from CL121 to Stuttgart straw red rice in 2001 (0.006%). In 2004 outcrossing rates with red rice as the pollen donor were generally greater and panicle height differences between rice and red rice were smaller than they had been in previous years suggesting that the vertical distance between the pollen donor and acceptor could have affected outcrossing rates. Outcrossing rates averaged over 5 years were 0.17% from red rice to rice, 0.04% from non-herbicide-resistant rice to red rice, and 0.012% from herbicide-resistant rice to red rice. Simple sequence repeat (SSR) marker analysis will be used as an additional confirmation of these outcrossing rates. Subsequent analyses can help ascertain the probable parentage of any unknown crosses present in these plots. These results provide insights into the expected ranges of outcrosses between diverse rice cultivars and red rice types under different environments/years.

Milling Yield Variation among Eight Different Rice Cultivars at Differing Harvest Moistures, Dates, and Years

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

Milling yield is important in determining monetary returns to rice farmers. Knowledge of a cultivar's milling quality and stability can help in their 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. Eight different rice cultivars (1 medium and 7 long grain) were grown in 2004 and 2005 at the Rice Research and Extension Center in Stuttgart, Arkansas. They were harvested at optimum harvest date (35 days after flowering), 7 days before optimum, and at 7, 14, and 21 days after optimum. The grain was oven dried to 12% moisture and milled to determine percent total rice yields (TRY) and head rice yields (HRY). Average harvest moisture varied little between years with 26.5 and 24.3% at the first harvest date and 12.2 and 11.3% at the fifth harvest date in 2004 and 2005, respectively. Average percent TRY was 67.7 and 67.5% at the first harvest date and 67.2 and 66.0% at the fifth harvest date in 2004 and 2005, respectively, while percent HRY varied from 60.8 and 60.5% at the first harvest date to 57.8 and 51.1% at the fifth harvest date in 2004 and 2005, respectively. TRY varied from 71.52% for Spring to 59.08% for LaGrue in 2004 and 71.01% for Francis to 64.05% for LaGrue in 2005 for the first harvest. HRY in the first harvest varied from 67.67% for Cypress to 45.31% for LaGrue in 2004 and 65.90% for Medark to 51.80% for LaGrue in 2005. At optimum harvest TRY ranged from 71.45% for Cybonnet to 63.20% for LaGrue in 2004 and 72.02% for Wells to 63.43% for Spring in 2005, and HRY ranged from 68.50% for Cybonnet to 50.89% for LaGrue in 2004 and 68.88% for LaGrue to 55.37% for Spring in 2005. In the fifth harvest TRY ranged from 74.69% for Medark to 61.34% for LaGrue in 2004 and 70.30% for Medark to 61.28% for Banks in 2005, and HRY ranged from 64.92% for Medark to 39.90% for Wells in 2004 and 65.96% for Medark to 36.46% for Wells in 2005. The difference between HRY percent at optimum harvest and at 21 days after optimum was least for Cypress (4.6%) and greatest for Wells (14.8%). The order of cultivars from least affected to most affected by late harvest was Cypress, Cybonnet, Banks, Spring, Medark, LaGrue, Francis, and Wells. A sample from the optimum harvest date of each cultivar was "rewetted" and milled to simulate delayed harvest. As with field delayed harvest, the difference between HRY percent at optimum harvest and using "rewetting" was least for Cypress (9.3%) and greatest for Wells (30.1%). The order of cultivars from least affected to most affected by "rewetting" was Cypress, Cybonnet, Banks, Medark, Francis, LaGrue, Spring, and Wells. Cypress and Cybonnet produced stable milling yields across harvest moisture, dates, and years.

Field and Milling Quality Analysis of the MY1 Mapping Population in Arkansas

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Jia, Y., Boyett, V., and Blocker, M.M.

A coordinated effort with Louisiana and Texas, as part of the RiceCAP project, is under way to evaluate the MY1 RT0034/Cypress mapping population for agronomic characteristics and milling quality.

In 2005, 156 F_{12} rice lines, the parents (RT0034 and Cypress) and six controls (LaGrue, Madison, Spring, Maybelle, Trenasse, and Presidio) were planted at the Rice Research and Extension Center (RREC), Stuttgart, AR, in a Crowley silt loam soil (fine, montmorillonitic, thermic Typic Albaqualfs) using a randomized complete block design with two replications. Each rice line was planted in two row plots approximately 0.6 m long (25-cm row spacing), using a seeding rate of 2.6 g/m^2. Quilt fungicide at 1534 ml/ha + Quadris at 438 ml/ha were applied at early booting and again 10 days later to prevent disease.

At germination, low and erratic stands were observed in certain plots and plants were transplanted into these plots to provide equivalent plant populations throughout the trial. Approximately 86% of the rows had at least one plant every 5-cm row length (normal stand), 9% had somewhat less (intermediate) and 5% of row length was judged thin after transplanting. Variability in maturity was not observed between parents. The parents were different in days to heading by only 3 days, but a range of 39 days was observed in maturity among the progeny evaluated, suggesting transgressive segregation for maturity. Overall, about 65% of the population was observed to head within 2-5 days, 26% within 6 to 10 days, 7% within 11 to 14 days, and 2% was observed to have less uniform maturity ≥ 14 days. The effect of heading date and the variability within lines on milling quality has yet to be determined.

Although fungicides were applied for disease control, a low level of brown spot disease (*Bipolaris oryzae*) was suspected in the test. The parents of the MY1 mapping population differed in reaction to putative brown spot disease. Cypress did not appear to be affected by brown spot; however, RT0034 had an intermediate reaction using a rating scale from 0 (no infection) to 9 (≥ 90% of leaf area affected). A great percentage of the population (about 80%) had a resistant reaction (0-3), 18% had an intermediate reaction (4-6), and 2% had a susceptible reaction (7-9). In general, a relatively later planting date in Arkansas might help to differentiate the recombinant inbreeding lines for milling quality.

Evaluating Milling Yield in a Cypress × Panda Cross with Traditional, Re-Milling and Re-Wetting Techniques

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

Milling yield, defined as the percentage of whole rice kernels recovered after de-hulling rough rice and milling, is a critically important trait in rice. Milling yields vary considerably between cultivars with low milling cultivars rejected by rice growers. It is a complex trait comprised of component traits, each of which is under the control of numerous loci. Breeding for improved milling yield is difficult because of the numerous sub-component traits, the quantitative inheritance, and the impact of the pre- and post-harvest environment on the grain. In conjunction with an investigation of quantitative trait loci associated with milling yields determined using standard milling procedures, a "Re-milling" protocol to measure kernel strength and a "Re-wetting" technique to simulate the affect of high moisture pre- and post-harvest environments on milling yield were tested.

The cultivar Cypress, well-known for high and stable milling yield over a wide range of harvest moisture levels, was crossed with the cultivar Panda, characterized by low milling yield to produce 137 F_{11} progeny lines for milling yield evaluation. Two row plots of the 137 families were harvested at estimated field moisture of 18 to 21%, threshed, and the moisture content determined using a Dickey-John grain moisture meter. The rough rice was placed in paper bags and stored in a climate controlled environment for approximately 2 months to allow moisture equilibration to ~12%. Four samples of rough rice from each family were then prepared for milling, two aspirated 125-g samples for standard milling, and two un-aspirated 125-g samples for re-wetting followed by milling.

Standard milling began with the 125-g samples of aspirated rough rice de-hulled with a Sataki (rubber roll) de-huller. Brown rice was milled for 54 seconds in a McGill No. 2 mill with a 636-g weight located at the middle position (12 cm) of the mill's saddle arm. The milled rice was separated with a shaker/separator and kernels with length greater than or equal to a ¾ full length kernel were considered whole kernels. Grain recovered after milling and separating was weighed, and standard milling yields were calculated based on the proportion of whole milled grains to the total milled rice.

A 100-g sample of the whole kernel milled rice recovered from the standard milling procedure was re-milled to determine kernel strength of whole milled kernels. Additional force was applied to the grain during re-milling with a 1471-g weight located at the middle position (12 cm) of the mill's saddle arm. The re-milled milling yields were calculated based on the proportion of whole re-milled grains to the total re-milled rice.

Rough rice samples were re-wetted by soaking in water to simulate a rain event in the field or a fluctuation from low to high humidity during storage. The samples were placed in perforated boil bags and sealed with a Food-Saver plastic bag sealer. The samples were soaked in 26.7°C (80°F) tap water for 2 hours, dried with un-heated forced air for 12 hours to ~12% moisture; and place in a climate controlled environment to equilibrate for 72 hours. The samples were then milled using standard milling techniques. The milling yields of the re-wetted samples were calculated based on the proportion of whole milled grains to the total milled rice.

Re-milled and re-wetted milling yields are being compared with standard milling yields. Re-milled whole kernel milling yields will be analyzed to identify markers specifically linked to kernel strength, and re-wetted milling yields will be analyzed to find markers associated with moisture induced fissuring. Progress will be presented in the poster.

High-Iron and Zinc Rice Lines for Latin America

Martínez, C.P., Borrero, J., Carabali, S.J., Delgado, D., Correa, F., and Tohme, J.

Micronutrient malnutrition, the result of diets poor in vitamins and minerals, affects more than half of the world's population. Women and children are especially susceptible to deficiencies in micronutrients, particularly vitamin A, iron, and zinc. As a result, they are at risk of disease, premature death, lower cognitive capacity, and poor quality of life. The costs of these deficiencies are high. In Latin America and the Caribbean (LAC), economic and health indicators have been deteriorating. To meet this challenge, the CGIAR is implementing a new paradigm that views agriculture as an instrument for improving human health and nutrition, as well as for increasing productivity. Nutritionally improved staple food provides an inexpensive, cost-effective, sustainable, long-term means of delivering micronutrients to the poor. The goal of the Biofortification Challenge Program (BCP) is to improve the health of the poor by breeding staple foods that are rich in iron, zinc, and vitamin A, for poor consumers with priority on Africa and Asia. This program gets funding from diverse sources, including among others, The Melinda and Bill Gates Foundation.

A project funded by CIDA-Canada complements the Biofortification Challenge Program and extends its benefits to Latin America and the Caribbean through the development of and deployment of high iron and zinc rice lines. Rice has become the most important food grain in LAC, supplying consumers with more calories than other staple crops. Rice has become particularly important in the diets of poor people, who make up about 40% of LAC's total population. Food purchases account for more than half of all expenditures by the poor, and rice accounts for about 15% of their food purchases. Among the poorest 20% of the population, rice supplies more protein to the diet than any other food source, including beef and milk. However, people living in several areas where rice consumption is high have been suffering from a number of major nutritional problems. This is the result of vitamins and/or minerals naturally present in the rice grain but otherwise removed during the milling process or that naturally are not present in sufficient amounts. Preliminary data obtained at CIAT from 11 cultivars planted under irrigated conditions indicated that on the average 59 and 26% of the total iron and zinc present in brown rice is lost after milling, respectively. There were significant differences at the 5% level among genotypes tested.

Research carried out at IRRI in close collaboration with NARS suggests that there is genetic variability in the rice genome to increase iron and zinc in the rice grain. More recently, Haas et al. reported that consumption of biofortified rice, without any other changes in diet, is efficacious in improving iron stores in women with iron-poor diets in the developing world.

In this project for LAC, we plan to increase iron and zinc content in the rice grain using a breeding strategy in two phases. On a fast track, landraces and breeding lines conserved in the germplasm banks will be screen for mineral content to identify products that could have immediate utility, as potential cultivars or donors. Meanwhile, a crossing program will be started to combine high-iron and zinc with high yield potential, tolerance to main biotic and abiotic stresses, and good grain quality. This project will be carried out in close partnership with research institutions in Colombia, Bolivia, Cuba, Brazil, Dominican Republic, and Nicaragua.

Functional Characterization and Expression Analysis of the NRAMP Gene Family in Rice

Narayanan, N.N., Vasconcelos, M.W., and Grusak, M.A.

In plants, several groups of gene families are responsible for the uptake, transport, and storage of different transition metals, such as iron, zinc, copper, and manganese. These are essential minerals for normal plant growth and development, although they can be toxic when present in excess. For healthy plant growth, these metals must be acquired from the soil, distributed throughout the plant, and stored within different cells and organelles in order to carefully regulate their concentrations. In order to supply the cells with necessary amounts of metals, a tightly regulated uptake/transport/storage network must be in place. Some of the metal-related gene families described in plants are the FROs, ZIPs, YSLs, IRTs, and the NRAMPs, all of which are responsible for different steps in metal acquisition and transport. The *Nramp* genes are widely distributed throughout living organisms and are involved in the transport of a broad range of divalent metal cations. The *Nramp* genes share remarkable sequence similarity and display broad substrate specificity. They were first identified in mice and later in other mammals, worms, insects, yeast, fungi, and more recently, in plants. In plants, they were first identified in rice, where three *Nramp*s were reported (*OsNramp*1-3). However, *Arabidopsis thaliana* has six *Nramp* genes. The somewhat smaller number of *Nramp* genes in rice does not seem likely. Moreover, their specific roles and metal transporting capabilities have not been elucidated. This information is crucial for the better understanding of the metal homeostasis mechanisms that regulate and maintain equilibrium in metal concentrations inside and outside the plant cells.

In this work, we used different molecular resources, such as NCBI, TIGR, and RGRC to identify what appears to be the entire *Nramp* gene family in rice. We further characterized the *OsNramp* genes in terms of sequence similarity using ClustalW and Tree View, and we analyzed their respective protein composition, in terms of amino acid number, number of transmembrane domains, and putative localization in the cell using bioinformatic tools such as PSORT and Target P. We also conducted semi-quantitative RT PCR in different rice tissues in order to understand the specific expression profile of this gene family in distinct plant tissues. Finally, the role of the *OsNramp*s in metal transport in rice was studied using heterologous expression and functional analysis in yeast.

Bioinformatic analysis revealed that in rice (*Oryza sativa* L.), there are eight distinct, putative *Nramp* genes (*OsNramp*s). These range from 216 to 515 amino acids and have from three to 11 putative transmembrane domains. Target P analysis indicated that OsNRAMP3 maybe a chloroplast thylakoid membrane protein, whereas OsNRAMP8 seems to be localized to the mitochondrial membrane. PSORT analysis indicated that all OsNRAMPs are most likely plasma membrane proteins, not ruling out the possibility of some being present in the mitochondria, the chloroplast, the golgi body, or the endoplasmic reticulum (ER). PSORT analysis also indicated that OsNRAMP5 is the only rice NRAMP with a possible targeting sequence for vacuolar membranes. Sequence alignment with Clustal W and SPRINT revealed that the characteristic motif 5 of the natural resistance-associated macrophage proteins (NRAMPs) is present in OsNRAMP1-7.

Semi-quantitative RT-PCR analysis indicated that most *OsNramp* genes have a wide distribution of expression in different plant tissues, with the exception of *OsNramp* 4, whose expression seems to be specific to the panicle branches. *OsNramps* 3, 5, and 7 were the only *OsNramps* showing expression in rice embryos.

In yeast, expression of OsNRAMP3 complements the phenotype of a yeast strain defective in zinc uptake. Expression of OsNRAMP2, 3, 4 and 8 restored the growth of the *smf* yeast mutant, which has impaired manganese transport activity. The *fet3fet4* mutant, a yeast mutant defective in both low and high affinity iron uptake system, was also used to study the possible role of the OsNramps in Fe transport, and results will be presented. It has previously been suggested that NRAMPs are able to transport Cd. However, when the *OsNramp*s were expressed in yeast, there was no apparent increase in cadmium sensitivity. These data indicate that the rice *OsNramp* genes encode metal transporters with multiple specificities.

Cloning of the *Rc G*ene Conferring Red Pericarp in Rice

Sweeney, M.T., Thomson, M.J., Pfeil, B.E., and McCouch, S.R.

Red pericarp is ubiquitous among the wild ancestors of cultivated rice (*Oryza rufipogon*) and in some regions of the world red cultivars are preferred for their taste, texture, and ceremonial or medicinal value. Consumer interest in red and purple rices represents a growing specialty market in the United States but at the same time, the constant presence of weedy red rice in farmers' fields is the most economically important pest and grain quality problem faced by U.S. rice growers. Red rices typically show seed shattering and dormancy along with red pericarp and they interbreed freely with cultivated, white-grained types, making weed control difficult. A better understanding of the genetics and molecular biology of red pericarp and the association of this character with other wild/weedy traits will provide important information for better management of both the negative and positive features associated with red rice. Two loci have been identified using classical genetic analysis, *Rc* (brown pericarp and seed coat) and *Rd* (red pericarp and seed coat). When present together, these loci produce red seed color. Here we report the cloning of the *Rc* gene on rice chromosome 7 using a cross between *Oryza rufipogon* (red pericarp) and *O. sativa,* cv. Jefferson (white pericarp). *Rc* was found to encode a bHLH protein. Sequencing of the alleles from both mapping parents as well as from two independent genetic stocks of *Rc* revealed that the dominant, red allele differed from the recessive white allele by a 14 bp deletion within exon 6 that knocked out the bHLH domain of the protein. RT-PCR experiments confirmed that the *Rc* gene was expressed in both red and white-grained rice but that a shortened transcript was present in white cultivars. Phylogenetic analysis, supported by comparative mapping in rice and maize, showed that *Rc*, a positive regulator of proanthocyanidin, is orthologous to *In1*, a negative regulator of anthocyanin production in maize, and is not in the same clade as rice bHLH anthocyanin regulators. An immediate application of the work presented here involves the use of 'perfect markers' that specifically target the 14 bp functional nucleotide polymorphism within the bHLH gene to screen for red rice contamination within certified seed lots. Using the recombinant lines generated in this study, we will be able to determine whether the association between red pericarp, shattering, and dormancy is the result of linkage or pleiotropy. The information will also facilitate the utilization of genes derived from crosses with wild relatives by allowing breeders to conclusively select against progeny carrying *Rc* and to do so before the plants set seed.

Progress towards Cloning the Rice Low Phytic Acid 1 (*Lpa1*) Gene

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

Phytic acid (*myo*-inositol-1,2,3,4,5,6-hexa*kis*phosphate) is the primary storage form of phosphorus in seeds and is important for seedling growth and development. Seed phytic acid plays a significant role in human and animal nutrition as it effectively chelates important mineral cations (e.g. zinc, calcium, and iron) reducing their bioavailability. Furthermore, non-ruminant animals are unable to digest phytic acid, which requires animal feeds to be supplemented with phosphorus and contributes to environmental pollution.

Mutants with reduced levels of seed phytic acid have been isolated in maize, barley, rice, wheat, and soybean. In rice, the low phytic acid (*lpa1*) mutant exhibits a 45% reduction in seed phytic acid with a molar-equivalent increase in inorganic phosphate. The *lpa1* mutation has been genetically mapped to a region of approximately 47 kb on rice chromosome 2L. We have initiated transformation of genomic clones spanning this region and are currently analyzing transformants for recovery of wild type levels of phytic acid.

In addition to functional complementation, we are examining the sequence and expression of the candidate genes at the locus in order to identify the *Lpa1* gene. A number of additional rice mutants with altered levels of inorganic phosphate (and presumably altered levels of phytic acid) have also been identified and are at various stages of analysis. Our progress in identifying the *Lpa1* gene and molecular characterization of the *lpa1* mutant will be presented.

Genetic Analysis of Cold Tolerance using Structured and Unstructured Populations

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

Low temperature has a variety of effects on rice ranging from poor germination and seedling development to non-uniform maturation and sterility. The two major stages affected by cold stress are the seedling and reproductive stages. Stress during the seedling stage leads to poor stand established and retarded growth which greatly affect yield. One of our major interests is to determine the genetic basis of seedling cold tolerance in rice. Towards that end, we are taking a two-pronged approach.

First, we are using a structured rice population of recombinant inbred lines developed from a cross between the cold tolerant California temperate japonica cultivar M-202 and the cold-sensitive indica cultivar IR50. Using this population, seedling tolerance to low temperature has been assessed under two controlled environmental conditions. Under the first condition, 2- to 3-week old seedlings are exposed to 9°C constant air temperature for 3 weeks, which leads to wilting and necrosis in IR50. The second condition consists of exposing the seedlings to 9°C air temperature during daylight (12 hours) and 9°C air temperature during night (12 hours) for 3 to 4 weeks, which leads to chlorosis and stunting in IR50. Following construction of a molecular genetic map, QTL analysis resulted in the identification of several QTLs associated with seedling cold tolerance under each conditions. Of these QTLs, one major QTL, qCTS12, on chromosome 12 was found to contribute to 40% of the phenotypic variance in tolerance to wilting and necrosis. Another major QTL, qCTS4, on chromosome 4 was found to contribute to 20% of the phenotypic variance in tolerance to chlorosis and stunting. Recently, we fine mapped qCTS12 to a region containing four candidate genes. Our effort to identify the gene(s) underlying qCTS12 will be detailed, as well as our progress in fine mapping and identifying candidate genes at the qCTS4 locus.

In addition to using a structured population-based approach, we are also examining the feasibility of using an unstructured population of germplasm for identifying genomic regions conferring tolerance to low temperature. A set of 179 accessions has been genotyped using about 250 microsatellite markers and phenotyped for seedling cold tolerance. Our analysis of this dataset and a comparison to the results of various QTL analyses of seedling cold tolerance will be presented.

Segregation of Major Gene Blast Resistance in Early Generation Breeding Material

Boza, E.J., Gibbons, J.W., Correll, J.C., Lee, F.N., and McNew, R.W.

In 2003 and 2004, the progeny and parental lines of six crosses were evaluated for rice blast in the greenhouse with races IB-49 and race IC-1K and in the field. The parental lines were IRAT 13, PI 560243, Wells, and Cypress. Greenhouse and filed data indicated that IRAT 13 has a major resistance gene against race IC-1K and partial resistance to IB-49. Cultivars Wells and Cypress have partial resistance to race IB-49 but no resistance against IC-1K, and PI 560243 was very susceptible to both IB-49 and IC-1K. Crosses were conducted between IRAT 13 and the other three parental lines, as well as the three reciprocal crosses. Statistical comparisons of blast reactions among the progeny of a given cross and its reciprocal cross indicate that there may be a type of cytoplasmic or maternal inheritance factor that affects disease reactions.

Two races, IB-49 and IC-1K, were used to screen for vertical resistance in the greenhouse based on a disease reaction of 0 = no infection and 9 = susceptible type lesions. At Pine Tree, a composite of several cultivars were mixed together as spreader and inoculated with a mixture of common Arkansas blast races.

Chi square comparisons of phenotypic distribution of crosses against their reciprocal indicate that crosses between IRAT 13/PI 560243 and PI 560243/IRAT 13 were different at 1% level of probability in the greenhouse and Pine Tree tests for both generations and years suggesting a type of cytoplasmic or maternal inheritance in these crosses.

Crosses IRAT 13/Wells and Wells/IRAT 13 in generation F_2 and F_3 in 2003 and 2004, respectively, were different at 1% level of probability when inoculated with race IB-49 in the greenhouse, and they also were different for lesion type and neck blast in the generations F_2 and F_3 in 2003 and 2004 in Pine Tree.

Crosses IRAT 13/Cypress and Cypress/IRAT 13 in generation F_3 in 2004 not only were different at 5% level of probability when inoculated with IB-49 in the greenhouse but also were highly significantly different for lesion type and significantly different for neck blast, suggesting a maternal influence or cytoplasmic effect in both instances.

Crosses IRAT 13/Cypress and Cypress/IRAT 13 in generations F_2 and F_3 in 2003 had a ratio 3:1 with race IC-1K and lesion type in the greenhouse and Pine Tree, respectively. But, only the F_3 for Cypress/IRAT 13 had a 3:1 ratio for lesion type at Pine Tree.

Moreover, *P. grisea* field isolates collected from families and spreader rows at Pine Tree belonged to MGR586 DNA fingerprint A and VCG US-01. However, a single isolate collected in the blast nursery from the *Pi-ta* containing cultivar Banks during 2004 had MGR586 fingerprinting B, VCG US-02, and a virulence phenotype race IC-1K.

Overall, preliminary results of 2 years of data of generations F_2 and F_3 indicate that Pine Tree has the potential for conducting field experiments to select and evaluate germplasm for horizontal resistance under high disease pressure against the most commonly encountered races in Arkansas.

Mapping Sheath Blight Resistance QTL(s) in Tropical *Japonica* Rice

Sharma, A., Kepiro, J.L., Fjellstrom, R.G., Pinson, S.R.M., Shank, A.R., McClung, A.M., and Tabien, R.E.

Sheath blight (SB), caused by the fungus *Rhizoctonia solani* Kühn, is a destructive disease of rice (*Oryza sativa* L.) causing severe loss in grain yield and quality each year in the United States and elsewhere. Resistance has been reported to be horizontal and quantitative and does not follow the gene-for-gene model. There are limited sources of strong genetic resistance that are adapted to the United States. No commercial long-grain cultivar of rice with an acceptable level of SB resistance is currently available. Widespread application of preventive fungicides is the most common control measure, greatly increasing production cost and environmental hazards. Breeders are seeking to develop genetically-resistant cultivars as a durable solution to control SB. Therefore, the identification of genes significantly controlling SB resistance is important. To facilitate the identification of QTL(s) for SB resistance among U.S.-adapted germplasm, a mapping population was developed by crossing two tropical japonica rice cultivars, Rosemont (semidwarf and susceptible to SB) and Pecos (tall and tolerant to SB). The population was advanced to F_2-derived F_3 families, and phenotypic evaluation for SB disease was performed on 279 F_3 family rows during the years 2002 and 2003 at Beaumont. In both years, the field inoculated screening experiment was replicated twice and three disease scores were recorded during the growing season in each replication. The disease scores were given based on a disease response rating of 1 to 9, where score of 1 indicates very resistant and 9 indicates very susceptible disease reactions. The three time-sequential scores from each plot were averaged to reflect disease development rates. To avoid the confounding impact of escapes, which are common during disease evaluations, later analysis will focus on the maximum plot average obtained from the four replications.

Leaf tissues were collected for DNA isolation from all F_3 progeny rows representing the original F_2 plants. Genetic analysis of this mapping population was initiated in May 2005. For high throughput SSR marker genotyping, ABI 3100 Genetic Analyzer and Li-Cor 4200 genetic analysis systems are being used. Both systems allow multiplexing of differently labeled primer pairs, facilitating generation of ~400 data points per day. Genotypic data for 127 polymorphic SSR markers have been generated on the 279 lines. Preliminary mapping analysis using JoinMap 3.0 revealed that the linear order of 127 SSR markers is in good agreement with IRMI-2003 map available at http://www.gramene.org/. The average inter-marker distance is less than 20 cM with a few exceptions covering all 12 chromosomes of rice genome. QTL analysis using MapQTL 5.0 thus far shows highly significant SB-QTLs on rice chromosomes 1 and 3. Additional QTL analysis being performed on the mapping population will be presented and discussed.

Gramene: A Comparative Genomics Resource for Grains

Hebbard, C., Avraham, S., Buckler, E.S., Canaran, P., Casstevens, T., Faga, B., Hurwitz, B., Jaiswal, P., Liang, C., McCouch, S.R., Ni, J., Ratnapu, K., Ren, L., Schmidt, S., Spooner, W., Stein, L., Tecle, I.Y., Ware, D., Wei, S., Yap, I., Youens-Clark, K., and Zhao, W.

Gramene is a curated, open-source, web-accessible data resource for comparative genome analysis in the grasses, with a focus on rice. The database provides agricultural researchers and plant breeders with invaluable genetic and functional genomic information on rice and other grasses. Gramene's web interface provides information on rice and other grains, such as genetic and physical maps, sequences, genes, proteins, genetic markers, mutants, QTLs, controlled vocabularies, and publications, and is accessed by researchers in over 100 countries around the world. In addition to curating publicly available data, Gramene focuses on developing information on QTL, markers and maps, and provides displays and tools that integrate these various types of information so the user may visually make comparisons between the genomes of grass species.

Online tutorials and help documents provide users with an overview of how to conduct a search within each database, as well as how to navigate the general website. The Gramene staff also presents workshops at conferences, or upon request, to train users in using the database. For timely answers to question users may use the "feedback" button at the top of any web page.

The database and the curated datasets are freely available for local use and installation. Quarterly releases provide researchers with new and up-to-date information and tools. The Gramene project (www.gramene.org) is a collaborative effort between the Cold Spring Harbor Laboratory (www.cshl.edu), the Department of Plant Breeding and Genetics at Cornell University (http://plbrgen.cals.cornell.edu/), and various national and international projects dedicated to cereal genomics and genetics research.

Development and Curation of the Diversity Module in the Gramene Database

Tecle, I.Y., Yap, I., Ni, J., Jaiswal, P., Ravenscroft, D., Younes-Clark, K., Casstevens, T., Bradbury, P.J., Avraham, S., Schmidt, S., Ren, L., Hebbard, C.E., Liang, C., Buckler, E.S.,Ware, D., Stein, L.D., and McCouch, S.R.

Allelic diversity data are being generated for rice, and organizing, storing, and making it easily retrievable in a systematic manner will promote communication among rice scientists and enhance the usability of the data. The Gramene database (http://www.gramene.org) is developing a genomic diversity module (http://dev.gramene.org/db/diversity/diversity_view) that will enable users to explore allelic variation, generated by microsatellite (SSR) and single nucleotide polymorphism (SNP) markers, across the genome. Users will also be able to view allelic variation in multiple rice accessions at particular loci.

Currently, we are curating SSR polymorphism data for 234 rice accessions at 169 SSR loci, generated from a single experiment. The module also holds passport data for the germplasms, a description of the experimental conditions used to generate the data, and literature references. Links are made to external databases, such as GRIN (http://www.ars-grin.gov) and IRIS (http://www.iris.irri.org), to enable users to search for relevant data and to request seed. Through links to the Gramene marker and the CMAP modules, marker details and positions on rice linkage maps (produced from multiple experiments) are available. In the future, we will also curate data on phenotypic diversity.

At this stage, the database can be searched for allele profile of a specific germplasm accession using the accession name, accession number (IRIS or GRIN), taxonomic class, and germplasm type. Tasks in progress involve curating additional datasets and developing advanced search tools and user-friendly interfaces. The diversity module is expected to be released in summer 2006.

We are actively seeking your input, suggestions, and comments to ensure that the new diversity module is useful to the rice scientific community.

Update on Genetic Stocks – *Oryza* (GSOR) Collection

Rutger, J.N.

Genetic Stocks 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 initial collection was comprised of 19 genetic stocks, which included dominant and recessive male sterile lines, goldhull lines, and semidwarf, induced mutants.

The first mapping population was added in April 2004. This population includes 353 F_{10-11} generation recombinant inbred lines of the japonica-indica cross, Kaybonnet *lpa*1-1 and Zhe 733, designated as GSOR entries 100001 to 100353. Agronomic data for each line in the population is available via the Current Entries link on the GSOR web site, http://www.ars.usda.gov//Main/site_main.htm?docid=8320. Also in 2004, the Katy Lesion Mimic Mutant 1 genetic stock (GSOR 20) was added by Dr. Yulin Jia in December. The mutant was induced by ethyl methane sulfonate (EMS) in the Arkansas rice cultivar Katy. In the absence of the pathogen attack, the mutant develops spontaneous lesions that resemble disease symptoms and hence is called lesion mimic mutant.

The GSOR became a distribution site for Nipponbare seed in early 2005. This material grown in Stuttgart is descended, via Cornell, from the single plant selection identified by Dr. T. Sasaki of Japan, for the International Rice Gene Sequencing Project. For molecular studies, it is deemed critical that Nipponbare seed must be descended from the Sasaki selection. Researchers may request samples of Nipponbare through the GSOR web site.

The GSOR Lab released four rice genetic stocks in December 2005. These entries, designated GSOR 21, 22, 23, and 24, were selected from a mutagenized (300 Gy) M_2 indica population grown in Stuttgart in 2003. The mutagenized line was a sib to the previously released germplasm line indica-9 (PI 634583) derived from the cross Zhe 733/IR64.

GSOR 21 was selected for its spontaneous expression of apoptosis (early plant death) in five out of 12 plants in a single M_2 row. Subsequent field and greenhouse progeny tests in 2004 and 2005 resulted in identifying one original plant that was heterozygous and would produce a genetic stock that would segregate 3 normal:1 mutant. This genetic stock may provide a source for studying programmed cell death in plants. GSOR 22 was selected as a narrow leaf mutant, designated as chives; it was found in two out of nine plants in an M_2 row. Average flag leaf length is comparable with the parent; however, flag leaf width of the chives mutant was 0.56 cm compared with 0.99 cm for the parent. Seeds of chives plants were composited to form a pure breeding stock. GSOR 23, extreme dwarf, was observed in five out of 11 plants in a single M_2 row in 2003. Average height for mutant plants was 24 cm compared with 80 cm for the homozygous tall sibs. Extreme dwarf seeds were composited to form a pure breeding stock. GSOR 24 was selected for its expression of gold leaf color; it occurred in two out of seven plants in a single M_2 row. The gold color appeared ca. 78 days after planting and remained in the leaf material through harvest. A pure breeding genetic stock was formed from the seeds of the gold leaf plants. This genetic stock may provide an alternative source for field marker material. Each of these four mutants was controlled by a single recessive gene.

On-going projects include a giant embryo mutant identified in the long-grain cultivar Drew and preparing a recently donated Japanese collection, via Susan McCouch of Cornell University, for entry to the GSOR.

Individually, the GSOR entries may provide opportunities for new genetic studies. As part of the GSOR Collection, they bring diverse germplasm backgrounds to researchers that may eventually enhance U.S. rice breeding programs.

Development of U.S. Genetic Resources for Rice Functional Genomics

Jia, Y., Rutger, J.N., Xie, J., Lin, M., Moldenhauer, K., and Gibbons, J.

To facilitate functional genomics studies and rice improvement, a large mutant population of the U.S. cultivar Katy and several recombinant inbred line populations derived from elite U.S. rice cultivars are being developed.

We aim to take 45,000 independent mutant lines to M_4 generation using a midseason U.S. rice cultivar, Katy. Katy, released in 1989 from Arkansas, is a long-grain cultivar with good yield potential and milling quality and contains effective and durable blast resistance genes. Katy was subsequently used as one of the major sources for U.S. cultivar development programs and was chosen as a vector for U.S. mutant population development. To date, 6,000 M_1 lines induced by ethyl methane sulfonate (EMS), 14,000 M_1 lines induced by fast neutrons, and 25,000 M_1 lines induced by gamma radiation were collected from 2001 to 2004. Preliminary analysis of M_2 seedlings revealed defects in chlorophyll synthesis in approximately 4% of EMS M_1 derived lines. A total of 42 blast susceptible mutants derived from fast neutrons and seven lesion mimic mutants (two from EMS and five from fast neutrons) were identified. Thus far, 20,000 M_2 seeds were collected from 6,000 EMS induced M_1 and 14,000 fast neutrons induced M_1 by single panicle descent.

We aim to advance mapping populations to F_{10} through single seed descent. The mapping populations that currently being advanced are: Lemont X Jasmine 85 (150 F_6 and 289 F_4); Katy X RU9101001 (237 F_9), Raminade Str. 3 X RU9101001 (140 F_6, 2000 F_2), Cybonnet X C101A51 (200 F_6), and Cybonnet X Saber 289 F_6.

All of these rice genetic materials will be deposited as genetic stocks in the Genetic Stocks-*Oryza* (GSOR) collection at Dale Bumpers National Rice Research Center (DB NRRC).

A Variant Albino Mutation in Rice

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

Complete absence of chlorophyll and early death of the plant are important phenotypic descriptions of an albino plant. Ten genes for these traits have been identified in rice. In this study, we identified an albino variant from our M_2 population of rice cultivar Cocodrie; the seeds of which were treated with 1.2% ethyl methane sulfonate (EMS). The variant showed nearly a complete albino condition at the seedling stage but later turned completely green and was stunted. When 16 seeds harvested from this plant were planted, all plants at the seedling stage showed similar phenotypic characteristics indicating true to type condition. Genetic studies will be conducted in this novel germplasm to determine the pattern of inheritance and its role in the development of chlorophyll and chloroplast biosynthesis pathways.

Characterization of K23 (*SuRr3*), A SET Domain Gene Involved in Regulating Plant Development and Transgene Silencing

Wang, T., Kertbundit, S., Shi, X., Iyer, L.M., and Hall, T.C.

Genetic engineering technologies promise to be powerful approaches to augment conventional breeding for improvement of rice and other crops. However, transgene silencing represents a major impediment. Towards elucidating and alleviating gene silencing, we are using RNAi and *Arabidopsis* as a test system and to screen for novel plant genes participating in this phenomenon. Genes encoding putative chromatin remodeling factors, especially those including a SET domain (that encodes the catalytic core of histone methyltransferase) were selected as initial candidates.

Of ~20 targeted *Arabidopsis* SET genes, inactivation of K23 (*SuRr3*) was found to reactivate a silenced reporter transgene. Down regulation of K23 expression in wild type plants also lead to abnormal floral development and altered petal number. These phenotypes can be inherited, with their frequencies increasing over generations, indicating the involvement of an epigenetic regulation mechanism. The delayed onset, and variable expression, of the epigenetic phenotype renders initial screening in rice laborious, necessitating the use of *Arabidopsis* as a facile model system.

Careful inspection of several databases revealed that K23 transcripts can exist in two isoforms, one of which lacks a region containing six highly conserved amino acids within the SET domain itself. While no rice ortholog of K23 has yet been found, we have identified three rice genes that have a domain architecture similar to that of K23 that may, therefore, be SET genes with similar functions to those of K23.

Abstracts of Papers on Economics and Marketing
Panel Chair: L.L. Falconer

Impacts of Alternative Well Pumping Depths on Arkansas Rice Farm Profitability

Watkins, K.B., Hill, J.L., and Anders, M.M.

Approximately 80% of Arkansas rice hectares are irrigated using wells. The Alluvial Aquifer is the primary source of well water for rice producers in eastern Arkansas, but intensive irrigation is depleting this water source in historical rice producing areas like the Arkansas Grand Prairie. Some rice growers are pumping from the deeper Sparta Aquifer due to limited access or availability to other viable water sources. Pump lifts vary throughout eastern Arkansas, ranging from 18 m (60 ft) or less in areas where water is plentiful to 91 m (300 ft) or greater in areas tapping into the Sparta formation. Higher energy prices have significantly increased the cost of irrigation in the state. Farm diesel prices in Arkansas ranged from approximately $0.48/L ($1.80/gal) at the beginning of 2005 to over $0.61/L ($2.30/gal) at rice harvest. These high fuel prices have significantly impacted rice profitability throughout Arkansas and have prompted many producers to question the economic sustainability of rice production for their particular farm situations.

This study evaluates the impacts of alternative pump lifts on both rice whole-farm returns and cropland hectares planted. A Mixed Integer Programming (MIP) model is used to determine optimal whole-farm returns and optimal cropland hectares planted at varying well pump lifts. The MIP model maximizes whole-farm returns above operating and ownership expenses and selects optimal machinery complements and the optimal number of irrigation wells for farms of varying size growing both rice and soybeans in a 2-year rotation. Two farm sizes are modeled: a 971-ha (2400-acre) farm and a 1214-ha (3000-acre) farm. All operating expenses are in 2005 dollars, and a diesel price of $0.5469/L ($2.07/gal) is used in the analysis. Irrigation wells are assumed to supply water for 49 ha (120 acres). Arkansas season average farm prices for the period 2001-2004 plus loan deficiency payments less drying and hauling expenses are used to represent expected rice and soybean market prices ($0.1607/kg for rice; $0.2028/kg for soybean). Average rice and soybean yields observed in the Grand Prairie during the 2001-2004 growing season are used as expected crop yields (7818 kg/ha for rice; 2690 kg/ha for soybean).

Total cropland hectares for each representative farm are split into 32% owned and 68% rented hectares based on tenure data from the 2002 Census of Agriculture for Arkansas, Lonoke, Monroe, and Prairie counties comprising the Arkansas Grand Prairie region. Two popular rice rental arrangements are modeled for rented cropland: 1) a 25% crop share arrangement in which landlords receive 25% of the crop and 2) a 20% crop share arrangement in which landlords receive 20% of the crop. In both arrangements, landlords pay their portion of drying expenses and pay all belowground irrigation expenses related to wells. The tenant pays all aboveground irrigation expenses related to wells, including 100% of all irrigation fuel expenses.

The results indicate that pump lifts have significant impacts on both cropland hectares planted and whole-farm returns given the farm diesel prices observed in 2005. Pump lifts of 18 m (58 ft) or less are necessary to ensure all cropland is planted for the 971-ha farm using a 25% crop share arrangement (optimal return of $120,309 at the 18 m level). Pump lifts greater than 18 m result in significant reductions in both cropland hectares planted and whole-farm returns for this farm operation, while pump lifts less than 18 m increase whole-farm returns. Deeper pump lifts are achievable with reduced landlord crop shares. For the 971-ha farm using a 20% crop share arrangement, pump lifts of 32 m (102 ft) or less are necessary to ensure all cropland is planted (optimal return of $105,842 at the 32 m level). Larger farm size also allows deeper pump lifts to be achieved. Pump lifts of 37 m (120 ft) or less are necessary to ensure all cropland is planted for the 1214 ha operation using a 25 percent crop share arrangement (optimal return of $91,955 at the 37 m pump lift), and pump lifts of 50 m (163 ft) or less are necessary to ensure all cropland is planted for the 1214 ha operation using a 20% crop share arrangement (optimal return of $58,321 at the 50 m level). These results draw into question the economic feasibility of rice production in areas tapping into the Sparta formation.

Production, Consumption, Trade, and Price Projections of the U.S. and Global Rice Economy, 2005-2015

Chavez, E.C. and Wailes, E.J.

This paper provides a 10-year projection of the global rice economy, with a focus on key exporting and importing countries. These projections provide production, consumption, trade, and price baseline estimates that can be used to analyze alternative policy and market assumptions. The Arkansas Global Rice Model (AGRM), a non-spatial econometric model developed in the Department of Agricultural Economics and Agribusiness at the University of Arkansas in Fayetteville, was used in this analysis.

The average international long-grain rice price strengthens in 2005/06 as world ending stocks tighten to 67.2 million metric tons, down nearly 8% from the previous year. U.S. rice prices in 2005/06 remain relatively flat as carry-over stocks from previous year's record crop dampen any upward price movement – further narrowing the price premium over the Thai long-grain rice price.

Global rice harvested area in 2005/06 increases 1.5% to 151.7 million hectares as India, Myanmar, Thailand, and Australia recover from declines a year earlier, and China expands area by 2.2%. Over 75% of the net gain comes from India and China. World rice production is estimated to be 406.1 million metric tons, only 1.0% above the previous year as world average yield declines 0.5% due to lower yields in a number of producing countries like India, Uruguay, the United States, E.U., South Korea, and Taiwan. Nearly 89% of the net output increase comes from China, Thailand, and Myanmar.

While world population grows by 1.2% on the average, global rice consumption declines 0.8% to 411.6 million metric tons in 2005/06 as per capita rice use declines by nearly 2%. The weakened per capita use is a result of the combined effects of westernization of diets, urbanization, diet diversification, and diet changes toward more protein-based foods, especially in rice economies with growing incomes like India, China, Indonesia, Japan, and Taiwan. About 80% of the net decline in consumption is accounted for by India and China.

Total world rice trade in 2005/06 is 26.8 million metric tons, down 2.3% from the previous year's level. The increases in exports from Thailand, the United Stats, and China do not offset the substantial declines in shipments from India, Vietnam, and Pakistan. Total world rice trade relative to total global rice consumption remains low at 6.5%. Net world rice trade in 2005/06 is 23.5 million metric tons, 2.7% below the previous year.

An expansion in rice production is projected in 2006/07. World rice area is projected to increase 1%; and average world rice yield is expected to improve by 2.8% as yields in India, Uruguay, the United States, E.U., South Korea, and Taiwan recover from previous year's declines, resulting in a production increase of 15.4 million metric tons or 3.8% above the 2005/06 level. With average world population growth of 1.2 percent and a slight increase of 0.7% in per capita consumption, total global rice consumption in 2006/07 is projected at 419.1 million metric tons or a 1.8% increase over the previous year. Total rice trade is expected to expand by 1.6% above trade in 2005/06. With increased available supply relative to demand, international rice prices are expected to weaken in 2006/07.

Over the next decade, global rice area is projected to stabilize at around 152 million hectares, as both average yield and total production continue to grow at 1.1% annually. Total rice consumption will continue to increase around 1% annually, with growth driven mainly by population growth as average per capita use declines marginally. Contraction of rice area is projected to occur in China, India, Pakistan, Japan, and South Korea, which will be offset by expansion in Brazil, Myanmar, Nigeria, and the rest of the world. Nearly 68% of the projected net growth in total rice production in the next 10 years will come from China, India, Bangladesh, Thailand, and Vietnam. Sixty-one percent of the projected net gain in world rice consumption over the same period is accounted for by India, Indonesia, Bangladesh, China, Vietnam, Philippines, and Nigeria. Driven by consumption and trade, international rice prices will continue to move higher, growing at 1.1% annually.

About 87% of the projected net export growth over the next 10 years will come from Thailand (30.3% share), India (28.3%), and Vietnam (28.2%). With increasing available rice supply, net exports of these three countries are projected to grow at 2.9, 5.3, and 4.9%, respectively. Over the same period, projected major net importers include Indonesia, Iran, Philippines, Bangladesh, Nigeria, Iraq, Malaysia, Saudi Arabia, Turkey, and Ivory Coast – which, combined, will account for 69% of the projected net growth in import volume.

USDA's 2006 Domestic Baseline Projections

Childs, N.W.

USDA's 2006 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 and import levels, growth in domestic use, and the season-average farm price. Underlying economic factors driving these projections are explained. Because almost half 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 2006 baseline forecasts were developed in November 2005.

The 2006 baseline projects a small decline in rice acreage in 2006 followed by stable-to-slightly declining rice acreage through 2010. From 2011 to 2015, U.S. rice acreage increases each year as market returns to rice production exceed returns from other planting options. The average U.S. yield is projected to rebound sharply in 2006 and increase about 1% annually through 2008. The growth rate then slowly declines over the remainder of the baseline period, falling to about .75% by 2015. 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 increase each year of the baseline, exceeding the current record by 2007. Imports are projected to continue to increase each year, with Asian aromatic varieties accounting nearly all of the growth.

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. Exports are projected to drop in 2006 and then remain stable through 2009. Exports slowly increase each year from 2010 to 2015, but still remain below the 2002 record. With total supplies growing slightly faster than total use each year, ending stocks are expected to increase from 2007 to 2015. The stocks-to-use ratio is projected to increase from a little over 10% in 2006 to 12% by the end of the baseline period.

Global trading prices, which have strengthened each year since 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. Global prices are projected to exceed the U.S. loan rate each year after 2007, making U.S. producers ineligible for marketing loan benefits. After dropping fractionally in 2006, the U.S. farm price is projected to increase each year for the remainder of the baseline period, a result of higher world prices and increasing domestic use. U.S. prices are expected to rise at a slightly slower pace than international prices, causing the U.S. price difference to contract. The U.S. season-average farm price is projected to exceed the loan rate each year of the baseline.

Sensitive Product Designation in the Doha Round: The Case of Rice

Durand-Morat, A. and Wailes, E.J.

A new round of World Trade Organization (WTO) negotiations known as Doha Development Agenda (DDA) began in Doha, Qatar, in November 2001. Negotiations on agriculture are included and were expected end at the Hong Kong Ministerial Meeting in December 2005. Despite the slow progress in agricultural negotiations and the differences that still exist among negotiating groups (mainly in regards to market access) that will preclude an agreement by the Hong Kong meeting, there are high expectations on the potential benefits of DDA. The World Bank estimates that significant benefits of around USD 248 billion are possible from global agricultural trade reform. Developing countries would likely perceive a large share of the benefits.

Previous studies have suggested that market access issues such as the "sensitive product" designation could greatly constrain the extent of gains from DDA. Estimates suggest that gains could shrink by 75% if 2% and 4% of the HS6 agricultural tariff lines for developed and developing countries, respectively, are classified as sensitive products. Sensitive product designation is especially important for rice. Three out of the total four countries that designated sensitive products in the Uruguay Round did it for rice, namely, Japan, Philippines, and South Korea. Under current negotiations, Japan and South Korea have already made it clear they will designate rice as a sensitive product, and other countries would likely decide to do so as well. Thus, the total number of countries designating rice as a sensitive product and the concessions granted to them are likely to be factors that would greatly impact the extent of the gains for the rice sector out of DDA.

The analysis is conducted using the GTAP general equilibrium model. GTAP is a multi-region, multi-sector computable general equilibrium model, with perfect competition and constant returns to scale. The GTAP 6.0 version database is used for this analysis. It contains detailed bilateral trade, transportation, and protection data among regions, linked together with country specific input-output tables. Major rice traders are disaggregated to capture the regional impacts of multilateral trade reforms. The rice sector is disaggregated into paddy and processed rice. Other agricultural sectors are disaggregated to allow for cross-sectoral impacts. This study assumes that the final agreement on agriculture would be close to what the U.S. proposed on October 12, 2005.

Preliminary results with the sensitive product designation use by major importers and a significant decrease in the aggregate measure of support (AMS), where most of the loan deficiency payments (LDP) would be removed, suggest that the U.S. proposal would not benefit the rice sector. Even though the U.S. as a whole will benefit, the negative impact of domestic policy reform is unlikely to be offset by the gains from market access and removal of export subsidies for the U.S. rice sector.

Investment in On-Farm Reservoirs to Sustain Rice Production in Arkansas: The Impact of Land Rental Arrangements

Highnight, J. and Wailes, E.J.

The depletion of groundwater resources in eastern Arkansas presents substantial challenges for irrigated agriculture in the state. Without sustainable groundwater or large surface water diversion projects, much of Arkansas agriculture will be dependent upon on-farm reservoirs to maintain current irrigation practices. The previous research on the economics of investment in on-farm reservoirs in Arkansas ignored land tenure relationships and was based only an assumption of owner-operators. However, in eastern Arkansas, where most of the irrigated cropland is found, a majority of land is only partially owned or rented.

The primary purpose of this study is to evaluate the economics of investment in on-farm reservoirs in Arkansas under alternative land rental arrangements. The analysis determines, for a specified irrigated rice and soybean farm, the optimal reservoir size for both the landowner and the operator under alternative crop share rents. The study suggests incentives that might entice a landowner to invest in an on-farm reservoir. The analysis examines two dominantly used types of share rents, the cost share and straight share rent.

The analysis presented in this paper is based on the Modified Arkansas Off-stream Reservoir Analysis (MARORA) model. MARORA is a simulation model developed at the University of Arkansas to estimate the optimal on-farm reservoir/tail-water recovery system that will maximize net returns. Net returns are calculated in MARORA by annually deducting the variable and fixed costs from the gross crop income per year. The annual stream of net returns is then discounted at 8% minus the wells and improvement costs to find the Net Present Value (NPV) over a 30-year period.

Previous studies have shown that a reservoir for an owner-operator under an inadequate groundwater situation is economically feasible and necessary to sustain current irrigation practices. The analysis found that without investing in an on-farm reservoir, the owner-operator and the tenant/landowner NPV would be less than optimal for the involved parties. Under a 50/50 cost share rental arrangement, the tenant and landlord achieve the highest NPV at the same size on-farm reservoir. With a 75/25 straight share rental arrangement, an on-farm reservoir is necessary to sustain rice and irrigated soybean production while the landlord did not need a reservoir to achieve the highest NPV.

Absentee landowners have a major economic interest in the sustainability of current irrigation practices. With the declining groundwater situation, absentee landowners need confirmation that an investment in an on-farm reservoir will be economically beneficial for them. Tenants and landlords could use the model as a tool to find an optimal reservoir size that would satisfy both individuals and sustain irrigated rice and soybean production in Arkansas under different crop share rental arrangements.

Impacts of Trade Liberalization: Results from the Arkansas Global Rice Model

Mane, R. and Wailes, E.J.

The primary objective of this paper is to evaluate consequences of the United States proposal to the WTO for agricultural trade reform that address the three pillars of reduced domestic supports, market access (tariff reduction) and elimination of export subsidies for the global rice economy. The analysis is based on the Arkansas Global Rice Model where the U.S. proposal for the Doha Development Round (DDR) negotiations is used as a framework to evaluate the prospects for the U.S. and global rice economy.

The U.S. proposal calls for expanded market access consistent with the July 2004 framework. The U.S. proposal specifies progressive tariff reduction, tariff rates not higher than 75% and use of limited tariff lines available to “sensitive products” designation. Special and differential treatment will be given to developing countries for import sensitive products. This means that developed countries will adjust in five years while developing countries will be given 10 years to achieve their commitment.

The U.S. proposal for export competition requires a rapid elimination of the export subsidies in three years for all products. The U.S. proposal on domestic support requires 60% reductions in domestic support. The blue box program reduction would at 2.5% of total value of agricultural production and deminius payment would be reduced by about 50%.

Arkansas Global Rice Model, (AGRM) a non-spatial dynamic econometric model is used to evaluate the impact of trade liberalization in rice. The effect of the domestic supports and trade policy are captured in the supply and demand framework of AGRM. The baseline projections for 2006 are used of as a basis for comparison with the trade reform scenario, reflecting the U.S. proposal.

The results of this study assume implementation of the agreement in the 2007 crop year. Estimates are generated for over the period until 2015. Preliminary results suggest that the U.S. proposal will increase world rice net trade 5.9% above the baseline estimate. Long- and medium-grain trade will expand by 5.2 and 33.7% over the baseline, respectively. The price of Thai 100% FOB (long grain world reference export price) and U.S. California medium grain (medium grain world reference export price) will be 8.8 and 25.8% higher, respectively, with trade liberalization. China, the United States, and Australia will be the key exporter beneficiaries with increases in exports of 31, 24, and 10%, respectively. The major increase in imports will be in Japan, Indonesia, Philippines, and South Korea, with increases of imports of 137, 20.9, 45.6, and 150% respectively.

Federal Budget and Input Price Impacts on Louisiana Rice Planting Decisions and Enterprise Cash Flow

Salassi, M.E.

Several economic factors are converging to make the 2006 rice crop year a very challenging year. Market prices have generally been below expectations. Currently, market prices for 2006 are projected at levels which would minimize or eliminate a counter cyclical payment. Federal budget reconciliation actions in 2005 and 2006 have the potential to impact rice program payments. Fuel and fertilizer prices have risen dramatically to the point where the projected cash flow for the 2006 rice crop could result in substantial acreage reduction in many states. In addition, discussions on the next farm bill has begun adding further uncertainty to the near term economic viability of rice production for many producers. This paper addresses several issues impacting the projected profitability of rice production operations in Louisiana. Primary attention is focused on an analysis of proposed farm program payment changes as part of the federal budget reconciliation activities in 2005. Additional analysis evaluates impacts of higher fuel and fertilizer prices on the projected profitability of alternative rice production enterprises in Louisiana.

The President's proposed 2006 federal budget included reductions in federal spending in several areas, including agriculture. Although several spending cuts in agriculture were proposed in the budget, two specific price support payment reduction proposals were evaluated in this analysis. These two spending reduction proposals were: (1) a 5% reduction in total direct payments, counter cyclical payments, and marketing loan program benefits and (2) marketing loan program benefits (loan deficiency payments) paid on 85% of direct payment program yields.

The analysis presented here is for the purpose of evaluating how the proposed farm program spending reductions would impact typical rice enterprises in Louisiana. The unit of analysis was a representative rice enterprise (acreage size level) and not an entire, diversified farm. A reason for the use of this unit of analysis is that on such farms, rice is the primary commodity of production. As a result, this analysis evaluates the impact of proposed agricultural spending reductions on the profitability of a representative rice enterprise. For each enterprise evaluated, gross income, variable production costs, fixed equipment costs, and general farm overhead expenses are included in the analysis. Share rent expenses are taken out of gross income (both market income and program payments). Basic labor costs for field operations are included in variable production costs, but no charge for management is included. Off-farm income and family living expenses are also not included in the analysis.

Four typical production enterprise sizes are evaluated in this study. Projections of income and expenses are made for a 6-year period (2005-2010), with program spending reductions beginning in 2006 and continuing through 2010. For each year of simulation, random market prices and crop yields are generated to allow for inclusion of price and yield risk.

General conclusions from the study indicated that minor changes in the program payment structure resulting in relatively small percentage changes in program payments would have substantial impacts on the net farm income of a rice enterprise. A 5% reduction in program payments would reduce rice gross farm income by 1.1 to 1.2%. Net farm income (returns above total costs) would be reduced by more than 20%. Loan deficiency payments paid on 85% of direct payment program yield (rather than actual production) would reduce rice gross farm income by approximately 2.5%. Net farm income would be reduced by more than 40% for rice enterprises. Both payment reduction proposals together would reduce gross farm income for rice enterprises by 3 to 4%. Net farm income would be reduced by more than 60%. Although elimination of the 3-entity rule was not specifically evaluated in this study, results for the one-entity crop enterprises analyzed here show that rice production enterprises of this size are not economically viable in the long run, given the inability to profitably expand acreage to lower fixed costs.

Forecasting the Adjusted World Price of Rice

Bryant, H.L., Anderson, D.A., and Outlaw, J.L.

Loan deficiency payments (LDPs) for U.S. rice producers are calculated using an "adjusted world price" (AWP) of rice that is calculated by USDA. The level of the AWP relative to the "loan rate" (LR) is thus of keen interest to producers (and processors who may assume from a producer the right to a LDP), and reliable forecasts of the AWP are needed for making optimal marketing decisions.

Moreover, probabilistic forecasts, rather than simple point forecasts, of the AWP are critically important because the LDP is a non-linear function of the AWP: LDP = min (0, LR – AWP). For example, suppose that the expected value of the AWP at some point in the future is equal to the LR that has been fixed for the marketing year. Then, a point forecast of the LDP that would be received upon marketing rice at that time would be zero. In reality, of course, there will be uncertainty regarding the AWP forecast. The expected value of the LDP is something greater than zero, and there is thus some value in maintaining the option to collect a LDP should it be available in the future (i.e., by not marketing the rice immediately).

The best probabilistic forecast of the AWP will provide decision makers with the most accurate and useful characterization of the LDPs that might be realized in the future. This research evaluates probabilistic forecasts of the AWP emanating from three competing econometric models – a simple autoregressive (AR) time series model, a slightly more complex time series model with a generalized autoregressive conditional heteroskedastic (GARCH) error structure, and a highly complex large-scale structural model. The results of this study might be useful to state extension rice specialists or sophisticated producers/processors who wish to forecast the AWP.

Each model has relative strengths and weaknesses. The large-scale structural model incorporates a much larger information set than the time series models, including supply and demand conditions from rice producing countries around the world, world macroeconomic conditions, and market conditions for other agricultural commodities. The supply and demand shifters necessary for this type of structural model are not available at a high frequency, however, and the model generates only annual forecasts of average AWP levels. Short-run forecasts for this model must thus be made by extrapolation between data points.

For all three models, simulations are used to generate probabilistic forecasts of the AWP for one and three month ahead forecast horizons over an out-of-sample period from January 2002 through July 2005. Plots of issued probabilities vs. outcomes are presented for each model at each forecast horizon. Watson and Anderson-Darling tests of the hypothesis that the AWP is drawn from the time-varying empirical forecast distributions generated by each model are conducted. Previous work regarding the power of these tests indicates that the Anderson-Darling test is good at identifying poor probabilistic forecasts in terms of measures of central tendency, while the Watson test is good at identifying poor probabilistic forecasts in terms of variability.

Results unambiguously indicate that the structural model generates forecasts that are poorly calibrated (i.e., unreliable) at both forecast horizons. Results for the AR model are mixed – we reject at the 10% level the hypothesis of calibration using both tests at the three month forecast horizon. For the one month horizon, we reject calibration using the Watson test, but not the Anderson-Darling test. This suggests that the calibration problems of the AR model may be due to inadequate modeling of the variability of the AWP, and that the AR-GARCH model (not implemented as of this writing) may be well-calibrated.

Challenges and Prospects for U.S. Rice Policy in the 2007 Farm Bill Debate

Wailes, E.J.

Support for agricultural commodity programs is being pressured by a number of factors. These include 1) the competition among many sectors for federal funds in light of the growing federal deficit; 2) the move towards global integration through multilateral (WTO) and regional (FTA) agreements; and 3) structural changes in the food and fiber sector where farms are becoming larger, more dependent on off-farm incomes, commodity payments becoming more concentrated and the general public more disconnected from farming while increasing their expectations for amenities such as a sustainable environmental, green space, and recreation.

The Farm Security and Rural Investment Act of 2002 will expire in 2007 and the USDA and various groups have held various forums to assess the prospects and issues that will guide the development of a new farm bill in 2007. While it is not inconceivable that the 2002 farm bill could be extended as is, changes in the framework have already been forced as a result of the WTO dispute ruling on cotton. Further, the U.S. proposal in the WTO Doha Development Round, if accepted, would require substantial changes. For example the Aggregate Measure of Support cap for U.S. agriculture is currently at $19.1 billion, but the U.S. proposal would reduce that cap to only $7.2 billion. Full counter-cyclical payment (CCP) exposure under the 2002 farm bill is approximately $7.4 billion but the U.S. proposal for Blue box cap in which the CCP would likely be placed would limit payments to only $5 billion.

As one of the program commodities, U.S. rice programs are viewed as important elements in sustaining the economic vitality of the U.S. rice sector. As one of the most protected commodities in world trade, market access is limited and government payments have been an important component of stabilizing and maintaining producer returns. Reform of commodity programs then will likely have a significant impact on the U.S. rice sector. This paper provides an analysis of various alternatives using the Arkansas Global Rice Model.

The key findings of this study show that on a per acre basis, government payments are critically important. Unilateral reform of government policy would result in a substantial decline in the U.S. rice sector. Finally, expanded market access to global markets through reduced import tariffs and increases in tariff rate quotas will be essential to offset any efforts to reduce domestic support to this sector.

Changing Cost of Production Estimates and Expected Acreage Responses in Texas - West of Houston

Falconer, L.L.

This paper presents an analysis of historic and projected cost of production estimates for rice production west of Houston and subsequent changes in planted acreage. Projected cost of production and planted acreage scenarios will be analyzed, with discussion including impacts of DCP.

Cost of production estimates are constructed annually using enterprise budgets created with the Mississippi State Budget Generator. The cost of production estimates are developed at the end of the preceding main-crop year (August) with input from producers, custom service and product suppliers, Texas Cooperative Extension (TCE) specialist and TCE agents. These budgets are intended to represent the cost structure for a hypothetical 450-acre rice operation on land that requires 18 to 20 levees per 100 acres. The budget scenario represents a high-yield, high input conventional tillage production system with heavy pest pressure. First and second crop budgets have been separated, and all general and administrative costs, crop insurance, consulting, land and vehicle charges assigned to first crop.

Annual usage rates for tractors are projected at 600 hours, with capital recovery factors calculated over an 8-year useful life. Annual usage rate for the combine was estimated at 200 hours with capital recovery factor calculated over a 10-year useful life. Fixed costs shown in the budget represent the cost of owning machinery and equipment and are the annualized capital recovery cost for owned durable items. No adjustment was made in aerial application costs for irregular shaped fields. Service fees represent a charge for crop management consultant services.

The budgeted fertility program for the 2006 main crop includes a base fertilizer application, one preflood application, and one topdress application. The total main crop fertilizer application is comprised of 183 units of N, 59 units of P, and 39 units of K and 4.3 units of S. This represents a downward adjustment in use of N by 32 units in 2006 from the 2004 and 2005 scenarios due to increased N prices. The budgeted main crop herbicide program includes an initial ground applied treatment of clomazone, an aerial application of a general tank-mix over the total planted acreage to control sedges, grasses and broad-leaf weeds along with a follow-up aerial application over one-half the planted acres to control escaped weeds. The budgeted pesticide program for the main crop includes one fungicide application to control foliar diseases, a pyrethroid application to control water weevils along with two pyrethroid applications, and one methyl-parathion application to control rice stink bugs.

The budgeted irrigation program for the main crop includes 1.57 hours per acre of labor for three flushes, flood maintenance, and draining. Total main crop water usage is budgeted at 2.75 acre-feet, with water charges based on projected LCRA Lakeside Irrigation System rates for 2006.

The budgeted fertility program for the second crop includes one topdress application. The total second crop fertilizer application is comprised of 69 units of N. The budgeted pesticide program for the second crop includes one application to control rice stink bugs.

The budgeted irrigation program for the second crop includes 0.71 hours per acre of labor for one flush, flood maintenance and draining. Total second crop water usage is budgeted at 1.9 acre-feet, with water charges based on projected LCRA Lakeside Irrigation System rates for 2006.

Based on these assumptions, breakeven prices per cwt to cover main crop projected direct expenses were $8.89 per cwt in 2004, $9.94 per cwt in 2005, and $10.64 per cwt in 2006. The projected percentage change in breakeven prices was 11.8% for 2005 followed by a 7% increase for 2006. Breakeven prices per cwt to cover main crop projected total expenses were $9.92 per cwt in 2004, $10.97 per cwt in 2005, and $11.92 per cwt in 2006.

Abstracts of Posters on Economics and Marketing
Panel Chair: L.L. Falconer

Impacts of Rising Fuel Costs and Rental Arrangements on Arkansas Rice Producers

Hill, J.L., Watkins, K.B., Wilson, Jr., C.E., Branson, J.W., and Runsick, S.K.

Increases in Fuel and Fertilizer costs in 2005 have caused some farmers to consider substantially reducing rice acreage or even abandoning rice production altogether. Other farmers are considering changes in their current rental arrangements to help counter the price increases. Whichever the case, some changes may be necessary in order to keep rice production economically viable given the near record prices of inputs.

The Arkansas Rice Research Verification Program (RRVP) is a University of Arkansas Extension program that is conducted in farmers' fields across the rice producing areas of the state. Valuable economic information is gained from these larger fields over the typical small plots in other research studies. Tillage practices, pest control, fertilization, and irrigation are field specific and result in accurate estimates of Variable Costs of Production. The results from the 2005 RRVP will be used to analyze select leasing arrangements and determine which if any input costs influence the optimum leasing arrangement.

Leasing arrangements on rice farms include: straight crop-shares, cash rents, and cost-shares. The predominant rental arrangement varies by region and by crop. Both the farmer and the landowner determine the type of rental arrangement, which may switch from one year to the next or between crops. Crop-share rents are arrangements in which the farmer gives the landowner a specified percentage of the harvested crop in exchange for use of the land. In a cash rental arrangement, the farmer pays the landowner a specified cash amount to use the land. A cost-share rent is essentially the same as the crop-share except that the landowner also shares certain expenses of producing the crop.

Risk is a major factor in determining a leasing arrangement for both parties. Cash rents are the least risky arrangement for the landowner but also are the most risky for the farmer. Crop-share or straight-share rents share yield and price risk between the farmer and landowner. Cost-share rents share the risks of yield, prices, and production costs between the farmer and landowner. Cost-share rents are the most risky arrangement for the landowner but can provide the landowner with the highest income under certain conditions. Each arrangement has its strengths and weaknesses, but the cost-share rent is the most favorable to farmers during years with high production costs, as in 2005.

The 50-50 cost-share rental arrangement was the most profitable overall, but the 80-20 straight-share arrangement was most profitable on farms with above average yields and lower than average production costs. In terms of covering direct cash operating expenses, the 50-50 Cost-share arrangement was superior to the 80-20 and 75-25 Straight-share arrangements. Yield and Irrigation were found to be statistically significant in determining net returns. Yield had a positive influence on net returns and Irrigation had a negative relationship with net returns.

Producer Decision Tool for Evaluation of Rice Base Planting Decisions

Salassi, M.E.

Rising fuel and fertilizer prices in combination with relatively low rough rice market prices are anticipated to have a substantial impact on the projected cash flow of rice farms in Louisiana for the 2006 crop season. One important decision facing rice producers is "What percent of base should be planted for the 2006 season to be able to cash flow and obtain crop financing?" The Projected 2006 Rice Farm Cash Flow Model was developed to assist producers in planning for the 2006 crop year. The model is an Excel spreadsheet which allows rice producers to enter projected acreage, yield, market price, and production cost data for 2006 to estimate net returns above variable production costs and to easily evaluate the impact of changing percent of base planted on net returns.

The Projected 2006 Rice Farm Cash Flow Model calculates projected net returns above variable production costs for a rice farm or specific tract of land of a specified acreage. For each farm or tract, data to be entered into the model includes estimates for the 2006 crop season, including rice acreage, base acres, percent of base planted, projected first crop and ratoon crop yields, program yields, projected prices, and production costs. Gross returns, variable costs, and net returns are calculated for the farm or tract based upon the data entered.

The first section of the model contains cells to enter data concerning projected 2006 rice acreage, production, and market prices. The second section of the model contains cells to enter data concerning projected variable rice production costs for the 2006 season. Costs are entered on a dollar per planted acre basis and should include the proportionate additional cost for any ratoon crop acreage. Special focus is given to fuel and fertilizer costs, allowing the user to enter the quantity of fuel and fertilizer used per acre as well as the projected price of each input.

Based on the acreage, production, price, and cost data entered, the model calculates net returns above variable costs (for the percent of base planted) on a per farm, per acre, per cwt., and per bbl. basis. Net return estimates are also included at the upper portion of the spreadsheet to allow for quick evaluation of the impact of changing percent of base planted on net returns above variable costs.

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

Differential Response of Rice Cultivars to RS-Toxin, a Pathogenicity Factor in Sheath Blight Disease of Rice

Brooks, S.A.

Sheath blight is widely regarded as the second most important disease of cultivated rice, and germplasm improvement is essential for disease management. Genetic sources of tolerance have been identified for the disease, however, phenotypic evaluation is ineffective for rice breeding programs due to environmental influence on disease and replications needed that result in extensive time requirements for reliable phenotypic data. To address this problem, we are developing an early generation screen for sheath blight tolerance using the host-selective toxin produced by *Rhizoctonia solani* (Kühn). RS-toxin assays are non-destructive to rice plants and quickly produce reliable replicated data on large sample sizes.

Using liquid and semi-solid media optimized for fungal growth and toxin production, cultures of *R. solani* are grown in constant light for 14 days at 30°C. Crude toxin is harvested by filtration, purified by organic extraction and precipitation, and concentrated to 10X the original volume. Bioassays using serial toxin dilutions are performed to determine relative toxin concentration in a preparation. Using a Hagborg device approximately 30 microliters of toxin is forcibly infiltrated into the leaves of 30- to 45-day-old rice plants. Response is recorded 5 days post-infiltration as a percentage of necrosis in the infiltrated area.

RS-toxin is host selective, and when purified from cultures of *R. solani*, it produces a differential response in rice cultivars Jasmine 85 (MR, tox-) and Cypress (VS, tox+) that is correlated with disease susceptibility. To confirm this correlation and evaluate RS-toxin as a means to detect disease tolerance, numerous cultivars with known disease ratings are being evaluated for toxin response. Preliminary data show a correlation exists and the methodology and verification will be reported.

Development of Molecular Strategies to Control Rice Sheath Blight Disease

Jia, Y., Singh, P., Jia, M.H., Wang, G., Wamishe, Y., Zhu, L., and Zhou, E.

Little is known about mechanisms of molecular interaction of host with the necrotrophic pathogen *Rhizoctonia solani*. After a detailed analysis of the pathogen population in the major rice producing state, Arkansas, the most virulent field isolate was identified among 124 characterized isolates. The most virulent field isolate was used to inoculate a cultivar, Jasmine 85, which contains minor resistance genes to the pathogen. Messenger RNAs, 16 hours after inoculation, were extracted to detect key components for the interaction. Experiments were repeated with three different molecular techniques: 1) Subtractive suppression hybridization (SSH) library, 2) DNA microarray, and 3) Robust Long serial analysis of gene expression (RL-SAGE). Thus far, 200 expressed genes were analyzed from a SSH library, a profile of 22,000 rice genes from DNA microarray, and 6720 SAGE clones of the treated and the control, each containing 40 to 45 tags. Our current analysis suggests that a sophisticated interaction between pathogen secreted proteins and the cell wall associated host proteins may occur during early infection, and these interacting genes may be key targets for the control of rice sheath blight disease.

Complementary Proteomic and Genetic Analyses of Rice Response to Challenge by the Fungal Pathogen *Rhizoctonia solani*

Lee, J., Bricker, T.M., Lefevre, M., Pinson, S., and Oard, J.H.

Rice is considered a model crop plant due to its importance worldwide as a food source, a small diploid genome suitable for genetic and proteomic analyses, and completion of the rice genome sequence. The objective of our research was to utilize both proteomic and genetic approaches that would complement and enhance our understanding of rice sheath blight disease caused by *R. solani*, a fungal pathogen of worldwide importance to not only rice but to many other important crops in the world as well. For our proteomic study, we identified 14 up-regulated proteins via 2D-PAGE and ESI Q-TOF MS methods in a rice-resistant mutant after challenge by *R. solani*. The proteins were identified with presumed functions relating to antifungal activity, signal transduction, energy metabolism, photosynthesis, protein folding, proteolysis, and antioxidation. The induction of 3-β- hydroxysteroid dehydrogenase/isomerase was detected for the first time in rice, suggesting a defensive role of this enzyme against attack by *R. solani.* For the genetic component, we identified 15 QTL regions on a genetic map for resistance to sheath blight in a large rice breeding population evaluated under field conditions. The upregulated proteins were found to map within the QTL regions of the breeding population which suggest that the identified proteins have functional roles in response to stress imposed by *R. solani*. These studies demonstrate that complementary proteomic and genetic approaches can effectively enhance our ability to identify candidate genes for disease resistance and their corresponding proteins for basic and applied research.

Identification of Rice Genes Induced in Response to Challenge by the Fungal Pathogen, *Rhizoctonia solani*

Ryan, A.B. and Oard, J.H.

Sheath blight disease caused by *Rhizoctonia solani* is a major rice foliar pathogen of worldwide importance with few known sources of resistance. All modern varieties in the United States, Asia, and Africa are susceptible to sheath blight, which causes significant reductions in grain yield and seed quality. Identification of specific genes involved in resistance will be required to develop rice varieties by conventional means with high levels of resistance. We used a cDNA-AFLP approach to identify genes that were upregulated only in the resistant varieties Jasmine 85 and Teqing when challenged by *R. solani* for 0, 15, 24, and 72 hr. Non-inoculated plants were used at each time point as negative controls. Forty-eight PCR primer combinations were used that produced a total of 20,160 AFLP fragments ranging in size from 100 to 400 bp. From ~ 200 polymorphic fragments showing up or down regulation, 92 bands to date have been selected for sequencing and compared with known sequences by NCBI BLAST procedures. The following proteins were identified as being upregulated 15 to 24 hr post inoculation: F-box protein, COP9 complex subunit FUS5, protein phosphatase 2C, proteasome regulatory non-ATPase subunit, and ripening regulated protein DDTFR18. A nucellin-like aspartic protease was down-regulated 72 hr post inoculation. These results suggest that the COP9 and ubiquitin ligase signaling pathways are involved in a resistant response of rice to challenge by *R. solani.* Microsatellite and SNP markers associated with the identified genes will be evaluated in the future for marker-assisted development of sheath blight resistant rice.

An Improved Method for the Inoculation and Evaluation of Rice Sheath Blight Disease

Park, D.S., Sayler, R.J., Hong, Y.G., and Yang, Y.

Sheath blight of rice, caused by *Rhizoctonia solani*, is one of the most important rice diseases worldwide. The pathogen has a wide host range and no rice variety has been found to be completely resistant to this fungus. To facilitate the study of this disease and the screening of rice varieties for resistance, an improved method was developed for the inoculation and evaluation of sheath blight.

To improve the efficiency of *R. solani* infection, different inoculum types (agar block, liquid cultured mycelia ball, and mycelia suspension) were tested on four rice cultivars (Chucheongbyeo, Junambyeo, Tetep, and Jasmine 85). Rice plants at the stage of maximum tillering were inoculated by placing *R. solani* inoculum under the collar of the lowest leaf. Ten culms were inoculated per inoculation type for each variety. Immediately after inoculation, the inoculated parts were wrapped with aluminum foil to maintain humidity. Lesion length on the sheath was measured at 7 days after inoculation. The results show that the type of inoculum used had a significant effect on lesion length caused by sheath blight. The mean lesion length was significantly longer using the liquid cultured mycelia ball (5.4 cm) than other types of inoculum, including agar block (2.4 cm) and mycelia suspension (1.6 cm).

To compare and improve the methods for evaluating sheath blight disease, three partially resistant varieties and five susceptible varieties were inoculated with liquid cultured mycelia balls. Forty-five days after inoculation, the lesion length of infected plants was measured. In addition, a new formula was developed to calculate the disease severity index. Lesion length and the severity index were generally correlated in each leaf, but there were discrepancies between the two evaluation methods. For example, the lesion length of the first leaf above the point of inoculation was longer for Jasmine 85 than that of the other varieties, while the severity index in this same cultivar was lower than the other cultivars, which is consistent with previously published results. In contrast, the lesion length of the first leaf above the inoculation point for Lemont and IR 50 was shorter than that of the other cultivars, but the severity index was higher, which is again consistent with previously published findings. Therefore, lesion length alone may not accurately represent the severity of sheath blight on rice. The severity index calculated with the new formula appears to be a better method for evaluating sheath blight disease.

Status of our Research on Developing High Levels of Partial Resistance to Sheath Blight in Lines with High Yield Potential and Good Agronomic Characteristics

Rush, M.C., Nandakumar, R., Zhang, S., and Groth, D.E.

By crossing sources of partial resistance to sheath blight (*Rhizoctonia solani)* with susceptible cultivars, selecting progeny for resistance in panicle rows through five to nine generations, then crossing among selected lines and selecting among their progeny, we have developed breeding lines with acceptable resistance, good agronomic characteristics, and high yield potential. These lines have sheath blight ratings of 2 to 5 on the 0-9 scale, they have yields comparable with commercial cultivars, and they have little or no yield loss when inoculated with *R. solani* in field plots.

Field tests with selected lines suggest that we have identified lines with tolerance to sheath blight, that is, there is no yield loss in inoculated plots even though the line has a susceptible sheath blight rating (6-8).

All yield-tested lines were shown to have acceptable grain quality characteristics before entry to yield tests. The most limiting characteristic in development of sheath blight-resistant lines has been acceptable milling. A line from this program, MCR 01-0277, was selected for use by the CAPS Program for sheath blight resistance studies.

Effect of Stratego Fungicide on Rice Yield and Milling Quality

Vodrazka, K., Hopkins, A., Garris, S., and Bloomberg, J.

Rice yield and milling quality can be significantly impacted when fields are infested by disease. The extent of the impact from diseases, such as sheath blight and blast, is often determined by such factors as the incidence and severity of disease, cultivar susceptibility, and management practices. The use of a well-timed foliar fungicide application can help to minimize the impact of disease and allow the rice cultivar to more fully express its genetic yield potential. An additional benefit that can occur from the use of a fungicide to control disease is improvement in milling quality.

Stratego fungicide, introduced by Bayer Crop Science in 2002, is a combination of two active ingredients with different modes of action. Trifloxystrobin, an active ingredient from the strobilurin class of chemistry, has translaminar activity that is effective on sheath blight and blast. It is combined with the systemic activity of propiconazole that is active against secondary diseases like kernel smut, false smut, and brown spot. Numerous small plot trials with extension pathologists and other rice researchers in the southern United States were conducted in 2004-2005 in order to evaluate the effect of applying Stratego fungicide for disease control on rice yield and milling quality. Fungicide treatments included Stratego at different labeled rates and application timings, as well as other commonly used rice fungicides. Evaluations included disease ratings, as well as yield and milling quality.

Possible Development of Resistance by *Pyricularia grisea* to Fungicides

Groth, D.E., Rush, M.C., and Lindberg, G.D.

Blast is one of the most important rice diseases in Louisiana and the Mid-south. Resistance is available in some varieties but not all. Control is enhanced by establishing and maintaining a flood as soon as possible, planting early to avoid late-season blast pressure, using recommended N fertilizer rates, and not planting in sandy soils or in tree-lined fields. Problems are escalating because current practices involving insect control, correction of herbicide damage, and straighthead prevention practices that require draining of fields have increased blast severity. Farmers often have to depend on fungicides to protect their rice crop from severe blast damage. Development of resistance by *Pyricularia grisea* to fungicides poses a major risk.

Blast fungicide trials have been conducted at the LSU AgCenter's Rice Research Station, Crowley, LA, since the 1970s. Small plots were usually 4.9 X 1.2 m, consisting of seven drill strips with an 18-cm row spacing. Seeding rates, fertility, and pest control followed current recommended practices. Experiments were arranged in a randomized complete block design with at least four replicates. Varieties selected were susceptible to blast and were managed to favor disease (i.e. fertilized with high N rates, planted late, drained at midtillering until the soil cracked and then reflooded, and/or located where disease pressure was high). Typically, fungicides were applied to small plots using CO_2-pressurized sprayers delivering 93 L/ha of water at 2-inch boot (B) and 50% heading (H). Benlate (50 WP or 50 DF) applied at B and H at 0.56 kg ai/ha and Quadris (2.08 SC or 70 DF) at H at 0.22 kg ai/ha were applied to plots. An unsprayed check was included. Blast incidence was determined by counting the number of heads infected with rotten neck blast. 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. Percent control was determined and graphed over time.

Historical data from 30 years of testing shows that control of rotten neck blast by Benlate decreased from 70 to 60% control to below 50% control from 1976 to 2001 with light disease pressure and from 50 to 60% to 10 to 20% control during the same time period with heavy disease pressure. Preliminary tests of *P. grisea* isolates showed significant variance in reaction to increasing concentrations of Benlate in agar plates, indicating the blast fungus was developing resistance or tolerance to Benlate. Decreases observed in Quadris activity over time also suggest that the blast fungus may be developing resistance to this fungicide also.

Assessing, Controlling, and Breeding for Resistance to Foliar Diseases and Stem Rots in American Wild Rice

Porter, R.A., Nyvall, R.F., and Carey, L.

American wild rice (*Zizania palustris*) has several known stem rot diseases caused by the fungal pathogens *Nakataea sigmoidea*, *Bipolaris oryzae*, and *B. sorokiniana*. The *Bipolaris* species also cause the foliar diseases fungal brown spot and spot blotch. Since these diseases have previously been the target of selection to improve varietal resistance, methods have been developed to inoculate leaves with conidia suspensions to develop resistant varieties. Selection for resistance to stem rots in wild rice has not been done. In this study, methods were developed for growing inoculum of *N. sigmoidea* and for inoculating all three species onto plots in a multilocation trial. Specific objectives were to: 1) develop and assess the effectiveness of a method of production and inoculation of *N. sigmoidea*, 2) assess the effectiveness of leaf and stem disease rating methods in detecting statistical differences produced by different fungicide treatments with a view toward future application of assessing varietal differences, and 3) assess the effectiveness of alternatives to the fungicide propiconizole (the only one currently labeled for wild rice) for controlling leaf and stem diseases caused by *Bipolaris* spp. and *N. sigmoidea*.

One cultivar, Itasca (a high-yielding, shattering-resistant variety that is also moderately resistant to fungal brown spot) was used in these on-farm experiments. The design was randomized complete blocks, with 1.5 x 3.0 m plots, eight fungicide treatments, and six reps at each of three locations. For inoculum production, *B. sorokiniana* was cultured on a medium consisting of course perlite, wildrice flour, and 1% PDA (1:2:4). *B. oryzae* was cultured on the same medium. Conidia were suspended in water and filtered after 15 (*B. sorokiniana*) or 18 (*B. oryzae*) days of growth. Inoculum of *B. sorokiniana* was applied to all plots at a rate of 4.5 million conidia per plot with a CO_2 sprayer at mid-tillering. *B. oryzae* was applied 5 days later at 1.8 million conidia per plot. Six *N. sigmoidea* isolates were cultured on the same medium. Mature sclerotia were produced in 14 days, at which time medium was dried, crushed, and filtered through a #10 sieve to produce the dried inoculum (750 sclerotia/ml). At late tillering, *Nakataea* inoculum was spread within all plots with a Spred-Rite granular applicator on the water surface just inside the side borders of each plot, at a rate of 16,000 sclerotia per plot. Fungicide treatments were: Tilt (propiconizole), applied at boot and heading for a total of 0.38 kg/ha of a.i.; Headline (pyraclostrobin) 0.11 hg/ha at boot; Headline 0.22 kg/ha total at boot and heading; Quadris (azoxystrobin) 0.22 kg/ha at boot; Quadris 0.45 kg/ha total at boot and heading; Quilt (azoxystrobin+propaconizole) 0.16 and 0.27 kg/ha, respectively, at boot; and Stratego (trifloxystrobin +propaconizole) 0.17 and 0.17 kg/ha, respectively, at boot. One control plot per replicate was untreated.

All plots at a location were harvested on the same day and grain yield measured. Ten stems and 20 flag leaves per plot were collected at harvest and frozen to be later rated for area affected by disease. Diseased leaf area was estimated by comparison with the Clive James key for *Septoria* leaf blotch (Key 1.6.1). Leaves were also scanned and diseased leaf area estimated using WinFolia software (Regent Instruments, Quebec). Diseased stem area was estimated without the aid of a key. Two pieces were cultured from each stem and one piece from each leaf (a total of 20 stem and 20 leaf pieces per plot). Five to 7 days later, fungal species were identified for each lesion to estimate the incidence of each pathogen. Indices were calculated for leaf and stem diseased area due to a particular pathogen by multiplying the visual rating by the frequency of the pathogen incidence on cultured leaf pieces. Each location was analyzed separately using SAS Proc Mixed, adjusting for spatial variability with the function sp (powa). Significance of pairwise comparisons at $P<0.05$ was used as the criterion for declaring treatments statistically different.

Significant treatment differences were found for diseased leaf area at all three locations, but the Aitkin location was especially severe, with many significant comparisons. Software-estimated diseased leaf area showed a pattern of treatment differences similar to the visual estimates, with greater ability to distinguish significant treatment differences at the location with moderate levels of disease and less at the location with severe disease levels. Incidence of *B. oryzae* was greater than *B. sorokiniana* in leaf lesions at two locations but was less at the third. When specific pathogen incidence was multiplied by visually estimated diseased leaf area, the index magnified treatment differences under heavy disease pressure. Diseased stem area showed significant treatment effects at two of three locations. When disease severity was indexed by specific pathogen incidence, the third location also showed significant treatment differences. Overall, two applications of Quadris gave more effective control of leaf and stem diseases than other treatments compared with the control and resulted in higher yields at the two locations where leaf diseases were more severe. Inoculation methods for *Bipolaris* appeared to be effective, but lower than expected incidence of *Nakataea* in stem lesions indicates further improvements in inoculation methods are needed.

Fungicide Timing for Multiple Rice Diseases

Groth, D.E. and Cartwright, R.D.

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. Grain smuts have also become important problems in rice production, causing significant quality reductions. 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 also 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.

Fungicide timing and rate trials have been conducted at the LSU AgCenter's Rice Research Station, University of Arkansas Rice Research Station, and in growers' fields in both states for a number of years. Typically, fungicides were applied to small plots using CO_2 pressurized sprayers although several aerial trials have been conducted. Fungicides were applied at either 7 days after panicle differentiation (PD+7), 2-inch boot (B), 50% heading (H), or 5, 10, or 15 days after heading (H+5, H+10, H+15). Varieties selected were either susceptible to sheath blight, blast or smut and were managed to favor disease (i.e. inoculated, fertilized with high N rates, planted late, and/or located where disease pressure is high).

Timing was an important consideration in sheath blight, blast, and smut fungicide control. Booting stage appears to be the best timing for smut control. Earlier applications may require higher rates to be effective, and applications after heading can be illegal, as well as ineffective. Sheath blight control was best at the boot growth stage. Applications at PD+7 can be effective, but higher rates are necessary for season-long control. Heading applications were effective; however, sheath blight was allowed to spread up the plant more, causing more damage. Blast control was best when fungicides were applied at heading. Post-heading applications lost effectiveness when delayed after heading for both sheath blight and blast.

Fungicide timing must be based on the most damaging disease present in a field. This is determined by knowing the varietal susceptibility, field disease history, what is occurring in your area, and, most important, scouting for disease in the field multiple times during the growing season. If sheath blight and smuts are both important in a field, a boot application is best. Earlier applications, with higher rates, are advisable only if sheath blight had started early in the season and is causing significant damage before the boot growth stage. If blast and sheath blight are both present, a heading application of a fungicide with sheath blight and blast activity is best because blast can be more damaging than sheath blight, and sheath blight heading applications are effective. If blast and kernel smut are both important in a field, a heading application would be advisable because of blast being more destructive and heading applications being somewhat effective for kernel smut. However, if kernel smut has been a major problem in a farmer's field, splitting applications of the smut fungicide at boot and the blast fungicide at heading may be advisable but much more costly. Most important, fungicides must be applied by 50 to 70% heading to maximize disease control and yields.

Progress in Developing Molecular Markers for Tagging *Magnaporthe griseas* Pathotypes in the United States

Jia, Y., Lee, F., Correll, J., Singh, P., and Zhou, E.

The *Magnaporthe grisea* avirulence gene *AVR-Pita* encodes a telomeric associated metalloprotease conferring the efficacy of the *Pi-ta* gene in the southern United States. Rice cultivars containing *Pi-ta* have been widely utilized since the deployment of the first *Pi-ta* containing cultivar, Katy, in 1989 in the United States. Recently, the efficacy of *Pi-ta* in controlling blast disease has been challenged by virulent *M. grisea* isolates. A total of 70 virulent *M. grisea* field isolates were collected from *Pi-ta* containing cultivars in Arkansas rice fields and blast nurseries over the years. Differences in the degree of the virulence toward several different rice genotypes were observed among these virulent isolates. Allele-specific PCR, repetitive element-based PCR, southern hybridization, molecular cloning, and sequencing techniques were used to analyze allelic variations at the *AVR-Pita* locus in these virulent isolates. Preliminary results suggest that these isolates contain a non-functional telomeric associated *AVR-Pita*. In one case, a Pot 3 transposon was found to insert into the protease motif of the AVR-Pita protein, resulting in loss of the avirulence. The homologous sequences of *avr-pita* were PCR-amplified and cloned from some virulent field isolates and are being sequenced. Progress in developing reliable PCR-based detection of these diverse virulent *avr-pita* alleles is described.

Blast Field Resistance Expression after the *Pi-ta* R Gene is Overcome

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

Rice blast, caused by *Magnaporthe grisea* Cav., limits rice yield and cultivar options in Arkansas. Growers utilize a combination of R gene resistance and field resistance for blast control. First deployed in 1989 in the Katy cultivar, the *Pi-ta* R gene conferred complete resistance to known blast races. True to form, two new races, IB-33 and IE-1k, capable of overcoming *Pi-ta* resistance quickly developed. Prior to 2004, however, only the race IE-1k had been isolated from a few random plants from commercial fields and field test plots. In 2004 and again in 2005, race IE-1k severely damaged small areas of the *Pi-ta*-cultivar Banks, which has a genetic background other than Katy and lacks minor blast resistance genes *Pi-kh* or *Pi-ks*. Observations suggest Banks is overcome during severe moisture stress. Growers rely upon field resistance in the absence of R gene resistance.

This research effort addresses the effectiveness of flood-induced field resistance as a control measure after the fungus overcomes major resistance genes. Field resistance develops as the root zone is exposed to anaerobic conditions. Upon flooding, dissolved oxygen in the root zone is quickly consumed to establish anaerobic conditions, which determine availability of plant nutrients associated with blast susceptibility, enhance production of hormones associated with disease resistance mechanisms, and induce morphological modifications that facilitate oxygen transport to the roots and restricts pathogen growth.

In replicated short-term greenhouse pathogenicity tests, seedlings of rice cultivars growing in either continuous dry land conditions or in a continuous flood were evaluated for blast severity following inoculation with spore suspensions of *Pi-ta*-avirulent race IB-49 or *Pi-ta*-virulent isolates of race IE-1k, race IB-33, and laboratory isolate MSG-19. Severity was estimated using a blast index based upon the 0-9 visual rating system.

As indicated by a higher blast index recorded following inoculation with either race IB-49 or *Pi-ta*-virulent isolate MGS-19, blast was more severe in susceptible cultivars Cypress, Mars, Wells, Newbonnet, LaGrue, and M-201 grown in dry land conditions than in a continuous flood. Comparable responses were observed when Arkansas *Pi-ta*-cultivars Katy, Kaybonnet, Drew, and Ahrent were inoculated with *Pi-ta*-virulent isolates IE-1k, IB-33, or MGS-19. Since Arkansas *Pi-ta*-cultivars are closely related, the more distant *Pi-ta*-cultivars Tetep (a parent of Katy), CICA 9, and Tadukan were tested for the flood-induced resistance response. When inoculated with race IB-33 or isolate MSG-19, the distant *Pi-ta*-cultivars growing in flood conditions had a lower blast index than when growing upland. These data show blast severity is more severe on cultivars growing upland than in a continuous flood, regardless of the *Pi-ta* gene being present or absent. To date, all rice cultivars inoculated with a virulent blast race have exhibited some degree of flood-induced field resistance.

Results define flood-induced field resistance as an effective control measure in situations where the blast fungus has compromised R gene resistance. Test data presented are from short-term greenhouse tests where the magnitude of treatment response is limited. However, previous research and field observations show induced resistance to be cumulative with duration and depth of flood, and the magnitude of resistance in certain susceptible cultivars appears to be comparable with that expressed by major R genes. Flood-induced blast field resistance functions to limit development and dispersal of virulent races because the overall effect of field resistance is to reduce the number of infections, the rate of lesion development, and number of spores produced per lesion. Following state recommendations, Arkansas growers used flood-induced field resistance as their primary blast control measure while producing record rough rice yields in blast susceptible cultivars Wells, LaGrue, and Francis during the disease-prone years 2000-2005. Information presented here aids in our developing high yielding resistant cultivars and/or practical control recommendations in the absence of effective major R genes.

Detection Methods for Bacterial Panicle Blight of Rice Caused by *Burkholderia glumae* and *B. gladioli*

Nandakumar, R., Rush, M.C., Shahjahan, A.K.M., O'Reilly, K.L., and Groth, D.E.

Bacterial panicle blight (BPB) of rice is an important disease in the southern United States. The damage in Louisiana was severe in 1995 and 1998, years of record high temperatures, with yield losses in some fields estimated to be as high as 40%. Significant losses were also experienced in Louisiana in 2000. This disease has been reported to be seedborne. Damage can be avoided or reduced by not planting seed with high levels of bacterial infection or by treating infected seed with antibacterial compounds. The objectives of this study were to isolate the bacteria associated with panicle blighting and identify the isolated strains through microscopic studies, and pathological, biochemical, serological, and molecular methods, to clarify the causal relationships of the *Burkholderia* species associated with blighted rice in the southern United States and to develop ELISA and PCR techniques for identifying and quantifying rice seeds infected with BPB pathogen(s).

A survey was conducted during 2000 in Louisiana, Arkansas, and Texas to collect infected rice panicles and sheaths for isolation of the pathogens. Over 420 bacterial strains were isolated from the infected samples using S-Pg medium, which is semi-selective for *Burkholderia*. Isolates were further purified by the serial dilution technique. Out of 364 strains tested for pathogenicity in greenhouse tests, 80% were pathogenic either on seedlings or panicles of rice. Virulent strains produced yellow green pigment on KBA medium. Electron microscopy studies revealed that the bacteria were rod shaped with 1 to 3 polar flagellum. Identification methods used included the Biolog GN2 system for utilization of carbon and nitrogen substrates, fatty acid analysis based on the MIDI Sherlock Microbial Identification System, PCR analysis with species specific primers, ELISA with monoclonal antibody raised against *B. glumae,* and real time PCR with Taqman probe identified 95% of these pathogenic strains as *B. glumae* and 5% as *B. gladioli*. Although strains of both the species produced similar symptoms on rice, *B. glumae* strains were generally more virulent. Cloning and sequencing of the 16s RNA gene using universal primers and the ITS region of 16s-23s RNA of the *B. glumae* and *B. gladioli* strains showed more than 98% homology with known published sequences. Recent research from our laboratory showed that *B. gladioli* strains pathogenic on rice were soilborne and these soilborne strains were identified using the above methods.

As *B. glumae* is the most common and most virulent pathogen causing BPB on rice, identifying infected seed-lots is still imperative. Monoclonal antibody specific to *B. glumae* and real time PCR studies identified and quantified the bacterium, even from single infected seeds, field infected seed samples, and seed samples from the Louisiana State Seed Laboratory. Among the different identification methods used, PCR and real time PCR appeared to be the most accurate and correct methods for identification and quantifying of BPB pathogens in rice seeds.

A Review of Texas Wildlife Services Activities to Control Wildlife Damage in Southeast Texas Rice Production Areas

Muir, T.J. and McEwen, G.M.

Texas Wildlife Services Program (WS) personnel conduct a variety of wildlife damage management projects to protect rice crops in southeast Texas. Most of the projects are related to damage caused by blackbirds and feral hogs. WS personnel use or recommend a broad range of methods to reduce or eliminate blackbird damage and feral hog damage to rice crops. WS employees assess each damage situation before choosing the best control method(s) to reduce or eliminate the wildlife damage problem.

Blackbird control methods used or recommended by WS personnel include: harassment, lethal shooting, habitat modification, and use of the avicide DRC-1339. In recent years, Texas WS personnel directed blackbird control efforts at elimination of blackbird roosts and blackbird population reduction using the avicide DRC-1339 in specific rice production areas of southeast Texas. Blackbird control projects involving the use of DRC-1339 were conducted in areas where roosting blackbirds congregate or "stage" after leaving or before returning to the roost. WS personnel have been conducting DRC-1339 baiting projects since 1994.

Feral hog control methods used or recommended by WS personnel include: trapping, snaring, shooting, hunting/harassment with dogs, and aerial hunting (hunting from aircraft). WS personnel conducted several feral hog control projects in southeast Texas using aircraft to hunt feral hogs in rice production areas. Aerial hunting may be a very effective feral hog population reduction method when factors such as vegetative cover and property access favor the use of aircraft.

The Threat of the Panicle Rice Mite, *Steneotarsonemus spinki* Smiley, to Rice Production in the United States

Castro, B.A., Ochoa, R., and Cuevas, F.E.

The panicle rice mite, *Steneotarsonemus spinki* Smiley (Acari: Prostigmata: Tarsonemidae), was first described by Robert L. Smiley in 1967 from specimens collected on delphacid insects in Baton Rouge, Louisiana. It was not until the mid 1970s that the species was reported to cause 30% reduction in yield of a rice crop in China and Taiwan. During the late 1990s, the mite was found in Cuba, the Dominican Republic, and Haiti where 30 to 100% reductions in yield were reported. The mite was reported in Panama, Costa Rica, and Nicaragua in 2004 and in Colombia, Honduras, and Guatemala in 2005. Losses to rice in Central America were observed between 30 and 90%. Injury is caused by direct feeding of the mite and, most importantly, by its interaction with the fungus *Sarocladium oryzae* (Sawada), which is the causal agent of sheath rot and is an important contributor to kernel spotting ("pecky" rice). The dramatic range expansion of the mite prompted several Latin American countries, such as Colombia and Brazil to impose quarantine measures to prevent introduction and further dispersion of this invasive species into other rice producing areas. Quarantine restrictions also are being considered in Mexico.

Since the mite was first reported in Louisiana in 1967, no additional report exists on its presence and/or establishment in the United States. A survey was initiated in 2005 in cooperation with the Louisiana State University Agricultural Center, RiceTec, and the USDA/ARS to determine if the mite occurs in rice producing areas of Louisiana. The survey included commercial rice fields with rice from southwest, central, and northeast Louisiana. Inspections were conducted in fields at the green ring, early boot, late boot, milk, soft dough, and hard dough stages. Plants collected from fields with emerged panicles included those with symptoms of panicle sterility and grain discoloration. A minimum of 10 plants were collected from each inspected rice field. Plants were hand clipped and the upper half of each plant was placed in a plastic bag, which was then put inside a cooler and transported to the laboratory. Under laboratory conditions, the basal portion of each leaf, leaf sheath, boot, and panicle was clipped into 1-inch pieces using hand scissors. The plant material was rinsed in 10 ml of 80% alcohol three times and the rinsate was observed using a 400x magnification microscope. In addition, the legs of cicadellids and delphacid insects collected in a separate survey were inspected for presence of the mite. Suspicious mites were collected and sent to the Systematic Entomology Laboratory (USDA/ARS) for confirmation. The only tarsonemid mite collected was identified as *Tarsonemus bilobatus* Suski, the panicle rice mite was not found.

This presentation provides important information about the panicle rice mite, including morphological characteristics, field biology, and control strategies. This mite species, *S. spinki*, is a serious threat to U.S. rice production. Stakeholders, scientists, and government agencies are urged to be aware of the serious threat of this highly destructive invasive species.

Effects of Lambda-cyhalothrin (Warrior) on Mosquito Larvae and Predatory Aquatic Insects in Rice Fields

Lawler, S.P., Dritz, D.A., Christiansen, J.A., and Cornel, A.J.

Rice fields are extensive sources of mosquito populations in many areas of the world. Agricultural pesticides used in rice can provide incidental suppression of mosquito populations, but are also implicated in promoting selection of pesticide resistance genes in medically important mosquitoes. Agricultural pesticides also sometimes disrupt biological control, but researchers have only rarely assessed whether insecticides used against agricultural pests disrupt biological control of mosquitoes. We examined the effects of lambda-cyhalothrin (Warrior; Syngenta Crop Protection, Greensboro, NC, USA), a pyrethroid insecticide that is used against rice pests, on mosquitoes and predatory insects in a full-scale field study.

We quantified the duration of toxicity of lambda-cyhalothrin to predatory insects in rice fields and to three kinds of mosquito larvae. One was a pyrethroid-susceptible strain of *Culex tarsalis* Coquillet 1895 and two were strains of *Cx pipiens* (sensu latu), one of which was susceptible and the other resistant to pyrethroids. The experiment took place in 2003 at the Biggs Rice Experimental Station in California. On 29 July 2003, one of two treatments was applied to four fields each: 1) no insecticide and 2) Warrior applied at 5.8 g ai ha^{-1} via airplane. Inter-field water flow was blocked for the duration of the study. Treatments and controls were randomized, and there was at least one untreated field serving as a buffer between treated and control fields. Caged mosquito larvae were replaced weekly to quantify the duration of insecticide effects, and predatory insects were sampled weekly to track their recovery.

Warrior killed most caged, susceptible mosquitoes for up to 21 days. Warrior killed fewer resistant *Cx pipiens* sl. but suppressed their survival for over a week. Warrior suppressed predatory insects through Day 29. Results confirm that agricultural use of lambda-cyhalothrin may provide incidental mosquito control. However, the insecticide persisted in sediment and gradually decreased in activity after application, which could contribute to selection of pyrethroid-resistant mosquitoes. Biological control disruption is possible because caged mosquitoes showed good survival before predators recovered. It is, therefore, advisable for rice growers and mosquito control agencies to communicate about pesticide use.

Fighting West Nile in the "Wilds" of The Woodlands

Aldrich, R.L.

Montgomery County Precinct 3 has been responsible for mosquito control in The Woodlands area for over a decade. Application of pesticide chemicals to kill the adult form of the mosquito, applied by truck-mounted sprayers, was the method used to control. Concern about repeated street spraying and the fact that The Woodlands had been a hotspot for human West Nile in 2003 led the Community Associations of The Woodlands to pursue research regarding the efficacy and cost effectiveness of the method. A graduate student intern was employed to begin a study in July 2004. The study showed that the spraying program, as it existed, was not impacting positive West Nile mosquito pools. In many test locations, residents' irrigation practices were responsible for much of the mosquito problem in the area. These factors, along with concerns about possible development of pesticide resistance lead to the recommendation of Integrated Mosquito Management with a strong community-based education program. The Community Associations of The Woodlands, Precinct 3, The Woodlands GREEN, and the local Water Districts worked together to change mosquito control in the community to IMM in 2005, leading to an 89% reduction in the amount of pesticides used. In addition, the new approach was successful in eliminating the positive West Nile pools in almost half of the test sites. In 2006, Texas Master Naturalists will assist in the neighborhood level grassroots community education to further improve the effectiveness of the new approach.

Integrated Malaria-Mosquito Management in a Riceland Ecosystem in Kenya

Novak, R.J., Weidong, G., Josephat, S., and Benjamin, J.

The spectacular success controlling agricultural and public health pests with synthetic insecticides in the decade immediately following World War II generated widespread enthusiasm that the major scourges of mankind, including yellow fever, malaria, and typhus, would soon be conquered. However, the approach to controlling arthropods of public health importance has shifted in the past 40 years from an almost exclusive reliance on insecticides to a blend of techniques based on the principles of integrated pest management (IPM). In general, IPM is an applied ecological approach for curtailing the damage of noxious pests to acceptable levels using a variety of long- and short-term interventions that are environmentally and socially sound. It is the goal of this research to develop and implement an IPM Program that focuses on the contribution of reducing the immature population of vector *Anopheles* species in rice-village complexes in Kenya. This presentation will address the "when," "where," and "how" to manage vector *Anopheles* larvae in rice-village irrigation complexes based on the ecological principles of IPM. Recently, we developed a new habitat-based framework to evaluate the impact of larval interventions on adult populations and exposure intensity as measured by entomological inoculation rates (EIR). Unlike traditional models that unrealistically assumed habitats are identical in adult productivity, our new models explicitly consider variability in productivity among habitats. We demonstrate theoretically that a significant reduction in populations of *Anopheles* mosquitoes, and thus malaria parasite transmission, can be obtained through habitat-based targeted larval control interventions. Moreover, we highlight the importance of ecological surveys of habitats and larval ecology in relation to the estimation of adult productivity and, thus, provide a theoretical base for empirical challenges in the field.

Summary of the Rice Pest Survey in Arkansas, 2004 and 2005

Sutton, E.A., Robinson, J., Yingling, J.A., Parsons, C.E., Chaney, H.,
Chlapecka, R., Baker, R., and Cartwright, R.D.

Rice pathogens and other pests are well known in Arkansas but have not been properly documented in recent years. Several new pathogens or historic but unreported ones were suspected in the state and the recent discovery of new pests in Louisiana in recent years increased the need for a modern survey. Benefits from a survey were considered to be a more realistic defense of domestic rice in the export markets and early detection and management of newly discovered problems.

Surveys were conducted in cooperation with the Arkansas State Plant Board, APHIS PPQ CAPS program, and the University of Arkansas Division of Agriculture. Samples were solicited from county extension agents from all Arkansas counties during the 2-year survey and processed at the Plant Disease Clinic in Lonoke. Samples were also accepted from Missouri rice production counties. Samples were directly collected by survey cooperators from plots in the Arkansas Rice Disease Monitoring Program located in various counties each year, as well as other research plots throughout the state. Selected fields in Arkansas were systematically surveyed in 2004 for disease incidence.

Samples (400-1000/yr) were inspected visually and microscopically for symptoms and signs of various pathogens and other pests. Suspected pathogens were isolated and further processed for identity or submitted to an expert cooperator for identification. In some cases, plant samples were submitted directly to cooperators for inspection. Insect pests were submitted to cooperating entomologists.

Survey results confirmed the presence of most previously reported pathogens and pests in Arkansas. However, stackburn and sheath blotch disease were not noted, although previously reported. The following diseases were confirmed in the state and will be reported in later publications: bordered sheath spot (*Rhizoctonia oryzae*) and aggregate sheath spot (*Rhizoctonia oryzae-sativae*). A rare race of the rice blast pathogen, designated IE-1k, caused economic damage on the new cultivar Banks in one field during 2004 and additional fields in 2005. *Burkholderia glumae* (bacterial panicle blight) was confirmed throughout Arkansas, primarily on Bengal rice, but no other bacterial diseases were found. A root and crown rot problem was noted in several fields and thought to be related to hydrogen sulfide toxicity or certain nutritional disorders – no pathogen was isolated. A "mystery" condition resulting in stem and panicle distortion was noted in both years and a suspected causal agent has been isolated. Testing continues to determine identity of the suspect and whether it is the true cause of the symptoms observed. The yellow sugarcane aphid was noted on rice at very low levels in Arkansas both years.

Insecticide Efficacy for Rice Insects in the Mississippi Delta

Robbins, J.T.

Tests were conducted with a new granular insecticide and a seed treatment. The granular treatment is etofenprox made by Mitsui Corporation, and the seed treatment is a combination fungicide and insecticide produced by Syngenta. These two new treatments target rice water weevils, chinch bugs, colaspis beetles, and other early-season insects of rice. Preliminary laboratory tests with etofenprox show excellent control of rice stink bugs. Calibration for different rates of etofenprox applied by air proved to be no different than fertilizer calibrations. The dispersion of the granules was very uniform due to the shape and size of the granules. Test results show that both compounds are very effective in controlling the target pests. Additional tests were conducted with different rates and application timings of Prolex, Mustang Max, Karate Z, Methyl Parathion, and others for control of rice stink bugs. Prolex applied at 1 gallon to 85 acres proved to be very effective and comparable with Karate Z applied at 1 gallon to 66 acres. Prolex is a 'gamma' cyhalothrin as opposed to Karate Z which is a 'lambda' cyhalothrin.

Highest average yields were from tests where both a seed treatment and foliar applications were applied. Yields averaged 5275 lb/A where only fungicides were used compared with average yields of 6160 to 6360 lb/A where both fungicide and insecticide seed treatments were used. Yields from test fields were low compared with previous years due to the hurricane damage.

Pecky Rice–Through the Past, Darkly

Bernhardt, J.L.

The amount of discolored kernels (pecky rice) is just one of several factors used by rice buyers and millers to assign a grade to rough rice. Among all of the reasons for pecky rice, the rice stink bug often causes the majority of discolored kernels. Feeding probes by adults and nymphs often result in shriveled kernels and/or kernels discolored by infection from a variety of pathogens. During discussions with entomologists and breeders in 1987, a decision was made to begin evaluation of rice varieties and advanced breeding lines for susceptibility to discolored kernels with emphasis on rice stink bugs. The objectives are to identify sources of resistance or reduced susceptibility to rice stink bugs and provide data on the susceptibility of rice varieties. To accomplish these objectives, procedures were developed that reduced, but did not eliminate, the intensive manual labor to separate pecky rice from undamaged rice. The cornerstone of the procedure is a high-speed sorting system based on optical properties that was adapted to separate brown rice into two fractions, discolored and non-discolored. However, time-intensive methods remain in the procedure and are as follows: de-hulling of rough rice with a sample sheller prior to machine sorting, a manual sort of the discolored fraction to remove non-discolored kernels, and separation of the discolored kernels into categories by manual examination with a dissecting microscope. Discolored kernels are separated into four categories and are as follow: discoloration caused by rice stink bug, discoloration caused by infection with kernel smut, discoloration due to linear damage, and a ‘catch-all’ category of all other causes of discolored kernels. This procedure was used yearly on uncleaned rough rice samples taken from replicated plots of advanced rice lines and check varieties in three to five locations of the Arkansas Rice Performance Trials (ARPT) since 1988 and from the Arkansas location of the Uniform Regional Rice Nursery (URRN) since 1993.

Evaluations of advanced rice lines provide rice breeders with information on the susceptibility of lines to rice stink bug damage and other causes of discolorations. Breeders can use the information in the selection of lines for further tests and eliminate lines that are highly susceptible to kernel discolorations. Farmers can use the information to select varieties and use management practices that will reduce quality reductions. For example, medium- and short-grain rice varieties are more susceptible to rice stink bugs than most long-grain lines. Careful scouting for stink bugs and the use of insecticides, when necessary, would prevent excessive discounts for discolored kernels.

Statistical analyses of the amount of discolored kernels in the categories indicated that discolorations were highly subject to genotype and environmental interaction. This was expected because environmental influences on rice stink bug populations would not affect kernel smut infection, other pathogens, and physiological causes in the same manner. In addition, each of the four categories was inherited independently, and genotype selection for reduced levels of discolored kernels must be conducted via independent programs. From the study, three long-grain varieties and one medium-grain variety (Katy, Kaybonnet, LaGrue, and Mars) had stable low levels of susceptibility to rice stink bugs. Additional research has shown that Katy, Kaybonnet, and Mars have relatively small panicles that mature kernels quickly, thus avoiding high amounts of damage from rice stink bugs. LaGrue has a large panicle and matures kernels slower than the previously mentioned varieties, but must have other sources of low susceptibility (resistance) to rice stink bug. LaGrue was a parent used in a cross with Katy and other sources for the variety Spring that was released in 2005. Spring is a very early maturing long-grain with an excellent low susceptibility to the rice stink bug.

Spatial Pattern and Development of a Visual Sampling Method for the Rice Stink Bug, *Oebalus pugnax* (Hemiptera:Pentatomidae), in Texas

Espino, L., Way, M.O., and Olson, J.K.

The objective of this study was to develop a reliable visual sampling methodology and a sequential sampling program for the rice stink bug (RSB), *Oebalus pugnax* (F.). Three different visual sampling methods were compared with the standard method, the sweep net. Commercial rice fields in the Texas Rice Belt were sampled during 2003 and 2004 and a total of 1036 visual samples were compared with an equal number of sweep net samples (10 sweeps per sample). Fields were sampled at different stages of panicle development and had different RSB population levels. Analysis of covariance revealed that sweep net sampling could be replaced by visual sampling using the "sweep stick." Taylor's equation was used to determine the variance-mean relationship for the sweep net and the sweep stick. Using Taylor's coefficients and current damage thresholds, sequential sampling plans were developed for the sweep stick and the sweep net. Validation of the sequential sampling plans was conducted during the 2005 growing season.

Impact of Management Strategies for the Rice Water Weevil on Populations of Non-Target Organisms in California Rice

Godfrey, L.D., Lewis, R.R., and Windbiel-Rojas, K.

West Nile Virus (WNV) is an important issue in California as it has been in much of the United States. Human cases of WNV in northern California, including the Sacramento Valley (California's primary rice production area) were first noted in 2004 and the caseload expanded in 2005. The aquatic nature of the rice agroecosystem makes it an obvious concern for mosquito population build-up and management activities. Best management practices were developed and adopted by the rice industry in California to assist with mosquito management and WNV mitigation.

Numerous invertebrates feed on aquatic stages of mosquitoes in rice fields and potentially reduce populations. This balance between pestiferous mosquitoes and their enemies can be upset by numerous activities during the rice production season. Water management, incidence of organic residue, and pesticide applications are a few of the factors which can influence this interaction. We evaluated the effects of insecticide applications, made for rice arthropod pest management, on populations of invertebrates in rice fields. In California, the rice water weevil is the primary arthropod pest that requires insecticidal control. About 20% of the acreage (and a higher percentage of the fields since the insecticide is typically only applied to the field borders) is treated with primarily pyrethroid insecticides. Armyworms have been on the upswing in recent years and a mid- to late-season application for management of this pest is becoming more common.

Studies were conducted in 2003 to 2005 at the Rice Experiment Station near Biggs, CA. The effects of registered insecticides on the rice field fauna were evaluated; insecticides under development nearing registration were also evaluated. Insecticides were applied to field plots either preflood or at the 3-leaf stage, depending on the product and the optimal use pattern for each product. One treatment was also included with a lambda-cyhalothrin application made in July, a timing which is used for armyworm control. Populations of invertebrates were sampled weekly between the time of application and field draining using three methods. First, floating barrier traps were used to sample actively swimming invertebrates. Mosquito dip samples were used to assess mosquito larval populations. Finally, square foot areas were delineated in each plot and as many invertebrates as possible were removed from these areas with an aquatic net. Rice water weevil populations were also sampled as an indication of the efficacy of each treatment on this pest.

In 2003, invertebrates were fairly rare for the first 2 to 3 weeks of sampling (until mid-June). Populations of total invertebrates were suppressed by the preflood treatments until early July; the Icon treatment suppressed populations season-long. The post-flood treatments were generally detrimental to invertebrate populations until mid-August (Dimilin had less effects than the other treatments [Warrior, Mustang]). The July Warrior application was particularly harmful to populations. On beetles, the effects of the preflood and post-flood treatments were significant and these clearly reduced populations. This is not surprising that these insecticides would kill beneficial beetles since these materials are targeted for the control of a beetle. On Annelids, the results were also fairly clear in that none of the treatments had any consistent detrimental effect on populations. The numbers of animals were much higher in 2004 than in 2003 early in the season; the field in 2004 had a high infestation of clam shrimp, which were not present in the field in 2003. For the preflood treatments, it appears that the insecticide had minimal effects on the total number of invertebrates in 2004. Post-flood applications were more detrimental than preflood treatments to the numbers of invertebrates with all five insecticide treatments reducing numbers for the first 2 weeks after application. After this initial period, the effects of the 3-leaf stage applications were minimal. Overall, it appears that the effects of the treatments on invertebrate populations in 2003 were more noticeable than in 2004. In summary, the effect of the materials on non-targets depends on the species/group in question and on the season. Data from the 2005 study are still being summarized.

New Options for Rice Water Weevil Management

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

The rice water weevil is the most important early-season insect pest of rice in Louisiana. Yield losses from this insect are caused primarily by feeding of larvae on the roots of young rice plants. This insect is a particularly severe pest in southwestern Louisiana, where its population densities are very high and where widely-used cultural practices (particularly pinpoint flooding) invite severe infestations of young rice. Yield losses from this insect regularly exceed 20% in small-plot experiments at the LSU AgCenter's Rice Research Station.

The rice water weevil was controlled for many years by post-flood applications of the insecticide carbofuran, but the use of carbofuran was disallowed by the EPA in the mid 1990s. The loss of carbofuran was followed by the introduction of several new insecticides into the rice market. These insecticides included Icon (fipronil), Dimilin (diflubenzuron), and several pyrethroid insecticides. Icon is a seed treatment; the remaining insecticides are formulated as liquids and have been used as post-flood foliar sprays in Louisiana. These insecticides have been used successfully against the rice water weevil for the past several years. However, Icon was voluntarily removed from the rice market by its manufacturer in 2005, leaving only the pyrethroids and Dimilin, which is rarely used. There are numerous challenges associated with the use of pyrethroid insecticides for weevil control. The most important of these challenges are the absence of a treatment threshold to guide timing of application (these products control rice water weevil larvae indirectly, by affecting adult weevils), the possibility that weevils will develop resistance to this class of insecticides, and most importantly, non-target toxicity associated with drift of the insecticides into crawfish ponds. There is clearly a need for the introduction of new insecticides for weevil control, and there has been renewed interest on the part of chemical companies in evaluating insecticides against the rice water weevil.

Over the past 2 years, the Rice Entomology Program of the LSU AgCenter has conducted over 15 small-plot tests to evaluate potential alternatives to currently registered insecticides. A number of seed treatments have been evaluated, and three of them have provided larval control comparable with, or better than, the control given by Icon. These seed treatments have been tested under secrecy agreements, and it is still unclear whether the manufacturers of these products plan to pursue registrations in rice.

Two granular formulations of insecticides have been tested for weevil control in recent years. One major benefit associated with the use of granular formulations is that they are less likely to drift when applied by air. One of these granular insecticides, Dinotefuran, provided outstanding control of weevil larvae when a preflood application was followed by a post-flood application made 6 to 20 days after flooding. Single post-flood applications of this insecticide also reduced larval numbers, showing that this insecticide has some larvacidal activity. This insecticide also appears to be less toxic to crawfish than the pyrethroids.

Another granular insecticide, etofenprox, is a pyrethroid-like insecticide that is used in a manner similar to the other pyrethroid insecticides; that is, the product works best when applied shortly after flooding. This insecticide has been used for almost 20 years to control rice water weevils in Japan. Etofenprox has given only moderate control of weevils in tests conducted at the LSU AgCenter's Rice Research Station, but its mediocre performance in these tests was probably related to extremely high weevil pressures in the tests in which it was applied (applications of foliar pyrethroids included as standards in these tests also failed to adequately control weevils). The successful use of etofenprox in Japan and positive results with etofenprox in tests in other rice-growing regions of the United States suggest that etofenprox should adequately control weevils under normal circumstances. Etofenprox may be available under a Section 18 registration during the 2006 growing season. Etofenprox is toxic to crawfish but, as a granular, is less likely to drift into crawfish ponds when applied to rice fields.

Finally, several tests have been conducted to evaluate the efficacy of pyrethroid insecticides impregnated (coated) on fertilizer. Data collected over the past 2 years indicate that pyrethroid insecticides coated on a granular fertilizer offer rice water weevil control as good as a foliar spray at the same rate. The method reduces drift problems because the insecticide is coated on a granular material. No evidence for direct larval control was detected.

Economic Analysis of Rice Water Weevil Control

Way, M.O., Nunez, M.S., and Wolff, R.A.

A planting date study employing registered rice water weevil (RWW) insecticides was conducted for 3 years (2003-2005) at the Texas A&M University Agricultural Research and Extension Center. Planting dates for each year were approximately mid-March, first of April, mid-April, first of May, and mid-May. In general, for all 3 years, Icon 6.2FS, Karate Z, Dimilin 2L, Mustang Max, and Prolex provided excellent control of RWW, regardless of planting date. RWW densities in untreated plots were highest during the recommended planting window (mid-March to mid-April). Very late-planted rice was associated with lower RWW populations, but yields were low, partly due to the inability to ratoon crop late-planting dates. The first three planting dates were ratoon cropped in 2003 and 2004, while only the first two planting dates were ratoon cropped in 2005. The ratoon crop in 2005 yielded poorly because of shattering caused by Hurricane Rita. Also, blackbird damage to heading main crop rice on the earliest planting date skewed yield data; thus, yield and economic information from 2005 are not as meaningful as the previous 2 years. The most inexpensive treatments were pyrethroids applied immediately before the flood because these treatments could be tank-mixed with preflood herbicides. This treatment method saves on application costs. Across planting dates and insecticide treatments, the average return above the cost of control was approximately $40 and $30/A in 2003 and 2004, respectively.

The Effects of Rice Cultivar and Crop Growth Period on Parasitization of Sugarcane Borer by *Cotesia flavipes*

Lv, J., Wilson, L.T., Beuzelin, J., Medley, J., Reagan, T.E., and Way, M.O.

This research investigated the survival rate of sugarcane borer larvae and parasitization of sugarcane borer larvae by *Cotesia flavipes* as affected by three rice cultivars (Cocodrie, Francis, and Jefferson) and three crop growth stages (the third tiller stage, the panicle differentiation stage, and the heading stage). A field experiment was conducted at the Beaumont Research and Extension Center, TX, during summer 2005. *Cotesia flavipes* adults were released into field cages enclosing rice plants that were artificially infested with sugarcane borers. Results from this experiment showed that the survival rate of sugarcane borer was density dependent and was significantly affected by crop growth stage and cultivar characteristics. The survival rate was higher during the earlier crop growth stage and on rice cultivar with greater stem diameter. Rice cultivar characteristic, crop growth stage, and sugarcane borer density did not significantly affect the parasitization rate. However, there was a trend towards a higher parasitization rate during the early crop growth stage.

Oviposition Behavior of the Sugarcane Borer, *Diatraea saccharalis* (F.) Lepidoptera: Crambidae), in Relation to Host Plant Phenology

Hamm, J.C. and Stout, M.J.

The proper timing of insecticide applications is an essential component of integrated pest management (IPM). In addition, the behavior and biology of the pest should also be a key consideration in the implementation of management programs. These experiments were conducted in order to characterize the oviposition behavior of the sugarcane borer, *Diatraea saccharalis* (F.) (Lepidoptera: Crambidae), on different phenological stages of rice. In essence, the aim of this study was to understand the “when” and the “where” of sugarcane borer oviposition on rice.

The first experiment was conducted at the Rice Research Station in Crowley, LA, in July and August of 2005. Plots of Cocodrie received standard cultural practices for southwestern Louisiana, with the exception that no insecticides were used. Different plots were used on four different dates, corresponding with four different stages of rice, tillering, panicle initiation, booting, and heading, and for each stage, five screened cages were placed in a plot. Adults were released in cages and allowed to oviposit. Six days later, cages were removed and within each caged area, 15 plants were randomly sampled and systematically inspected for egg masses. The vertical distribution (upper, middle, lower) and the leaf surface locations (adaxial, abaxial) of the egg masses were recorded for each release.

The second experiment was conducted in a greenhouse on the LSU campus in August 2005. A completely randomized block design with five replications was utilized. In each replication, two treatments were examined -- age (mid-tillering, panicle initiation, booting, and heading) and variety (CLXP 730 and Cocodrie); treatments were randomly arranged such that each variety was available at each phenological stage, so that two of each variety x age combination was present in each replication, for a total of eight plants. Adults were allowed to oviposit in cages for 6 days, then plants were inspected for egg masses; the number of egg masses per plant, and the number of eggs per mass were recorded. Data were analyzed using PROC MIXED and mean separations were done with Tukey’s adjustment.

The results of these two experiments indicate that females prefer to oviposit on the upper parts of the plants and a majority of the egg masses (62%) are deposited on the adaxial surface. Additionally, the booting stage of Cocodrie was the most attractive stage for oviposition, while in cutlivar CLXP-730 heading was most attractive for ovipositing females. Taken together, the results of these experiments indicate that early-season plants may not be suitable hosts, but as plants age and populations build up, reproductive plants are the most susceptible for oviposition. These results can be incorporated into an IPM program for the sugarcane borer in rice in order to ensure the proper timing of insecticide applications.

Oviposition Preference of the Mexican Rice Borer as Affected by Rice Phenology and Physiology

Reay-Jones, F.P.F., Way, M.O., Wilson, L.T., Reagan, T.E., and Showler, A.T.

The Mexican rice borer, *Eoreuma loftini* (Dyar), originated from Mexico and has been the dominant insect pest of sugarcane in the Lower Rio Grande Valley of Texas since it became established in 1980. By 1989, its range had expanded into the rice production area of Texas where it is responsible for major yield losses in rice. With *E. loftini* moths discovered in the sugarcane production area near Beaumont, Texas, invasion of Western Louisiana, where sugarcane and rice are grown in close proximity, is imminent. Insecticides are used in the Texas Rice Belt to reduce infestations of stem borers, mainly *E. loftini* and *Diatraea saccharalis* (F.). To better understand insect-crop dynamics in Texas and Louisiana and to assist in evaluating the resistance of rice cultivars to *E. loftini*, oviposition preference on both sugarcane and rice was determined. Oviposition of Lepidoptera insects is a critical step in the life cycle because of the limited mobility of first instar larvae to feed and survive. Levels of non-preference can help control pests of crops in some IPM systems and may assist in developing a defense strategy against *E. loftini*.

Greenhouse experiments involved two rice cultivars (susceptible Cocodrie and resistant XL8) and two sugarcane cultivars (susceptible LCP 85-384 and resistant HoCP 85-845) at different phenological stages (3- to 4-leaf, 6- to 7-leaf, boot and heading for rice; 5 and 11 internodes for sugarcane). In addition, two irrigation regimes were used for sugarcane treatments. Each test consisted of placing four treatments per cage replicated in four greenhouse cages (2×2×2 m). Two plants of each treatment were randomly placed on a 1.5 m circle in the center of each cage. Seven experiments were conducted to cover all treatments. Oviposition tests were initiated with the release of 30 male and 30 female moths in each cage and ended 6 days later. Number of eggs, number of egg masses, and location on plant were recorded, as well as plant characteristics such as plant height, dry weight, green leaves, dry leaves, water potential (sugarcane), and leaf free amino acid levels (using HPLC). Preference estimates were established using non-linear regression models. Correlation and regression analyses were performed between insect oviposition variables and plant characteristic variables.

Eoreuma loftini eggs were distributed on rice green leaves, leaf sheaths, stems (54%), and dry leaves (46%). The tillering stages were not as attractive as either the boot or heading stages, possibly due to a reduced number of oviposition sites (i.e. green and dry leaves) on young rice plants. The more resistant cultivar in the field (XL8) was more attractive for egg laying than susceptible Cocodrie. Egg masses were 9.2-fold more abundant and 7.0-fold larger when laid on sugarcane than rice. Drought-stressed sugarcane was 1.8-fold more attractive based on egg masses/plant than non-drought-stressed sugarcane. Rice leaves, despite being less attractive for oviposition, had higher levels of free amino acids essential for insect growth and development than sugarcane. On rice, associations were established between egg masses per plant and essential free amino acids (threonine and valine) and dry leaves. Rice cultivar XL8, which was more attractive for oviposition compared with Cocodrie, had higher levels of the essential free amino acid histidine and more tillers. *Eoreuma loftini* laid more eggs on rice plants of large biomass, a common response in oviposition behavior among other insects. Because sugarcane is more attractive than rice, populations from rice fields will be expected to contribute to enhancing infestations on proximate sugarcane in some areas in Louisiana. Despite being more attractive for oviposition compared with Cocodrie, rice cultivar XL8 was more resistant to stem borers in a field study. Our study would indicate that from an areawide IPM perspective, the use of a resistant rice cultivar would be expected to be effective in reducing infestations on proximate host crops if the resistance mechanisms are antibiotic.

Abstracts of Posters on Plant Protection
Panel Chair: M. Way

Strategies for Screening Multiple Rice Diseases

Groth, D.E., Rush, M.C., and Shahjahan, A.K.M.

Rice diseases pose a major threat to rice production. Three major diseases, sheath blight, blast, and bacterial panicle blight, 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 and requires constant efforts to improve and maintain. Most long-grain cultivars are susceptible to sheath blight and bacterial panicle blight, and several major cultivars are also 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, but these tend to be expensive and occasionally ineffective. Major problems are encountered when screening for disease resistance, including limited seed supplies, not enough plot area to run multiple trials, interference between disease expressions, and economic restraints. Screening for multiple diseases in the same plot would reduce these limitations and increase efficiency of screening programs. The objectives of these studies were to develop effective and accurate rice disease screening methods that allow screening of multiple diseases in the same plot.

Experiments were conducted at the LSU AgCenter's Rice Research Station, Crowley, LA, in 2004 and 2005. Small plots consisted of three rows, 2-m long, of various cultivars drill-seeded with 18-cm row spacing. Planting dates, seeding rates, fertility, and pest control followed current recommended practices. Treatments were organized into a randomized complete block design with four replicates. Sheath blight epidemics were initiated at green ring by inoculating one-half of the plots with a rice grain/rice hull culture. Bacterial panicle blight epidemics were initiated at the boot split on the other half of the plots by spraying a 24-hr old culture of bacteria on emerging heads twice at 2- to 4-day intervals. Blast and minor foliar diseases were from natural sources. Disease severities were assessed using 0-9 rating scales 2 to 4 days before harvest maturity.

Rice disease resistance ratings were successfully collected simultaneously for multiple diseases in small plots, including sheath blight, blast, bacterial panicle blight, and secondary foliar diseases. Strategies to evaluate multiple disease development without interference will be discussed.

An Overview of Foliar Fungicide Evaluation in Arkansas

Parsons, C.E., Yingling, J.A., Sutton, E.A., and Cartwright, R.D.

Foliar fungicide use in Arkansas has increased from approximately 48,000 ha (10% of total hectarage) to more than 243,000 ha (40% of total hectarage) since 1997. This increase has been primarily due to the introduction of more effective fungicides (azoxystrobin and trifloxystrobin) and increased marketing efforts by crop protection companies. While there is no question that input costs for growers using fungicides have increased during this period, questions remain about net return from fungicide use in the state.

Fungicide efficacy trials in rice have been routinely conducted in Arkansas for many years. However, most were conducted under artificial conditions where plots were managed to maximize disease potential and the pathogen was inoculated. While this provided good to excellent conditions to compare products for control of a particular disease, a realistic comparison with commercial fields was not possible. Thus, aerially-applied fungicide trials were conducted for comparison of products. While relative efficacy of the products was similar in small plot and aerial trials, yield and milling quality benefits were typically lower in aerial plots–probably due to erratic disease distribution and crop management differences when compared to small plot studies. Nevertheless, all fungicide studies provided new guidelines for the use of different rates and application timing to control sheath blight in the state and for the control of kernel smut and false smut diseases.

New studies began in 2003 to evaluate the economic benefit of preventive fungicides. Since 1997, more growers had shifted to preventive fungicide applications for most of their hectarage, believing that fungicide applications at least paid for themselves and provided crop protection security without the cost of extensive scouting. Since rice cultivars differ in disease susceptibility, four cultivars were selected for study. These included Clearfield CL161, Francis, Bengal, and RiceTec CLXL-8. CL161 was considered highly susceptible to sheath blight and several other diseases endemic in Arkansas while CLXL-8 hybrid was considered moderately resistant to most diseases in the state. Francis and Bengal were considered intermediate in disease reaction. Trials were conducted using a split plot design with cultivar being the main plot and fungicide being the sub plot, with four replications. Fungicide treatments were applied with a self-propelled rice plot sprayer and typically included untreated, Stratego (trifloxystrobin + propiconazole) at 1169 ml/ha applied at the booting stage to simulate scouting and timing systems common in many fields, and Quilt (azoxystrobin + propiconazole) at 2483 ml/ha applied prior to booting as a preventive treatment. Trials were planted in growers' fields in different areas of the state each year since 2003 and managed by the grower with the rest of the field. Plots were harvested for yield, and grain samples were graded and milled according to GIPSA standards.

Results indicated that economic benefit from the preventive use of these foliar fungicides depended on cultivar, than location. For CL161, a break-even or positive economic return was observed in approximately 60% of the trials; Francis approximately 40%; Bengal 15%; and CLXL-8 less than 8%. The highest return per hectare observed was $112.78 in 2003 where sheath blight was heavy, while losses of more than $86.45 were noted at various locations. Thus far, yields in treated plots tend to be slightly higher overall, but usually not enough to be statistically significant unless a major disease like sheath blight is present and severe. Milling quality results have been inconsistent. Results generally support scouting and utilizing fungicides only when disease incidence and development warrant. Further research is planned.

Effect of Prohexadione Calcium and Trinexapac-Ethyl and Fungicides on Height, Lodging, Yield, and Milling Quality of Two Rice Cultivars in Arkansas

Yingling, J.A., Sutton, E.A., Parsons, C.E., Robinson, J., Dawson, V., Ginn, H., and Cartwright, R.D.

Lodging remains a common problem for many high-yielding southern U.S. rice cultivars. And, it is a constant problem in the older cultivars, Koshi-hikari and Carolina Gold, produced in the South for specialty markets. Modern fertilizer management, weather, and planting date influence lodging in the South. Fields where high levels of nitrogen fertilizer were used or fields impacted by high winds later in the summer are subject to lodging. Lodging results in yield loss due to inability to pick up all fallen rice and shattering, and may contribute to poor quality through increased trash in harvested grain, as well as sprouted kernels and dirty grain.

Plant growth regulators in crop production have been heavily used in recent years. Various products are used routinely to manage vegetative over-development in cotton, fruit ripening and load in apples, and height and standability in European small grains. Recently, crop protection companies and certain Arkansas growers expressed increased interest in the potential use of two plant growth regulators on rice standability and yield. These products, prohexadione calcium (Apogee) and trinexapac-ethyl (Palisade), result in stunting of grasses as well as some stiffening of straw in small grains. Interest by Arkansas growers focused on using these products to minimize lodging in Koshi-hikari and Carolina Gold cultivars.

Field trials were established in 2004 using both cultivars, but only Koshi-hikari was used in 2005. Treatments included various rates of both growth regulators and included a combination treatment with a standard rice fungicide for comparison. Treatments were arranged in a randomized complete block design with four replications and applied using a self-propelled rice plot sprayer. Plots were harvested for yield, and samples were milled according to GIPSA standards.

Results showed both products were very effective at reducing plant height from 10 to 35%, depending on rate and timing. Unfortunately, yield was also reduced up to 40%, depending on treatment. Milling quality varied considerably with these cultivars, but no clear treatment effect was noted in 2004. Lodging was eliminated in both cultivars by rates of Apogee from 584 ml/ha and above while the Palisade product eliminated lodging at rates of 935 ml/ha. Lower rates resulted in a reduction in lodging of 60 to 100% and yield losses of 0 to 25%, depending on rate and timing. The addition of a fungicide did affect yield or milling quality in these trials. Further research is needed to determine the optimum rate and timing of both plant growth regulators to minimize lodging without reducing yield significantly. The potential of these and other plant growth regulators in overall management of lodging-sensitive rice cultivars, as well as very high yielding cultivars, remains to be determined.

Progress in Developing RNA Markers for Determining Disease Reactions in the Rice Blast System

Jia, Y. and Valent, B.

Hypersensitive cell death as indicated by the presence of autofluorescent materials, and rapid defense gene activations are two significant outcomes in rice plants during their resistant reaction to *M. grisea* infection. A resistant rice cultivar, Katy, and a Sekiguchi like-lesion mimic mutant of Katy (LmmKaty) were used to develop methods to detect the resistant response. Lesion mimic phenotype of LmmKaty was rapidly induced by virulent *M. grisea* isolates or by avirulent *M. grisea* isolates only at higher levels of inoculum. Autofluorescence was visible under ultraviolet light 24 h post-inoculation in the incompatible interaction, whereas, autofluorescence was not evident in the compatible interaction. Autofluorescence was also observed in LmmKaty 20 h post-inoculation, indicating that rapid cell death is a mechanism by which LmmKaty restricts pathogen invasion. Doubled haploid lines, YT14 (containing the *Pi-ta* gene) and YT 16 (lacking the *Pi-ta* gene), were used for disease reactions and northern blot analysis. Plants were grown to the 3-leaf stage and were inoculated with *M. grisea* containing *AVR-Pita* at 5 X 10^6 spores/ml. Rapid accumulations of defense-related (DR) gene transcripts, phenylalanine ammonia lyase and ß-glucanase, were observed beginning at 6 h and were obvious at 16 and 24 h in an incompatible interaction. Rapid transcript accumulation of PR-1 and chitinase had occurred by 24 h post-inoculation in an incompatible interaction. Accumulation of these transcripts was delayed in a compatible interaction. We suggest that the resistance gene in rice may recognize and actively respond to the pathogen 24 h post-inoculation, and DR gene expression is a useful marker for rapid determination of the host reaction to *M. grisea*.

Identification of *Pythium*-Resistant Cold-Tolerant Rice Germplasm through Controlled Environmental and Field Evaluations

Rothrock, C.S., Sealy, R., Lee, F.N., Gibbons, J., and Cartwright, R.D.

Stand problems consistently cause significant production losses and management problems in Arkansas rice fields. *Pythium* species play an important role in stand establishment, especially under cool soil temperatures. Genotypes of rice that have the ability to germinate and grow at colder temperatures than current cultivars, cold-tolerance, have recently been identified as part of the breeding program of Dr. James Gibbons. The objective of this study was to screen 346 genotypes of rice that have been evaluated for cold-tolerance for their level of resistance to *Pythium* seed rot and damping-off. Selected genotypes also were evaluated in the field to confirm their cold-tolerance and *Pythium* resistance and validate the screening procedure.

Growth chamber studies used potting media infested with a virulent *Pythium* isolate at a constant temperature of 15°C. In each growth chamber study, three controls were included: PI560281, cold-tolerant and moderately resistant to *Pythium* spp; Kaybonnet, cold-tolerant but susceptible to *Pythium* spp.; and Lemont, neither cold-tolerant nor resistant to *Pythium* spp. In addition to infested pots, noninfested pots were included to examine seed viability and cold-tolerance of each genotype. For the genotypes screened to date, almost 70% have been screened, all genotypes had some reduction in stand in the presence of *Pythium*. Only 8% of the genotypes screened had stand counts in the inoculated treatment comparable with or better than those of the resistant control, indicating at least moderate resistance. Another 9% of the genotypes tested had stand counts exceeding those of the susceptible and cold-resistant standard but less than those of the resistant control, indicating some degree of resistance to the pathogen. The other 81% of the lines studied had extremely low or no stand counts in the infested treatment, indicating a high degree of susceptibility to this pathogen. A few genotypes evaluated under these conditions had extremely low stand counts in even the noninfested treatments, indicating that they may not possess the ability to reliably germinate and grow at cold temperatures.

Three planting date studies at three locations in Arkansas were conducted in 2005; mid-February, mid-March, and mid-April planting dates at Colt, Keiser, and Stuttgart, AR. Each study includes 42 different genotypes each having the seed treatments 1) not treated or treated with the fungicides, 2) Allegiance (metalaxyl), or 3) Dynasty (azoxystrobin). Each test was a split-plot design with genotype as the main plot and fungicide treatment as the subplot. Analyses of selected sites suggest stand for the untreated seed and the relative stand for the Allegiance/untreated seed treatments support results from the controlled environmental studies, with genotypes designated as cold tolerant and *Pythium*-resistant having the greatest stands for the untreated seed and demonstrating little improvement with the use of selective fungicides.

These studies have identified specific genotypes with cold-tolerance and *Pythium* resistance, holding the promise for more reliable stand establishment for rice under marginal planting environments in the future. From the results, it appears that cold-tolerant genotypes differ in resistance to *Pythium* diseases and that this character will need to be screened separately as cold-tolerant cultivars are developed.

Carolina Foxtail (*Alopecurus carolinianus*): Susceptibility and Suitability as an Alternate Host to the Rice Blast Disease (*Pyricularia grisea*)

Jia, Y., Gealy, D., Lin, M., Wu, L., and Black, H.

Carolina foxtail (*Alopecurus carolinianus*), a common cool-season weed of intermittently flooded soils, was found to host rice blast fungus (*Pyricularia grisea*) in the greenhouse. A collection of Carolina foxtail over 4 years in Arkansas was inoculated with a range of predominant races of rice blast fungus in the United States. Irregular, yellow, and brown lesions without obvious gray centers were observed after each inoculation with *P. grisea* isolates. Differences in these lesions were not observed among foxtail collections over the years. Consistently, these disease-like lesions that were significantly different from a typical blast lesion were evident after the artificial inoculation in the greenhouse. *P. grisea* races that differed in their pathogenicity toward rice cultivars also displayed differences in lesion development on Carolina foxtail. The most virulent isolate on rice cultivars also produced lesions most rapidly on Carolina foxtail. These lesions developed sooner on Carolina foxtail than the most susceptible rice cultivars tested, including the California cultivar, M202. Conversely, *P. grisea* isolates cultured from these lesions in the infected Carolina foxtail also caused typical disease symptoms of blast, indicating that they also were pathogenic toward rice cultivars. Susceptibility and suitability of Carolina foxtail as an alternate host to rice blast disease is discussed.

Factors Influencing Incidence and Spread of Bakanae Disease of Rice (*Fusarium fujikuroi*) in California

Anderson, L.L. and Webster, R.K.

Bakanae was first observed in California in 1999 and, by 2001, could be found in the majority of the rice production areas of the state. While yield losses have been low thus far in California, it is important to understand the factors that influence the incidence and spread of the causal agent *Fusarium fujikuroi*. The threat of significant yield loss from Bakanae, coupled with the rapidity with which it spread throughout the state, have necessitated research for a greater understanding of this disease in California.

The research discussed here investigated the potential of different inoculum sources to cause disease development. The primary goal was to develop a meaningful seed assay for *F. fujikuroi*. Comparing potential seed assays also allowed for an insight into the current prevalence of *F. fujikuroi* in California's rice seed industry. Further, the roles of infested soil, infected crop residue, and alternate disease hosts as potential sources of initial inoculum that could maintain inoculum levels in a seed lot or prohibit obtaining clean seed sources were investigated.

Comparisons were made among three seed assay methods: (1) plating seed on *Fusarium* selective medium, (2) growth of seedlings on germination boards, and (3) grow-out assays in the field, on 198 seed lots from nine different seed sources. Low correlations between the percent infestation observed on plated seed, and Bakanae incidence on germination boards with the amount of disease that developed in a grow-out assay showed that the grow-out assay was the most reliable seed assay method.

Bakanae symptom expression is affected by the concentration of *F. fujikuroi* that seed is exposed to. Lower concentrations of the pathogen yield typical elongation and chlorosis symptoms; increasing concentrations of the pathogen often result in stunting and crown rot symptoms. In comparing assay methods, it was determined that different seed sources produced significantly different amounts of Bakanae disease. Significantly different amounts of disease were also observed among cultivars.

Analysis of potential alternate sources of inoculum indicates that infested seed is not the only source of Bakanae infection in the field. Infested soil and infected crop residue have been shown to be capable of initiating disease, though the amount of time that *F. fujikuroi* can survive in soil or on crop residue is unknown. Early Water Grass, *Echinochloa oryzoides*, and Barnyardgrass, *E. crus-galli*, have both been shown to be susceptible hosts to Bakanae and may also serve as reservoirs of inoculum in the field.

These results show that while obtaining pathogen-free seed is critical in managing Bakanae disease, the potential exists for "clean" seed to become infected in the field from inoculum in soil, crop residue, or alternate weed hosts. Our results also show that a grow-out assay is the best predictor of disease incidence in the field from a given seed lot.

Chemical Ecology and Population Dynamics of the Rice Stink Bug, *Oebalus pugnax* F., and Natural Enemies around Rice Plantings

Singh, N., Johnson, D.T., Bryant, R.J., and Bernhardt, J.L.

Rice stink bug (RSB), *Oebalus pugnax* F. (Hemiptera: Pentatomidae), is one of the most important pests of rice during grain formation in the United States. The RSB punctures rice grains and sucks out its milky contents, resulting in loss of both grain quality and yield. A chemical ecology study was conducted to determine the volatiles induced in grass host panicles after RSB feeding occurred and if limonene, methyl salicylate, or both attract RSB or natural enemies in the field. A comparison was made in the quantity of headspace volatiles released into air by panicles of several RSB grass hosts. Hosts were either healthy or had 20 RSB adults caged and feeding on four panicles for 1, 3, or 5 days (induced volatile production). Grasses used were barnyardgrass (BG), dallis grass (DG), ryegrass, vasey grass, prairie grass (Tall), and rice. Volatiles were collected on a Super Q trap for 8 daylight hours, eluted with 150 µl dichloromethane + 10 µl ethyl caprate (a standard) and a 1 µl sample injected into gas chromatograph/mass spectrometer (GC/MS) to identify and quantify volatiles. Effect of habitat diversity on RSB population density and their movement into rice at six different rice planting sites were also studied. Yellow sticky cards (7 X 12 cm) attached to yellow pyramid traps were baited or unbaited with lures releasing limonene, methyl salicylate, or a combination of both to determine their attractiveness to RSB or other beneficial insect species. Traps and cards were sampled biweekly for RSB, and other insect species. Concurrently, 10 sweeps were made through grass panicles adjacent to each of these traps and insects were placed in zip lock bags for later identification and quantification. The adjacent rice field was also swept to estimate density of RSB.

Limonene and, to a lesser extent, methyl salicylate were the major volatiles induced by RSB feeding on rice and other host grass panicles. Rice and vasey grass panicles produced more host-induced plant volatiles when fed upon by RSB than did other host grasses. Panicles fed upon 3 days had more induced volatile production than did panicles unfed or fed on for 5 days. Fed on panicles were induced to produce significantly more limonene than methyl salicylate. No difference was found in RSB counts from baited and unbaited traps, but some dates had high counts of meloid beetles (350) only in the methyl salicylate baited traps. Rice stink bug counts were more in traps and in grass sweep net samples before and after rice heading period compared with higher sweep counts in rice only during heading. Rice stink bug counts were higher in traps and grass sweeps of areas adjacent to rice fields surrounded by host grasses than in sites with mostly broadleaf plants and/or non-host grasses.

Influence of Age of Rice when Flooded on Rice Water Weevil Infestation and Damage

Bernhardt, J.L.

About 90% of Arkansas rice farmers dry seed rice followed by a delay of variable length before permanent flood is applied. Commonly, the delay is until rice plants reach the 4- to 5-leaf stage at about 25 to 30 days after emergence. The delay can be lengthy (up to 35 to 40 days) if rice is grown on alkaline soils or the delay can be shorter if farmers choose to apply a permanent flood when rice plants are in the tillering or 3- to 4-leaf stage. With the onset of permanent flood, rice water weevil adults are attracted to the field and begin to lay eggs. Previous greenhouse research in 1976 indicated that adults would lay eggs in plants of all ages, but when given a choice of plant ages, the highest larval densities were found in plants 30 to 40 days of age. However, in the field, the impact on rice water weevil infestation and damage is mostly unknown when plants of different ages are present.

In 2001 and 2002, rice plots were planted on three dates. The second and third planting dates were timed after the emergence of plants from the previous planting date. The separation of planting dates gave a 10-day difference in the ages of plants when all plots received permanent flood on the same date. Standard agronomic practices were applied to all plots. Plots were arranged in a randomized block design with four replications. Each plot of rice was 10.8 m^2 and was surrounded by levees. Plots were not treated for any insect and were infested by a natural population of rice water weevils. At 3, 4, and 5 weeks after permanent flood, plots were sampled for rice water weevil larvae. Standard procedures were used to take core samples and for separation of larvae from the soil and plant roots.

Each year of the study, rice with the shortest duration of delayed flood (20 days) had the highest infestation of rice water weevil larvae, the normal duration (30 days) had an intermediate density of larvae, and the longest duration (40 days) had the lowest infestation. These results of older plants with fewer larvae were similar to the study in 1976, but these results of younger plants with more larvae differed from the study in 1976. The plots with the 40-day delay headed 2 to 3 days before the 30-day delay, and the plots with the 20-day delay headed 2 to 3 days after the normal delay. The older plants averaged 43% fewer larvae than the normal delay plants and yielded statistically the same amount of rough rice (20.4 kg less than the normal). The plants with the 20-day delay averaged 43% more larvae than the 30-day delay and yielded statistically less (186 kg less). In 2002, the older plants averaged only 14% fewer larvae than the normal delay plants and yielded statistically the same amount of rough rice (96 kg more than the normal). The plants with the 20-day delay averaged 45% more larvae than the 30-day delay plants and yielded statistically less (122.6 kg less).

The use of delayed flood as a cultural practice to lower the number of rice water weevil larvae was successful and also would reduce the amount of water needed to grow the rice. The delay in application of permanent flood for 10 days did not appear to be detrimental to rough rice yield.

Development of a Preliminary Action Threshold for Use of Adulticidal Insecticides against the Rice Water Weevil in Southwest Louisiana

Stout, M.J., Riggio, M.R., and Geaghan, J.P.

The rice water weevil is the most important early-season insect pest of rice in Louisiana. Yield losses from this insect are caused primarily by feeding of larvae on the roots of young rice plants. This insect is a particularly severe pest in southwestern Louisiana, where its population densities are very high and where widely-used cultural practices (particularly pinpoint flooding) invite severe infestations of young rice. Yield losses from this insect regularly exceed 20% in small-plot experiments at the Louisiana State University Agricultural Center's Rice Research Station.

The rice water weevil was controlled for many years by post-flood applications of the insecticide carbofuran, but the use of carbofuran was disallowed by the EPA in the mid 1990s. The loss of carbofuran was followed by the introduction of several new insecticides into the rice market. These insecticides included Icon (fipronil), Dimilin (diflubenzuron), and several pyrethroid insecticides. Icon is a seed treatment; the remaining insecticides are formulated as liquids and have been used as post-flood foliar sprays in Louisiana. These insecticides have been used successfully against the rice water weevil for the past several years. However, Icon was voluntarily removed from the rice market by its manufacturer in 2005, leaving only the pyrethroids and Dimilin, which is rarely used. There are numerous challenges associated with the use of pyrethroid insecticides for weevil control. One of the most important challenges arises from the fact that these insecticides reduce densities of weevil larvae (the damaging stage) indirectly, by killing adult weevils. Because this is true, there always have been questions about the optimal timing of these insecticides in commercial rice fields. Current recommendations call for applications of insecticides to be made when weevils are present in a field and conditions conducive to egg-laying are also present. This recommendation may result in applications of insecticides when they are not really needed.

Greenhouse, laboratory, and field experiments were conducted to determine the relationship between densities of adult rice water weevil and densities of larval rice water weevils on young rice. These data were used to develop a preliminary action threshold to guide timing of applications of adulticides in commercial rice fields. The assumptions involved in developing this preliminary threshold and data needed to verify and refine it will be discussed. If implemented, a treatment threshold may allow farmers to avoid unnecessary applications of insecticides in rice.

Armyworm Control in California Rice

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

In recent years, two species of armyworm, the western yellow-striped (*Spodoptera praefica*) and true (*Pseudaletia unipuncta*) have become significant pests of rice. As a result of their increased range and incidence, an insecticide application for armyworms is now common in some production areas. Pyrethroids have been the material of choice for larval suppression, and outbreaks tend to occur mid- to late-season. The timing of their use has the potential to upset the "balance" of other organisms in the rice field and may contribute to the loss of natural enemies. It also raises additional concern with mosquito abatement because the same chemical class is used to control mosquitoes and some fear increased rates of resistance may develop. West Nile virus is now well established in California and adds to the need for having good management practices.

We began studies in 2003 to gain a better understanding of the nature and timing of armyworm infestations. Weed control has been the major pest problem facing growers due to resistance and new regulations. Because the western yellow-striped armyworm is reported to only lay eggs on broadleaf weeds, we wanted to look at this relationship. We established plots with 1) few weeds, 2) grassy weeds, 3) broadleaf weeds, and 4) grassy and broadleaf weeds and monitored them throughout the season. Pheromone traps were used to monitor adult populations of both species across the rice production area. This provided insight as to the timing and intensity of flights, as well as population movements or fluctuations. As a general survey, we did weekly timed searches in selected grower fields for larval presence. Individuals we collected were brought back to the lab and reared on artificial diet. We found a significant portion of these to be parasitized. Overall, three different parasites were collected, two hymenopteran and one dipteran.

Thus far, we have been able to show a trend for more armyworms in plots with more weeds, particularly broadleaf weeds. We have also been able to show pheromone traps can be a useful tool for monitoring moth flights and aid in predicting the timing of armyworm larvae in rice fields. Natural enemies of the armyworm, including parasites and microbial organisms, can provide effective control when present and they are common in some fields. We will continue to develop our understanding of all these factors and use them to integrate an effective control strategy.

The South American Rice Miner, *Hydrellia wirthi* Korytkowski: Insect Description and Distribution in Louisiana Rice

Castro, B.A., Mathis, W.N., and Zatwarnicki, T.

The South American rice miner (SARM), *Hydrellia wirthi* Korytkowski, is a new invasive insect pest of rice in the United States. The species was first described from collections in rice fields from Peru and Colombia. It was reported for the first time in the United States from rice fields in Jefferson Davis Parish in Louisiana in 2004. The species was then reported in different rice areas of Louisiana and Texas. The SARM is a shore fly (Diptera: Ephydridae). The only shore-fly species previously known to infest commercial rice in the United States was the smaller rice leaf miner, *Hydrellia griseola* (Fallén).

A field survey for the SARM was conducted in the most important rice producing areas of Louisiana in collaboration with the LSU AgCenter, the Smithsonian Institution, and the USDA/APHIS. The objective of the survey was to determine the distribution of this new invasive species and to assess the severity of infestations in rice fields. Efforts were focused to inspect rice fields from 1 to 6 weeks of emergence. Commercial rice fields in Louisiana were scouted using a standard 15-inch sweep net. Ten sweep passes at five different locations were performed in each field. Fly adults (dipterans) were collected from nets using a mouth aspirator. Suspicious dipterans were preserved in 70% ethyl alcohol and forwarded to the USDA-ARS-Systematic Entomology Laboratory (SEL) identifier for official confirmation to species level. In addition, suspected damaged plants were taken to a laboratory and fly larvae reared until adult emergence. Fly adults and associated parasitoids that emerged in the laboratory were shipped in vials containing 70% ethyl alcohol. A total of 15 different Louisiana parishes were surveyed, which included 1223 hectares (3023 acres) of rice. The following parishes were surveyed in 2005: Vermilion, 260 hectares (642 acres); Acadia, 191 hectares (471 acres); Lafayette, 12 hectares (30 acres); St. Landry, 85 hectares (210 acres); Jefferson Davis, 168 hectares (414 acres), Allen, 103 hectares (254 acres); Calcasieu, 45 hectares (110 acres); St. Martin, 81 hectares (200 acres); Cameron, 81 hectares (200 acres); Evangeline, 12 hectares (30 acres); Avoyelles, 36 hectares (90 acres); Concordia, 133 hectares (328 acres); Tensas, 3 hectares (7 acres); Franklin, 2 hectares (5 acres); and East Carroll, 13 hectares (32 acres). Forty-five vials containing suspicious fly samples (including five vials with emerged parasitoids) were sent to the SEL identifier for identification to species level. The field survey revealed that the SARM is widely distributed in all the important rice producing areas of Louisiana. Higher infestations, i.e. those causing significant yield losses, were observed in coastal parishes, including Acadia, Cameron, Jefferson Davis, and Vermilion. The insect was found at very low levels in other rice areas of central and northeastern Louisiana.

This poster presentation provides important information about the known field biology of the SARM in Louisiana and morphological descriptions of different developmental stages of this insect. In addition, images of different insect stages and field damage are presented. Descriptive drawings of the male terminalia will offer taxonomical differences between this species and other *Hydrellia* spp. known to infest rice plants.

Effect of Late-Season Karate Applications on Populations of Mosquitoes in Experiment Rice Plots

Sanchez-Cuadra, A.M. and Stout, M.J.

Rice fields serve as habitats not only for a number of pest insect species that feed on rice plants but also for a number of species of mosquitoes that use flooded rice fields as larval habitats. Some of these mosquito species are important from both a public health perspective because they can vector diseases such as West Nile Virus and from an economic perspective, because they are nuisances and/or because they vector diseases of veterinary importance. Thus, it is important to understand how important rice fields are as breeding grounds for mosquitoes and to understand how rice production practices impact mosquitoes in rice.

Populations of mosquito larvae in rice fields are low in April and May, when control measures for the rice water weevils are typically taken. High populations of mosquitoes in rice fields do, however, coincide with movement of stink bugs into rice at the heading stage. Thus, management practices for rice stink bugs may affect populations of mosquitoes. The impact of one such management practice, applications of the broad-spectrum pyrethroid insecticide Karate, was assessed in experimental rice plots and fields. Effects of Karate applications were evaluated by sampling natural populations of mosquito larvae in plots using a standard dip-sampling method and by placing lab-reared larvae in plots in cages and evaluating mortality after treatment. Applications of Karate for stink bug control were shown to reduce populations of mosquito larvae in both a small-plot study and a field-scale demonstration. Mosquito larvae placed in water samples taken from Karate-treated plots also suffered higher mortality than larvae placed in water from control (untreated) plots. Residual levels of Karate on foliage were sufficient to kill adult mosquitoes as well. Thus, applications of pyrethroid insecticides for late-season control of stink bugs have the potential to reduce populations of mosquitoes in rice fields.

Genetic Diversity in California Isolates of *Sclerotium oryzae*

Snyder, L.J., Colowit, P.M., and Tai, T.H.

Sclerotium oryzae is the causal agent of stem rot disease in rice, one of the most important rice diseases in California. Resistance to stem rot has been identified in *Oryza rufipogon*, a wild relative of cultivated rice, and this resistance has been introgressed into various long- and short-grain breeding materials in California. However, no varieties with this level of resistance have been released, and the genetic and molecular basis of resistance remains to be determined.

Extensive work on characterizing the biology of *S. oryzae* has been reported in the literature, including the identification of different levels of virulence among isolates. However, genetic diversity as measured at the molecular level has not been assessed. In order to characterize the genetic relationships among *S. oryzae* present in California, we have collected isolates from various locations for analysis using amplified fragment length polymorphism (AFLP) fingerprinting and DNA sequencing.

Our progress in using AFLP and genomic sequence, along with morphological traits and virulence assays to describe the species diversity present in California isolates of *S. oryzae* will be reported. It is anticipated that the information developed here will be useful in our efforts to understand the genetic basis for resistance and to ultimately contribute to the development of stem rot resistant germplasm.

Management of Friendly Weed and Insects to Control Africa's Worst Rice Insect Pest

Nwilene, F.E., Youm, O., Oikeh, S.O., Okhidievbie, O., and Togola, A.

The African rice gall midge (AfRGM), *Orseolia oryzivora* Harris and Gagné (Diptera: Cecidomyiidae), is a major constraint to rainfed and irrigated lowland rice production in Africa. The insect causes severe crop losses during the vegetative stages by feeding on and converting the potential grain-bearing panicle into an 'onion shoot-like gall.' Recent research has shown that managing, rather than destroying, a "friendly weed" offers African farmers free, non-chemical control of the continent's worst rice insect pest. The most common parasitoids associated with AfRGM are the polyembryonic endoparasitoid *Platygaster diplosisae* Risbec (Hymenoptera: Platygasteridae) and the solitary ectoparasitoid *Aprostocetus procerae* Risbec (Hymenoptera: Eulophidae). The parasitoids also attack the Paspalum gall midge, a 'cousin' gall midge, that lives and feeds on the *Paspalum scrobiculatum* weed on- and off-season but does not attack rice. In order to assess if management of Paspalum around the edge of rice fields could favor population build-up of these parasitoids, three gall midge-tolerant varieties, BW 348-1, Cisadane, Leizghung, and a susceptible check variety ITA 306, were evaluated for their effects on gall midge damage. The effect of different Paspalum densities (1, 2, 3, and 4/m^2 and control) was measured at 21, 42, and 63 days after transplanting. The susceptible variety ITA 306 had higher AfRGM damage compared with the other varieties. It was observed that the damage decreased with an increase in Paspalum densities in all the four varieties but was inversely related to the crop growth stage, resulting in slightly higher damage in younger plants (21 DAT) than in older ones (63 DAT). Yield results showed that the varieties differed in their response to Paspalum density. For instance, with Paspalum density of four per m^2 at 63 DAT, there was as much as 414% grain yield gain in Leizhung as compared with 204 and 269% in BW 348-1 and Cisadane, while the increase was lower still at 168% in the susceptible ITA 306. There was a positive correlation between Paspalum density and percent parasitism (r = 0.83). It was shown that a simple intervention to increase the carry-over of parasitoids at maximum Paspalum density gave better control of gall midge damage and higher grain yield than control treatment without Paspalum. Implications of these findings on the management of AfRGM and future research are discussed.

Abstracts of Papers on Processing, Storage, and Quality
Panel Chair: O. Sanford

Effects of Drain and Harvest Dates on Rice Sensory and Physicochemical Properties

Champagne, E.T., Bett-Garber, K.L., Thompson, J.F., Mutters, R., Grimm, C.C., and McClung, A.M.

Timing of field draining and harvesting of rice with meteorological conditions can allow growers to foster conditions for high head rice yield (HRY). The effects of timing of draining and harvesting on rice sensory and physicochemical properties are not well understood. The objective of this study was to determine the effects of varying drain and harvest dates on the sensory and physicochemical properties of M-202 grown in California under controlled field conditions.

A plot at the Rice Research Station in Biggs, California, was divided into three sections that could each be drained separately. The entire plot was planted in 2003 with M-202 medium-grain rice, and each sub-plot was subjected to identical cultural practices. The sub-plots were drained early (September 12), normal (September 18), and late (September 26) and harvested at four dates (September 30, October 6, 13, and 16) beginning when the rice in the early drain section reached 24% moisture content. These dates corresponded to 32, 38, 45, and 48 days after flowering (DAF), respectively, where DAF date is at 50% heading. Each sub-plot was hand-harvested in six to eight locations and threshed with a small plot thresher. Harvest moisture content (HMC) was determined on 200 grains of each sample taken at each harvest location using a single grain moisture meter (Kett). Samples were dried to 13% moisture, milled, and shipped to the USDA, ARS Southern Regional Research Center (New Orleans, LA) for identification of volatile compounds by gas chromatography/mass spectrometry (GC/MS) (Agilent 5973, Walnut Creek, CA) and sensory panel evaluation of flavor and texture using descriptive analysis techniques. Protein, amylose, and rapid visco-analyser (RVA) analyses were conducted on portions of each sample at the USDA ARS Rice Research Unit (Beaumont, TX).

Drain date had a very small, significant ($P < 0.05$) effect on amylose and protein contents, with amylose highest at the late-drain date and protein the lowest at the early-drain date. Breakdown and setback were lowest for early- and normal-drain dates, respectively; however, no significant ($P > 0.05$) differences in texture were measured as a result of these parameters being low. Drain date did not affect the volatile composition or flavor of the rice. Harvest date had no effect ($P > 0.05$) on amylose content and a very small, significant ($P < 0.05$) effect on protein content. Harvesting at the earliest date (9/30) resulted in rice with higher setback and lower breakdown than at last harvest date (10/16), and subsequently, the early harvested rice cooked harder, more cohesive, and absorbed less saliva in the mouth. The differences in texture measured by the panelists, although detectable, were small. The lowest levels of the lipid oxidation products 1-pentanol, hexanal, and nonanal occurred in rice having the lowest harvest moisture content: that harvested on 10/13 and 10/16. Differences in levels of lipid oxidation products and branched chain hydrocarbons did not lead to significant ($P > 0.05$) differences in flavor. In summary, M-202 demonstrated stable composition, physicochemical properties, flavor, and texture across drain and harvest dates.

Association between Rice Grain Quality, Grain Moisture, and Soil Characteristics

Marchesi, C.E, Mutters, R.G., Thompson, J.F., and Plant, R.E.

Head Rice (HR), a measure of grain quality, is an important component of rice profitability. It is defined as the percentage of unbroken whole kernels. The normal proportion of HR from 100% rough rice is about 55%. Genetic, environmental, and management factors can have an influence on HR. Although spatial variability in grain yield in California rice production has been well documented, the variability in HR has not been studied. Rice is commonly harvested at higher moisture content than is appropriate for storage. Rice grain moisture content (GMC) at harvest seems to be related to the final HR; as the GMC increases within an interval from 15 to 25%, HR is observed to increase from almost 40 to more than 65%. Land leveling increases soil variability by removing topsoil from cut areas. Surface soil in the cut areas contains a higher clay fraction (SC) than the fill areas. Stands in these parts of the field tend to be sparser, with smaller plants that mature more quickly. As a result of this difference in maturation rate, plants in these areas tend to not only have lower yields but also lower moisture content at harvest. To the extent that HR is related to GMC at harvest, these portions of the field would display reduced grain quality.

The objectives of this study were: a) to evaluate at a field scale the association between GMC at harvest and the percent of HR; b) to evaluate at a field scale the relationship between soil clay content and GMC and HR percentage; and c) to identify some of the variables that are affecting these associations and establish management options. The study was carried out in 2003-2004, in two fields located in northern California, USA. Varieties used were Kokuho Rose, M202, and M401, all medium grains. Yield map data files (yield and grain moisture) were collected and imported into Arc View (ESRI, Redlands, CA) geographic information system to be analyzed. Outlier corrections were made and interpolation was done using the Inverse Distance Weighting methodology. Prior to or during harvest, grain samples from various parts of each field were taken to measure GMC and HR. Soil samples prior to seeding were taken from the same points in 2004.

Although different in precision and magnitude, GMC obtained with the grain monitor seems to be a good predictor of GMC of samples in the field. The relationship between GMC and HR is positive and significant in 2003, when North wind conditions were present. No association was found in 2004. The pattern the relationship has varies, depending on the range of GMC. SC seems to be negatively related with GMC and also HR, when North wind was present previous harvest and/or GMC is optimum to low. We built a flowchart with the possible interactions between the mentioned parameters that are influencing HR. Based on the data and ideas discussed, under North wind conditions, we can advise growers to harvest areas with high SC first, trying to avoid fissuring after rewetting of rice grains, to reduce the risk to obtain low HR.

Genotype and Environment Effects on the Tocotrienol, Tocopherol, and Gamma-Oryzanol Fractions of an International Rice Germplasm Collection

Bergman, C., Pinson, S., and Chen, M.H.

Rice bran contains many phytochemicals with proposed health benefits and industrial applications. To date, the levels of these fractions from samples grown under controlled conditions have been reported for only a few southern U.S. cultivars. Thus, little is known about how genetics, the environment, or their interactions impact the levels of these compounds in rice germplasm at large. This information is needed to determine the possibilities for manipulating the levels of these fractions using cross breeding techniques. In addition, an understanding of the role genetics versus the environment plays in creating the variation in these phytochemicals' levels is needed to design robust field experiments during the breeding process.

The objectives of this research were to quantify the levels of individual E-vitamers and total gamma-oryzanol in an international germplasm collection and to determine the effects of the environment on their levels. Rice accessions (n = 200) from over 50 countries were selected in an attempt to capture as much genetic diversity as possible within the constraints of the amount of labor available for the grow-out and the requirement that genotypes needed to flower within 120 days of planting to be compatible with the experiment's growing environment. The accessions were obtained primarily from the USDA Germplasm Resources Information Network.

The cultivars were grown during two seasons in Beaumont, Texas, using cultural management practices common for the region. Sample size availability was low; therefore, the accessions were cultivated in single plots, arranged in a completely randomized design. To limit environmental effects, genotypes were planted in blocks designed to synchronize heading times. The effects of planting dates and micro-environment differences across the field were captured by planting a control, Lemont, randomly spaced throughout each block. At maturity, the plants were threshed by hand, the grains were dehulled, and all broken, diseased, and immature kernels were removed. The dehulled kernels were milled, the bran fractions sieved and then stored at -20ºC, under nitrogen, until analysis. Surface lipid content was determined using petroleum ether in a Goldfish extraction apparatus. This measurement was used to ensure that all samples were milled within a similar range in degree of milling (i.e., <0.5% surface lipid content). An enzymatic procedure was used to determine the starch content of the bran. These values were then employed to express the phytochemical data on a zero starch basis. The E-vitamer and gamma-oryzanol contents of the samples were determined using a method previously published by the authors which uses reverse-phase HPLC with UV and florescent detection. All analytical procedures were performed in duplicate.

The phytochemical levels varied significantly due to genetics, year, and planting date. Across the two growing seasons, the accessions varied in E-vitamer content from 0.18 to 0.43 mg/g and in gamma-oryzanol content from 2.9 to 6.5 mg/g. These values are of the same magnitude as previously reported but cannot be directly compared due to the differences in analytical procedures used. The variability for the control's tocotrienol, tocopherol, and total E vitamer contents were greater in Year 2 (RSD 12.9, 27.7, and 18.0%, respectively) compared with Year 1 (RSD 5.2, 7.1, and 5.0%, respectively), thus, indicating the effects of micro-environment and planting date on E-vitamer levels interacts with growing year effects. This was not the case for gamma-oryzanol, as the control's values for this fraction varied to a similar degree in both Year 1 and 2 (RSD 4.85 and 5.6%, respectively). The within laboratory repeatability for the HPLC method used for this study was previously reported to be low for all phytochemical fractions (RSD < 5.3%). Thus, the effects of the environment are much greater on E vitamer levels than gamma-oryzanol content.

The germplasm collection studied contained 47 U.S. accessions. Of these, the long- and medium-grain cultivars with the greatest mean total E vitamer and gamma-oryzanol levels were L-201 and M-201 and A201 and Vista, respectively. Thus, programs interested in developing high yielding U.S. rice cultivars with superior phytochemical levels will need to consider both recent and historical cultivars as breeding parents, depending on their breeding objects.

Effect of Proteins and Surface Lipids on Cooked Rice Firmness and Stickiness

Meullenet, J.F. and Saleh, M.I.

Rice is consumed largely as cooked whole grain, which is produced after de-hulling and milling by respectively removing the hull and bran layers of the rough rice kernel. However, the amount of bran removed varies depending on the milling process. Starch, proteins and lipids have long been reported to influence rice functional properties. For instance, high amylose cultivars are known to be firmer and less sticky than low amylose cultivars. However, rice of similar amylose content can differ in their viscoelastic properties. Recently, proteins and lipids have attracted researchers' attention because changes in these components after harvesting and during storage reflect some of the changes occurring in rice functional properties. Furthermore, most of the research dealing with establishing the role of protein and lipid fractions toward rice functionality has been carried out on rice flour and it is yet unclear if these findings translate for an intact rice kernel. The following studies were aimed at investigating the effect of surface protein disruption, using a proteolytic treatment on milled rice, and the removal of surface lipid, through varying rice-milling durations, on the texture properties of cooked rice.

Proteins disruption study: Wells and Francis rice cultivars harvested at high and low moisture contents in Arkansas and Missouri were used in this study. Rice was fractionated, small and large kernels discarded, and the medium-size fraction was milled to approximately 0.4% surface lipid content (SLC). Twenty grams of head rice was soaked into 100 ml of either, distilled water, 0.03M phosphates buffer (pH=7.4) or 0.03M phosphates buffer (pH=7.4) containing 0.2% protease (*Streptomyces griseus*, Sigma EC 232-909-5) and allowed to soak for 30 minutes at 37^{o}C. Soaked rice was drained and washed before cooking. A water to rice ratio of 2:1, accounting for the amount of water absorbed by the rice during the soaking procedure, was used for rice cooking. Rice was cooked using a miniature precision rice cooker, featuring a heating mantle (TM 102, Glas-Col, Terre Haute, IN) controlled by a temperature controller (89000-10, Eutech Instruments Pte Ltd, Singapore), for 20 minutes at a maximum cooking temperature of 98.5±1°C. The texture attributes of cooked rice were determined by a uniaxial single compression method using a TA-XT2 plus texture analyzer (Texture Technologies, Scarsdale, NY). Ten cooked rice kernels placed on a non-lubricated flat aluminum plate were compressed using a 50-Kg load cell to leave a gap between the two compression plates at the bottom of the compression cycle of 0.3 mm. The crosshead was also stopped for 5 seconds at its maximum travel distance before returning to an anvil separation of 20 mm. The crosshead speed of the texture analyzer was set at 10 mm/s. Texture attributes were obtained using the texture exponent software (Stable Microsystems, version 1,0,0,92 (2000) Surrey, England). The maximum compression force (N) was used as an indicator of cooked rice firmness while the adhesion energy (i.e. area under the curve, N. sec) measured during the upward travel of the compression plate was used as the indicator for cooked rice stickiness. Each rice sample from each cultivar, harvest moisture content, and soaking treatment was cooked in duplicate and six measurements were conducted for each cook. Cooked rice moisture content was determined in triplicate using a conventional oven.

Surface lipids content removal study: similar cultivars were used as in the proteins disruption study. Rice was milled to 0.2, 0.3, 0.4, 0.5, and 0.6% SLC. The rice was cooked using a 2:1 water to rice ratios in the miniature precision rice cooker previously described.

Proteins are believed to provide structural integrity to rice kernels, restricting starch granule swelling while lipids may impede hydration during cooking. Proteolytic treatment, as well as increased milling, resulted in a significant ($P<0.05$) reduction in milled rice proteins and SLC (i.e. due to milling and washing of soaked rice). This caused an increase in cooked rice moisture uptake during cooking either because of the greater availability of water to interact with starch. The increase in cooked rice moisture content resulted in softer and stickier rice after cooking. Furthermore, samples milled to low SLC were significantly ($P<0.05$) softer and sticker than those milled to higher SLC. This was attributed to the alteration in rice water uptake kinetics during cooking. Greater solubility and leaching of the starch, in the absence of proteins and lipids, during cooking is thought to play a key role in the significant ($P<0.05$) increase in cooked rice stickiness.

Changes in Protein and Starch Conformation during Variable Temperature Parboiling of Rice: FT-Raman and ^{13}C CP-MAS NMR Spectroscopic Assessment

Himmelsbach, D.S., Manful, J.T., and Coker, R.D.

FT-Raman and solid-state ^{13}C CP-MAS NMR spectroscopies were employed to assess the conformational changes to protein and starch in paddy rice under artisanal conditions used for the parboiling with TOX 3108 rice from Ghana. The results of these treatments were compared with the raw rice and a commercial parboiled rice product. Viscometry via RVA showed lower pasting curves with increased temperature and steaming times as expected. Principal component analysis (PCA) of the FT-Raman spectral data indicated that soaking at 70^{o}C or above was necessary to generate parboiled rice similar to the fully parboiled commercial product. Analysis of the Amide I region from the Raman spectra indicated conversion of the protein from α-helix to β-sheet and β–turn conformations upon parboiling with as little as 4 min of steaming. Solid-state ^{13}C NMR spectroscopy indicated that starch did not become as gelatinized with 90^{o}C soaking and 12 min of steaming as it did with the high-temperature/pressure treatment utilized in the commercial parboiling process.

Susceptibility of Long-, Short-, and Medium-Grain Rice to the Lesser Grain Borer, *Rhyzopertha dominica* (F.)

Arthur, F.H., Chanbang, Y., and Wilde, G.E.

Physical properties of the rough rice hull and chemical characteristics of the kernel may confer resistance to the lesser grain borer, *Rhyzopertha dominica* (F.) and other stored grain insects. In this study, 28 varieties of commercial rough rice, 10 long-, 11 medium-, and 7 short-grain varieties, were assessed for resistance by introducing neonate lesser grain borer larvae on each variety and determining the median development time, the number of emerged adults, and progeny production from those emerged adults. The percentage of solid or intact hulls, split and cracked hulls, and hull thickness was also determined for each variety.

There were no general differences among rice types (long, medium, or short grains); however, two distinct groups of varieties were identified as being either resistant or susceptible to the lesser grain borer. Wells, Jupiter, Pirogue, and Bengal varieties were considered resistant, with low adult emergence, progeny production, and susceptibility indices. Similarly, varieties Rico, Francis, Jefferson, and Delmati were considered susceptible with a high proportion of emerged adults and significantly more progeny production compared with the resistant group. The Dobie indices for progeny production for Wells, Jupiter, Pirogue, and Bengal varieties were 1.1 ± 0.6, 1.2 ± 0.4, 1.5 ± 0.2, and 1.6 ± 0.3, respectively, in contrast to indices of 3.8 ± 2.1, 3.8 ± 0.2, 3.7 ± 0.2, and 3.7 ± 0.2 in Rico, Francis, Jefferson, and Dellmati varieties, respectively. The percentage of solid or intact hulls in the four resistant varieties ranged from 88.2 ± 1.1 to 91.6 ± 1.2%, while the range for the four susceptible varieties was 61.4 ± 1.0 to 76.5 ±%. In addition, the hulls of the resistant varieties were thicker than the hulls of the susceptible varieties, as determined by measurements taken at four selected points.

Our results indicate that the individual varietal characteristics of hull soundness and integrity may be important factors in conferring resistance to the lesser grain borer. However, external factors such as differences in location and growing conditions, along with variation in drying practices, may also affect the condition of the rough rice hull in individual rice varieties.

Milling Characteristics of Rice Cultivars and Hybrids

Siebenmorgen, T.J., Matsler, A.L., and Earp, C.F.

Many rice cultivars and hybrids have unique physical characteristics that affect milling performance. The purpose of this study was to quantify the rate of bran removal during milling for several rice cultivars and hybrids common to the southern United States and compare the quantity of lipids remaining on the kernel surface to that located throughout the kernel. This was accomplished by analyzing two sample sets. The first comprised cultivars Cocodrie, Cypress, and Lemont and hybrids XL7 and XL8 were milled for 0 (brown rice), 20, 30, 40, 50, 60, and 70 sec in a laboratory mill. In the second set, cultivars Cocodrie, Cypress, and Wells and hybrids XL7 and XL8 were milled for 0, 20, 40, and 60 sec. The surface lipid content (SLC) and color of milled head rice samples were measured as indications of the degree of milling (DOM). The total lipid content (TLC) of ground head rice was also measured to determine the total amount of lipids present throughout the entire kernel. Results showed that at a given milling duration, SLC and color varied across cultivars and hybrids. In particular, the SLCs of hybrids were lower than those of cultivars, particularly for Cocodrie, for all milling durations. This research indicated that it may be necessary to mill different cultivars and hybrids for varying durations to attain comparable DOMs. Milling to a consistent DOM is necessary to ensure equitable head rice yield comparisons across cultivars and hybrids.

Milling Quality Trends with Harvest Moisture Content and the Relationship to Individual Kernel Moisture Content Distribution

Bautista, R.C. and Siebenmorgen, T.J.

This study investigated the individual kernel moisture content (MC) distribution effects on rice milling quality, specifically head rice yield (HRY). Rice varieties Bengal, Cypress, and Drew were harvested from two locations in Arkansas in 1999 and 2000 at various harvest moisture contents (HMCs). HRYs for a given variety and location were found to be related to the percentages of kernels in a sample having less than 14% MC and the percentage of kernels greater than 22% MC. As the percentage of kernels with MC <14% increased, the propensity for moisture adsorption fissuring increased whereas breakage due to the presence of immature kernels increased as the percentage of kernels >22% increased; both situations result in decreased HRY. Generally, the HMC at which HRY was maximum corresponded to the HMC at which both of these percentages were minimized.

Effectiveness of Infrared Radiation for Rough Rice Disinfestations

Pan, Z., Gebreil, R., Lewis, R., Godfrey, L.D., Thompson, J.F., and Salim, A.

The ultimate goal of this research was to develop a rapid, non-chemical, safe alternative method using infrared heating to eliminate insect pests from storaged rough rice. The alternative is needed to replace the planned decommissioning of currently registered pesticides. The objective of this project was to study the effectiveness of infrared heating for disinfestations. The storage rice, medium grain (M202), with moisture content of 11.0% was used for the study. Each 250-g rice sample was infested with 100 adult lesser grain borers, *Rhizopertha dominica*, and 50 adult angoumois grain moths, *Sitotroga cerealella,* at 18 and 6 days before the thermal treatment to produce larvae and eggs of the insects in the sample. The infested rice samples were heated as single-layer bed using a catalytic infrared emitter with the radiation intensity of 5300 W/m^2 and five exposure times from 10 to 30 s. The final temperatures of heated rice were in the range of 46°C to 67°C. After heating, the samples were held at the heated temperature for various times, up to 3 h, and then cooled gradually to a room temperature. The moisture losses of the rice samples caused by the heating were calculated based on the weight losses. The heat treated samples were then stored at 27°C, 60% RH, and continuous darkness for 38 days to observe the effectiveness of disinfestations. It has been found that lesser grain borers were more heat resistant than angoumois grain moths. The recommended minimum disinfestations temperature was 60°C, which caused the reductions of 0.6 percentage points in total rice yield and 0.3 percentage points in head rice yield for the rice samples with 3 h tempering. The treatment also caused 0.53% moisture loss.

Prediction of Rice Surface Lipids and Color by Diode Array Near-Infrared Spectroscopy

Meullenet, J.F., Roques, E., Siebenmorgen, T.J., and Couch, A.

Degree of milling (DOM) is a measure of the extent to which rice bran has been removed from brown rice during milling. Visual examination is the current standard method used by GIPSA to determine DOM and is also a common practice in the milling industry. Even with standard line samples, this method is relatively subjective, inherently incorporating both color and level of oil remaining on kernels; there is a need for reliable instrumental methods capable of predicting milled rice DOM and/or grade.

Near-infrared spectroscopy (NIR) is an analytical technique that has been used for the past 20 years to quantify the level of various cereal grain constituents, including moisture, protein, and oil. With regard to rice, NIR has been used to predict apparent amylose, protein, and surface lipid contents. Although the technology has shown success for predicting surface oil content in rice, it has not been used in an attempt to assess rice color.

Consequently, the objective of this project was to develop NIR-based calibrations to predict SLC in multiple cultivars, harvested in multiple locations across two harvest seasons, and to assess the potential of NIR to predict milled rice color.

The database of rice samples used in the experiments were from milling experiments conducted in 2004 and 2005 from samples harvested from the 2003 and 2004 rice crops. A total of 960 samples were used. From the 2003 harvest, four cultivars (CF-XL8, Cocodrie, Francis, and Wells) grown in four locations (Davidson, AR; Essex, MO; Lodge Corner, AR; and Riggs AR) were sampled. The samples harvested in 2004 consisted of five cultivars (Cocodrie, Wells, XP723, Bengal and XP716) grown in five locations (Essex, MO; Hazen, AR; Jonesboro, AR; Lodge Corner, AR; and Newport, AR). The samples were harvested at approximately 18% moisture content (MC) and dried to approximately 12%. They were cleaned, placed in sealed buckets, and stored at room temperature. Sub-samples were evaluated 0, 1, 2, 3, 6, 9, 12, 18, and 24 months. On each sampling date, duplicate 150-g samples were milled for 0, 10, 20, 40, and 60 seconds from each harvest location/cultivar combination using a McGill #2 laboratory mill. After milling, samples were assessed for surface lipids using a Soxtec system (Avanti 2055, Foss North America, Inc., Eden Prairie MN) while kernel color was assessed using a color meter (Colorflex, Hunterlab, Reston, VA). The instrument used for NIR scanning was a Near Infrared Reflectance instrument (Diode Array 7200, PERTEN Instruments, Springfield, IL). It is a designed for analysis of various types of grains and feed products. Reflectance was measured in the range of 900 to 1700 nm in 2-nm intervals. Samples were held in a spinning sample cup while the NIR spectrum was collected. Two scans per samples were collected.

NIR, color, and lipid content data were processed using the multivariate regression software Unscrambler (Version 8.1, Camo, AS, Norway). The spectral NIR data and its first and second derivatives were used to predict SLC and color using Partial Least Squares (PLS-I) and the Jack-knife optimization options of Unscrambler. The first and second derivatives were obtained using the Savitzky Golay algorithm.

Results indicated that the prediction of both SLC and rice color, especially lightness (L), was possible across cultivar, harvest location, and harvest year. SLC ranged from 0.102 to 1.379% across samples. The correlation between observed and NIR predicted values was high (R=0.972) and the average error of prediction relatively low (RMSEP=0.064). When the sample set was limited to samples with SLC contents ranging from 0.2 to 0.9 (n=755), the average error of prediction decreased to 0.052 which is similar to previously reported prediction errors. For L, data ranged from 59.78 to 77.64 and the predictive models were also satisfactory. The correlation between observed and NIR predicted L values was 0.968 and the prediction error low (RMSEP=0.892). When samples in the range of 0.2 to 0.9% SLC were included in the predictive model of L, the average error of prediction decreased to 0.629.

This established the potential of NIR for the prediction of rice surface lipids and color. Further research should concentrate on further assessing the technology by determining the role sample moisture content on NIR spectra and on the establishment of a NIR based grading system.

Diatomaceous Earth Plus Methoprene for Control of the Lesser Grain Borer, *Rhyzopertha dominica*, in Rough Rice

Arthur, F.H., Chanbang, Y., and Wilde, G.E.

The lesser grain borer, *Rhyzopertha dominica* (F.), is a major insect pest of all stored grains, including rough rice. Females lay eggs outside the kernels, and the newly hateched neonate larvae bore into the kernels and develop within the kernel until they reach the adult stage. Diatomaceous earth (DE), a natural inert dust, and methoprene, an insect growth regulator (IGR), are two insecticides registered for direct application on stored rough rice. However, DE may not give complete control of the lesser grain borer, and IGRs, such as methoprene, normally do not cause adult mortality.

In this study, DE at 0, 125, 250, 375, and 500 ppm was combined with methoprene at 0, 0.25, 0.50, 0.75, and 1 ppm (25 treatment combinations) and applied to varieties Cocodrie, M-205, and S-102 (long-, short-, and medium-grain rice, respectively). Mortality of adult lesser grain borers was assessed after 2 weeks of exposure at 32°C and 75% relative humidity on each of the 25 combinations. The parental adults were discarded and the rice was then held for an additional 8 weeks at the same conditions to collect F_1 progeny adults. With DE alone, adult mortality did not exceed 20% even at the highest concentration of 500 ppm and there was extensive progeny production in all treatments. Mortality was greater in the Cocodrie and M-205 varieties than in the S-102 variety, but progeny was greater in Cocodrie, S-102, and M-205. The inclusion of methoprene was highly effective, and progeny suppression was 99 to 100% at any concentration.

Results indicate that DE alone may not control the lesser grain borer on rough rice, but the addition of even a small amount of methoprene will suppress progeny production and help ensure protection of rough rice during storage.

Annealing Properties of Rice Starch

Shih, F., King, J., Daigle, K., and An, H.J.

Thermal properties of starch can be modified by annealing, i.e. a treatment in excessive amounts of water at temperatures below the gelatinization temperature. This treatment is known to improve the crystalline properties, displaying an increase in the gelatinization temperature and a narrowing of the gelatinization temperature range. It can be considered as a useful tool to gain a better control of the functional properties of the starch and its interactions with other components in complex food systems. Furthermore, in the common processing of rice starch, conditions often fall into the range of the annealing treatment. Therefore, it is desirable to study the effect of annealing on the structural and functional properties of rice starch. In this study, rice starch of various cultivars will be treated under various annealing temperature conditions. The modified products will be analyzed by Rapid-Visco Analysis (RVA), Differential Scanning Colorimetry (DSC), and other pertinent instruments. Essentially, annealing improved the pasting and gelling properties of rice starch by generally increasing its viscosity peak height and reducing peak width or gelatinizaion temperature range. The complication in the alteration in the crystallites of the starch granules will also be discussed.

Starch Fine Structure and Physicochemical Properties of Specialty Rice Varieties for Canning

Patindol, J., Gonzalez, C., and Wang, Y.J.

Bolivar, Cheniere, Dixiebelle, and L-205 are long-grain, high-amylose rice cultivars used primarily for canning. These specialty rices have similar gross chemical composition but showed differences in canning, pasting, and gelatinization properties. Starch fine structure analyses were conducted to rationalize observed differences in functionality. Cheniere amylopectin had the lowest weight-average molecular weight (M_w), shortest average chain length (CL), smallest z-average radius of gyration (R_z), lowest proportion of long chains (DP37-65), and highest polydispersity; while its amylose had the largest M_w and R_z. These structural features were associated with more leached solids in the canning broth, lower volume expansion, lower peak and final viscosity, and lower gelatinization temperature and enthalpy. Bolivar amylopectin had the largest M_w, longest average CL, largest R_z, highest proportion of long chains (DP25-65), and lowest proportion of short chains (DP6-12); while its amylose had the smallest M_w and lowest polydispersity. These structures were associated with lesser leached solids, higher volume expansion, and higher peak and final viscosity. L-205 was similar to Bolivar in most structural and functional properties; those of Dixiebelle were either comparable with Bolivar or intermediate of Bolivar and Cheniere. Amylopectin molecular size and long chains are crucial to the leaching and canning stability of rice.

Thermal Properties of Rice Flour

Mahapatra, A.K. and Lan, Y.

Determination of thermal properties of food materials is very useful not only to quantifying thermal processes but also for designing of various processing systems. Though thermal properties of rough rice have been studied by several researchers, rice flour thermal properties have not been extensively studied. With the increasing quantity and variety of rice flours being produced by food industries, there is a need for information about their thermal properties. The objective of this work is to measure some of the thermal properties of rice flours.

The thermal conductivity and thermal diffusivity of four kinds of rice flours and one type of rice protein were measured using the KD2 Thermal Properties Analyzer (Decagon Devices, Inc., Pullman, WA). The probe length was 60 mm and its diameter was 0.9 mm. This analyzer gives direct readings of thermal conductivity and thermal diffusivity. Five minutes gap was provided between each reading. The probe was calibrated in glycerol ($C_3H_8O_3$) at room temperature. The brand names of the rice flour samples used in this study were RF-M01080-12 (California medium-grain rice), RF-W01080-12 (specialty rice), RF-L00080-12 (all three from Sage V Foods, Freeport, TX), and King Arthur Flour (Baker's Catalogue, White River Junction, VT). The brand name of the rice protein was Brown Rice Protein (MLO Products Inc., Fairfield, CA).

The initial moisture contents and bulk densities were measured for all the samples. The samples were conditioned to different moisture contents by drying or rewetting them. In case of rice flours, thermal conductivity and thermal diffusivity were determined at four levels of temperatures between 4.8 and 36.8°C, at seven levels of moisture contents between 4.8 and 16.7% (w.b), and at four levels of bulk densities between 602.6 and 875.8 kg m^{-3}. For rice protein, thermal conductivity and thermal diffusivity were determined at temperatures between 5.4 and 36.5°C, moisture contents 2.6 and 15.7%, and at bulk densities 535 and 702.3 kg m^{-3}. All measurements were carried out in three replicates.

It was found that thermal conductivity increased with increasing temperature. In case of rice flours, thermal conductivity increased from 0.045 W m^{-1} K^{-1} at 5.2°C to 0.083 W m^{-1} K^{-1} at 36.6°C. For rice protein, thermal conductivity increased from 0.05 W m^{-1} K^{-1} at 5.4°C to 0.064 W m^{-1} K^{-1} at 36.5°C.

The thermal conductivity values were found to increase with bulk density. The values increased from 0.066 W m^{-1} K^{-1} at 657.7 kg m^{-3} to 0.124 W m^{-1} K^{-1} at 837 kg m^{-3} for rice flours. In case of rice protein, thermal conductivity increased from 0.057 W m^{-1} K^{-1} at 535 kg m^{-3} bulk density to 0.085 W m^{-1} K^{-1} at 702.3 kg m^{-3}.

Thermal conductivity increased from 0.057 W m^{-1} K^{-1} at 5% to 0.073 W m^{-1} K^{-1} at 16.7% moisture content in case of rice flours. For rice protein, thermal conductivity increased from 0.054 W m^{-1} K^{-1} at 2.6% moisture content to 0.066 W m^{-1} K^{-1} at 15.7% moisture content.

However, the thermal diffusivity found to decrease with increase in temperature. In case of rice flours, thermal diffusivity decreased from 0.138 mm^2 s^{-1} at 5.2°C to 0.103 mm^2 s^{-1} at 36.8°C. For rice protein, thermal diffusivity decreased from 0.132 mm^2 s^{-1} at 5.4°C to 0.119 mm^2 s^{-1} at 36.5°C.

Similarly, thermal diffusivity decreased with bulk density. In case of rice flours, it decreased from 0.113 mm^2 s^{-1} at 662 kg m^{-3} to 0.094 mm^2 s^{-1} at 875.8 kg m^{-3}. In case of rice protein, thermal diffusivity decreased from 0.132 mm^2 s^{-1} at 535 kg m^{-3} to 0.103 mm^2 s^{-1} at 702.3 kg m^{-3}.

It was observed that thermal diffusivity values decreased with moisture content as well. For rice flours, they decreased from 0.122 mm^2 s^{-1} at 5.2% to 0.106 mm^2 s^{-1} at 16.7% moisture content. In case of rice protein, thermal diffusivity decreased from 0.129 mm^2 s^{-1} at 2.6% to 0.119 mm^2 s^{-1} at 15.7% moisture content.

Activities of Enzymes Related to Starch Synthesis and Functionality in Selected Rice Lines

Bryant, R.B. and Counce, P.A.

Rice cultivars vary in their functionality from one year to another and from one location to another. Reasons for this variability have more often been speculated about than tested. Very little is known about the role the starch synthesizing enzymes play in influencing the processing quality of rice. Therefore, we sought to study five enzymes that are integral to the production of starch by conducting a 2-year study in Stuttgart, Arkansas. In that experiment, five U.S. long-grain rice cultivars (Cocodrie, Cypress, Francis, Lemont, and Wells), three Chinese indicas (Zhe 733, Guichao, and Oiguizao), and two F_{12} lines derived from a cross of Guichao and Lemont (LG 13A and LG 13B) were grown in 2004 and 2005 in field experiments with randomized complete block designs at the University of Arkansas Rice Research and Extension Center in Stuttgart, AR.

Twelve or more panicles between the R6 and R7 growth stages were collected, immediately placed on ice, and stored at -80°C. Crude protein extracts were obtained from R6 rice seeds from each plot with hulls (lemma and palea) and aleurone layer removed. These seeds were then ground frozen and homogenized in buffer. Protein extracts were assayed for sucrose synthase (SS), uridine diphosphoglucose pyrophosphorylase (UGP), starch branching enzyme (SBE), and soluble starch synthase (SSS). Apparent amylose content (AAC), RVU, and DSC were determined on the mature seeds after dehulling, milling, and grinding each sample. Head rice yield was also determined.

Cypress had highest head rice yield (70%) and LG 13B had the lowest (46%). The variation in AAC of the U.S. long grains ranged from 0.7% for Lemont to 4.1% for Cocodrie. For the indicas, the AAC variation ranged from 2.0% for Qiguizao and Guichao to 3.0% for ZHE 733. The crosses, LG 13A and 13B, had a variation range of 1.8% and 2.0%, respectively. For DSC, the ranges of T_o, T_p, and T_c for the U.S. long grains were 67.3°C to 68.5°C, 77.4°C to 77.7°C, and 90.3°C to 92.5°C, respectively. Except for ZHE 733, the T_o, T_p and T_c ranges for the indicas and the crosses were 59.3°C to 61.8°C, 68.7°C to 71.4°C, and 84.8°C to 88.5°C, respectively. ZHE 733 had T_o, T_p and T_c values of 69.3°C, 79.1°C and 92.8°C, respectively. Cocodrie had the lowest peak viscosity (181 RVU), Francis had the highest (242 RVU), and all the indicas had a higher final viscosity of >340 RVU.

In 2004, Zhe 733 and Guichao had the highest SS activity at 39 mU/grain each. The crosses, LG 13A and 13B, had the lowest at 21 and 17 mU/grain, respectively. The U.S. long grains, except Francis, had the highest UGPase activity, whereas the indicas and the crosses, except Guichao, had the lowest. Except for Lemont, the U.S. long grains had significantly higher SBE activity than both the indicas and the crosses. Lemont and Guichao had the highest SSS activity at 4.7 and 4.2 mU/grain, respectively, and Cypress had the highest SBE, 22 mU/grain.

It has been shown that the synthesis of amylose lags behind that of amylopectin and that SSS has a 10X greater affinity for ADP-glucose. This means that if ADP-glucose is limited, either by the production (low SS activity) of or increase use (high SSS activity) of ADP-glucose, then the amount of AAC will be affected and AAC has been shown to greatly affect processing quality.

Nitrogen Nutrition Affects Protein Content and Lots More of the Rice Grain

Fitzgerald, M., Martin, M., and Resurreccion, A.

Increasing the rate of nitrogen (N) nutrition applied to cereals increases the protein content of the grains. In rice, higher protein affects the physical quality of the rice, the cooking and eating quality of the rice, and the nutritional quality also. Some countries even breed for low protein to maximize the quality of rice. A direct effect of higher protein in the grain is a concomitant decrease in the starch content. The aim of this work is to determine the impact on starch content, composition, structure, and synthesis from differences in the N nutrition applied. Nine varieties were chosen, three of high amylose, three of low amylose, and three of intermediate amylose. N was applied at two rates, low and high. Protein content of the endosperm was about 7% for all the low N treatments, and for the high N treatments, protein content ranged from 12 to 17%. By increasing the sink strength of protein for carbon (C), the C was diverted from amylopectin in the low amylose rices, but was diverted from amylopectin and amylose in the intermediate and high amylose varieties suggesting (i) that protein is a more dominant sink than starch and (ii) that a threshold for amylopectin content is reached more quickly in high amylose rices, causing C to be diverted from amylose. Expression of a number of the enzymes of starch synthesis was also affected by high N, perhaps in response to the diversion of C from starch. The structure of the amylose and the amylopectin was also altered. Thus, increasing rates of N nutrition do not just affect the protein content of the grain but have dramatic impacts on starch synthesis and structure, which carry on to alter the functional properties of the rice.

Enzyme Responses to Nighttime Air Temperatures during Rice Kernel Development

Counce, P.A., Siebenmorgen, T.J., and Cooper, N.T.W.

High night temperatures have been shown to lower head rice yields. A study was conducted to more fully understand the underlying reasons for this. Kernel physicochemical properties largely determine rice quality and functional properties. Starch is formed in the grain-filling process that begins with sucrose and ends with the finished starch granule. There are seven enzyme steps in the pathway from sucrose to starch. These enzymes are affected by environmental conditions during grain filling. Soluble starch synthase (SSS) is partially deactivated at high temperatures in wheat and maize; the objective of this study was to determine if this was true in rice.

A controlled temperature experiment was conducted at RiceTec, Inc. facilities at Alvin, Texas. Rice plants were grown in a greenhouse until the R5 stage of development (at least one caryopsis on the main stem panicle expanding within the hull). At that point (R5), plants were matched by size and stage of development, assigned to one of four phytotrons with each phytotron set at a different nighttime temperature treatment, and further randomly assigned to a location within each of four beds in each phytotron. Plants were then moved into the phytotrons. The treatments were night temperatures of 18, 22, 26, and 30ºC. The cultivars were Cypress, LaGrue, Bengal, M204, XL8, and XP710. Panicles were sampled between the R6 and R7 growth stages for the plant in such a way as to maximize the number of individual kernels at the active filling stage of development (R6 - expanded caryopsis to the tip of the hull). Three panicles per replication were placed on ice and stored at -80ºC. Afterwards, the individual R6 kernels were removed from the panicle, dehulled, and had the aleurone layer removed. These kernels were ground in liquid nitrogen, extracted with buffer, centrifuged, and the supernatants were assayed for the enzymes. Five enzymes were assayed: sucrose synthase, UDP-glucose pyrophosphorylase, starch synthase, starch branching enzyme, and starch debranching enzyme.

Significant responses to night temperature and cultivar were found for four of the enzymes but the most dramatic responses were for SSS. The SSS activities were significantly affected by temperature and cultivar and by a cultivar by temperature interactions. The enzyme activity response to nighttime temperature can be characterized as (1) an expected temperature optimum for enzyme activity for LaGrue, Cypress, and M204 at 22ºC; (2) an optimum response to temperature for Bengal at 26ºC; and (3) little change between 18 and 22ºC for XL8 and XP710 and a decrease as night temperatures increased between 22 and 30ºC. Others have found similar quadratic responses for maize and wheat to those we found for LaGrue, Cypress, M204, and Bengal. The SSS builds the amylopectin molecules glucose unit by glucose unit. This enzyme has been reported to have a lower temperature optimum than other enzymes in the grain filling process. The significant temperature by variety interaction is promising for development of varieties that are insensitive to high night temperature stress. Of particular interest in this regard is the higher temperature optimum for Bengal relative to the other cultivars. The responses of the hybrids were also noteworthy, in that both XL8 and XP710 responded to night temperature differently from the other cultivars in the test. It would appear that selection for improved rice yield and quality could result from effectively manipulating SSS in the rice grain.

Explaining Head Rice Yield Variation Using Interpolative Historical Weather Data Analysis

Cooper, N.T.W., Siebenmorgen, T.J., Counce, P.A., and Meullenet, J.F.

Rice yield and quality, specifically head rice yield (HRY), can vary inexplicably from one lot to another and from year to year. In an effort to correlate high and low growth temperatures to observed HRY, interpolation techniques were applied to a set of 17-year historical data that included HRY and days to 50% heading for two long-grain rice cultivars, Newbonnet and Lemont, as well as area weather data. HRY was most strongly affected by the average daily low temperature (or nighttime temperature) during the late stages of kernel development for both cultivars. High nighttime temperatures during this period caused a decrease in HRY. When used as a single variable in the model, the nighttime temperature at this stage of rice development explained over 25% of the variation in HRY.

Chemical Reaction Kinetics Approach to Model Moisture Adsorption of Rough Rice

Jat, P. and Osborn, G.S.

Field rice fissuring is one of the leading causes of reduction of whole-grain milling yield. Prior to harvest, formation of small cracks in the starchy endosperm of rice seed is called field fissuring. Fissures reduce the mechanical strength of endosperm, and such fissured kernels are more susceptible to breakage during milling. According to USDA Economic Research Service Data, broken rice has a market value of approximately one half of whole grain rice.

The rate at which moisture enters and moves into the rice grain (diffusivity) plays a major role in fissure response of rice endosperm. The goal of this research is to develop a simulation tool capable of predicting the moisture adsorption rate for given adsorptive environmental condition. Model development was used as an analogy with “chemical reaction kinetics,” linking the model coefficients to the process parameters. The problem is the one of the considerable interest and practical significance as the model will help to understand the moisture transport properties of rice endosperm. Moisture transfer properties of endosperm of the rice kernel can help for better understanding of key mechanism of fissuring. Experimental adsorption rate data were fitted to a kinetic model for Saber and Earl rice varieties. Predicted and experimental data are found in good agreement.

Relating Rough Rice Moisture Content Removal and Tempering Duration to Head Rice Yield Reduction

Schluterman, D.A. and Siebenmorgen, T.J.

Previous research has indicated that while drying rough rice using air temperatures above the glass transition temperature (Tg), kernels will fissure if a sufficient portion of the kernel surface transitions to a glassy state while the interior remains in the rubbery state; a condition that can result due to intrakernel moisture content (MC) gradients created by drying. State transitions can occur by such extended drying using high-temperature air or when kernels are cooled below Tg immediately after drying and before sufficient tempering has occurred. The objectives of this experiment were to determine the maximum amount of MC that could be removed per initial drying pass and the associated tempering durations required, without incurring head rice yield (HRY) reduction. Two long-grain cultivars, Francis and Wells, at two harvest MCs (HMCs) were used. Samples were dried with air at either 60°C/17% RH or 50°C/28% RH for various durations to create a range of intrakernel MC gradients and were subsequently tempered at the drying air temperature in sealed bags for durations ranging from 0 to 160 min. After tempering, samples were cooled to cause a state transition and then slowly dried to 12.2% MC. Samples were then milled to determine HRY. Control samples were dried at 21°C/60% RH. Results showed that the amount of moisture that could be removed in the initial drying pass was directly related to the HMC and the drying air condition. The tempering duration required to prevent HRY reductions increased with the amount of MC removed in a drying pass. The HRY reduction patterns concurred with a hypothesis that explains fissure formation during the drying process based on rice kernel property changes associated with the glass transition temperature.

Possibility of the Development of High Protein Rice with Acceptable Grain Quality for West African People in Interspecific Breeding Between *Oryza sativa* and *O. glaberrima*

Futakuchi, K., Watanabe, H., and Jones, M.P.

African rice (*Oryza glaberrima* Steud.), which was domesticated in West Africa more than 3,500 years ago, is the other cultivated *Oryza* species other than Asian rice (*O. sativa* L.). Since the yield level of *O. glaberrima* was lower than that of *O. sativa* in general due to grain shattering and lodging, its cultivation area has been decreasing. However, many *O. glaberrima* lines have resistance to biotic and abiotic stresses in West Africa and are important genetic resources to develop rice suitable to resource poor farmers in West Africa. To combine the resistance of *O. glaberrima* to indigenous stresses in West Africa and the characteristics of *O. sativa* associated with high yielding, interspecific progenies of the two species were developed by WARDA. Although high protein content was not included in the initial selection criteria of the interspecific breeding, a number of interspecific progenies had been tested prior to this experiment in relation to protein content of milled rice since another asset of *O. glaberrima* was high protein content compared with *O. sativa*. In that trial, the *O. glaberrima* parent (CG 14) of the interspecifics showed the same protein content level with the *O. sativa* parent (WAB56-104), which was exceptionally low as an *O. glaberrima* line. However, transgressive segregation was observed in protein content and several interspecific progenies with higher protein content than popular *O. sativa* varieties in West Africa inclusive of WAB56-104 were identified. In West Africa, almost half of the demand of rice is filled by import and the import cost gives a heavy burden to the sub-region. To reduce the import, rice production has to be increased and also the products in the market should have quality not inferior to imported rice. In this study, interspecific progenies were tested in terms of relationship between protein content and other grain quality traits. The objective is to examine the possibility to develop high protein interspecific rice with high quality.

Forty-seven interspecific progenies developed from the cross of WAB56-104 (*O. sativa*) and CG 14 (*O. glaberrima*) were tested with the parents and Bouake 189, which is one of the leading *O. sativa* varieties in Côte d'Ivoire. The materials were raised on an irrigated lowland field at WARDA's research station at M'bé (7º52'N, 5º6'W and altitude 300 m) in Côte d'Ivoire. The seedlings were transplanted 21 days after seeding at a rate of two seedlings per hill with a space of 0.25 x 0.25 m based on a randomized block design with three replications. The plots were fertilized at a rate of 90-18-18 (N-P_2O_5-K_2O) kg/ha. Sixteen hills were sampled for each plot at harvesting. Paddy samples of the three replications were mixed together for each line and winnowed. Total nitrogen content was determined with powder samples of milled rice by near infrared reflectance analyzer. Protein content was calculated by multiplying total nitrogen content by 5.95 and expressed on a dry matter basis of milled rice. Viscosity parameters, i.e. peak (PV), minimum (MIN), break down (BD), final (FV), and set back (SB), were determined by Brabender viscogram. Amylase content, milling characteristics (husking yield, milling yield, and head rice ratio) and grain appearance (length, width, thickness, chalkiness, translucency, and whiteness of a milled grain) were also determined. The experiment was made in the 1997 wet season, 1998 wet season, and 1999 dry season.

Protein content showed a significant correlation only with BD and FV of 1999 in the viscosity parameters. In a multiple regression analysis, all viscosity parameters other than MIN were sufficiently explained by protein and amylase contents in the three seasons (a coefficient of determination was from 0.57 to 0.88). Higher values of both contents corresponded to viscosity producing harder texture. However, amylase content had a much more dominant effect on the parameters (except MIN) than protein content, judging from their standard partial regression coefficients. The influence of protein content on viscosity was very small and limited, and it could be possible to develop high protein content varieties with various textures in the interspecific breeding.

Regarding milling characteristics, protein content depicted a significant negative correlation with husking yield of 1999 and a significant positive correlation with milling yields of 1997 and 1998. When those characteristics were compared between 10 interspecifics with the highest protein content and those with the lowest protein content, the difference of husking yield between them in 1999 was as small as 1.30% though the difference was significant at 5% probability level. The difference of milling yield between the high and low protein interspecific progenies in 1997 and 1998 was also about 1%. The effect of protein content on milling characteristics was negligible. No significant correlation was observed between protein content and grain appearance. Selection of high protein content could be made independently from milling characteristics and grain appearance.

Allelic Variation in the Wx^a Locus of Non-Waxy Rice

Ward, R.M., Gilbert, R.G.G., and Fitzgerald, M.A.

Before the availability of genotyping technology, the two alleles of the *Wx* locus in rice were defined by the amount of GBSS protein remaining in starch granules of mature rice. By that definition, the Wx^a allele is identified as a large amount of GBSS protein remaining when the rice was grown at high temperature, and the Wx^b allele is identified as the one with very little protein remaining at high temperature. When genotyping became available, a SNP was discovered at the splice site of exon 1, whereby the presence of a G gave correct splicing and the presence of a T gave incorrect splicing, and a tendency has evolved to label the G as the Wx^a and the T as the Wx^b allele. That polymorphism is reported to explain 90% of the variation in amylose content. Furthermore, a dinucleotide repeat in the flanking region of the gene was reported to explain tolerance of varieties to growth temperature. Those with a dinucleotide repeat of 11, 14, and 20 and a G at exon 1 were deemed growth temperature tolerant, and those of 17, 18, and 19 and a T at exon 1, as temperature sensitive.

Here, we analyze a diverse selection of varieties subjected to environmental growth conditions synonymous with climate change – increasing air temperatures and atmospheric carbon dioxide levels. At maturity, the rice was examined for quality traits at the functional, structural, and synthetic level. This enables many relationships to be drawn between quality attributes. For example, the viscosity parameter of setback is relative to the molecular weight distribution of amylose chains, which is in turn related to the amount of Granule Bound Starch Synthase I. Without this depth of information and the reliance on just one parameter, such as amylose content, misleading conclusions will inevitably occur.

This comprehensive study found that the response to environmental stress is uniform amongst *japonica* varieties, but two distinguishable phenotypic responses amongst *indica* varieties were observed. The discovery of this second response amongst indica varieties opens the discussion for rice classification, offers a marker for varieties exhibiting tolerance to environmental stress, and suggests allelic variation in the Wx^a allele (defined by a G at exon 1) for amylose tolerance to high temperature.

A Method for the Molecular Characterization of Rice Starch Using an Aqueous HPSEC-MALLS-RI System

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

Rice starch composes approximately 90% of milled rice. It is made up of two major glucose polymers, amylose and amylopectin. The amylose content of rice starch ranges from 0 to 30% w/w. Cooked rice texture and rice starch functional properties are reported to be primarily impacted by amylose content. However, evidence is building that variation in other aspects of rice kernels are also important determinants of rice cooking and processing quality. Some of these attributes include: water soluble versus insoluble amylose content and debranched amylopectin chain length (CL). Examples of other starch characteristics that might influence rice functional properties that have received limited attention are molecular mass and mass distributions and branching parameters such as root mean-square radius (Rg) and connectivity between branches. In this report, we present the development and evaluation of a method for studying various aspects of these rice starch characteristics.

Eight rice cultivars used for this study included two high, intermediate, and low amylose and glutinous types. Protein and lipid fractions were extracted using NaOH and 85% methanol, respectively. Starch was gelatinized with dimethylsulfoxide and digested with isoamylase. The isoamylolysates were resolved and the molecular structure of amylose was characterized using high-performance size exclusion chromatography and multi-angle laser light scattering and refractive index detectors (HPSEC-MALLS-RI). The columns used were one guard column and two analytical size-exclusion columns connected in tandem, which were packed with polystyrene divinylbenzene cross-linked copolymer, and were maintained at 70ºC. The mobile phase was 50 mM $NaNO_3$ and 0.02% NaN_3. The debranched starch was precipitated with the addition of butanol, and the supernatant amylopectin chain structure was characterized using HPSEC-MALLS-RI.

Three different mass fractions of amylose were observed and their distributions differed among the samples analyzed. The specific parameters determined included: weight-average molecular mass (Mw) (or weight-average degree of polymerization, DPw), number-average molecular mass (Mn) (or number-average degree of polymerization, DPn), polydispersity, and Rg. Most of the molecular parameters for the amylose fraction and its subfractions were reproducible (coefficients of variation < 5%). The range of Mw and Mn of amylose was 5.1 – 6.9 x 10^5 and 1.4 – 1.8 x 10^5, respectively, for six cultivars varying in amylose content. Small linear chains of DPn < 3.07 x 10^3 (Mn = 3.66 x 10^5) accounted for >90% of the molar population. Considering the molar-distribution, the high amylose-type and the low amylose-type primarily differed quantitatively, relative to the intermediate amylose-type, Dellmont, in the smaller-DPn range of the linear chains.

Two debranched amylopectin subfractions, the high- (AmpF1) and the low- (AmpF2) hydrodynamic-volume fractions, were observed. Good repeatability was obtained for the Mw determination of AmpF1 and AmpF2 (CV < 2%) and for the mass ratio of AmpF2/F1 (CV <6%). The molar distributions of the amylopectin weight-average chain length (CLw) of L201 and Bengal demonstrated that L201, an intermediate gelatinization-temperature cultivar, has a higher molar proportion between CLw 15 to 25 and less between 9 to12 relative to Bengal, a low gelatinization-temperature cultivar. These results are comparable with those reported using high-performance anion-exchange chromatography with pulsed-amperometric detection in that the higher gelatinization-temperature cultivars are rich in chains of 12<DP<24 and lower in chains of DP<11. However, no artificial normalization of mass response to CL is required in the present method.

The method described above enables the measurement of starch characteristics that are known to impact rice functionality, as well as others that are hypothesized to, including weight- and molar-based distributions of DP, Mw and Mn of amylose, and amylopectin fine structure. With this method, large sample sets can be analyzed within a relatively short time frame with good repeatability, thus making it suitable for use in studies directed at understanding rice starch functionality and the genetics controlling these traits. This method also should be applicable for starch structural characterizations of diverse botanical sources.

Determination of the Amylose/Amylopectin Ratio in Rice Employing Gel Permeation Chromatography

Grimm, C.C., Miller, J.A., Daigle, K., and Shih, F.

The cooking qualities of rice are in large part determined by the relative amounts of amylose contained within the kernel. Rice with high ratios of amylose results in rice where the individual kernels do not adhere to one another (non-sticky) and is usually found in long-grain varieties of rice. Conversely, rice with low amounts of amylose results in gains that readily adhere to one another and in appearance are shorter and fatter. The straight chain isomer of starch forms amorphous regions, which lowers the gelatinization temperature. Furthermore, there is some indication that during cooking amylose "leaks" out of the kernel yielding a starchy flavor to the rice. Current practice employs the iodine method to measure the amount of amylose present. Iodine complexes with the linear form of starch and quantization are obtained by measuring the color intensity with a spectrophotometer. The Gel Permeation Chromatography (GPC) method requires that the rice be ground to a flour and then subjected to a debranching enzyme such as pulluanase. The amylose remains intact while the amylopectin is rendered into a series of short chains. An aliquot of the sample is injected into the GPC where the larger molecules of amylose are readily passed through the system while the shorter branched chains of the amylopectin make a more tortuous path through a myriad of pores in the gel too small for the larger amylose to pass through, resulting in separation of the two types of starch. A refractive index detector is then employed to measure the relative amounts or the two types of starch as a function of relative peak areas.

Influence of Drying on Rice Fissure Formation Rates and Mechanical Strength Distributions

Siebenmorgen, T.J. and Qin, G.

Tests were conducted to determine the effects of drying conditions on the rate of fissure formation after drying and the resultant mechanical strength distributions of individual rice kernels. Long-grain varieties Cypress, Drew, and Wells at 21% harvest moisture content (HMC) were dried at 40, 45, 50, 55, and 60°C and constant 17% relative humidity (RH) to 12% MC. Immediately after drying, the samples were placed in sealed plastic bags at 21°C. Fissure enumeration, milling tests, and individual kernel breaking force measurements were made at 1, 24, 48, and 120 h after drying ceased. Head rice yields (HRYs) decreased as drying temperature increased. Very few fissures were visible immediately after drying. Most fissures appeared within 24 h of drying cessation and corresponded to HRY reductions. There was no difference in the kernel thickness distributions of fissured and non-fissured kernels taken from the dried samples. The drying treatments produced samples having greater variation in kernel breaking forces than that of control samples. Thus, the breaking force distributions (BFDs) were affected by drying treatment but were also affected by post-drying durations. The percentage of strong kernels in a sample, defined as those brown rice kernels withstanding a 20 N force in a three-point bending test, was strongly correlated with HRY (R2=0.804, 0.835, and 0.915 for Cypress, Drew, and Wells, respectively).

Effect of Extreme Drying Weather on Quality of California Medium-Grain Rice

Thompson, J.F. and Mutters, R.G.

California's medium-grain rice production industry experiences a wide range of head rice yield (HRY). Average grain moisture of a representative sample is the principle determinant of when to harvest. A 2-year field study demonstrated the rice moisture at harvest alone is not an adequate predictor of HRY. The history of rice moisture caused by varying humidity conditions is needed to predict rice quality. At harvest time in California, daytime humidity is low and at night humidity increases, exposing rice to dew. During this meteorological pattern, HRY could be predicted by assuming that all kernels that dry below 15% moisture during the day rehydrate at night and fissure, resulting in lost HRY. Harvest weather is also characterized by occasional episodes of a dry North wind lasting several days. These periods have insufficiently long rehydration periods to completely fissure kernels that have dropped below 15% and actual HRY is much above predicted HRY. HRY dropped somewhat during North wind periods. However, rice value (government loan value minus drying costs) did not drop significantly during the windy period because the lower loan value was offset by lower drying costs. After the wind period ended rice was again subject to nighttime dew and regained moisture, resulting in a large reduction in HRY and value. A combination of the range of kernel moisture at harvest and the history of rice moisture influenced by weather conditions explained a great deal of the total HRY variation experienced by the California rice industry.

Quality of Rice Dried by High Temperature Fluidization

Truitt, E.E. and Siebenmorgen, T.J.

With the increase in rice production due to higher yielding varieties and more rapid harvesting and transport capabilities, the rice industry must find quicker, quality-assured methods of drying rough rice to a safe storage moisture content (MC) of 12 to 14% (wet basis). Fluidized bed drying (FBD) utilizes drying air temperatures (90-200°C) that are much higher than those used in current commercial drying systems in the United States (~60°C). A pilot-scale air-impingement oven was used in this study to accommodate small sample sizes for more controlled experiments to simulate FBD of rough rice in an evaluation of drying curves, head rice yield (HRY), color, pasting and thermal properties, degree of milling (DOM), protein content, and degree of gelatinization. Drying conditions were 60°C, 90°C, 120°C, and 150°C with an air velocity of ~3-4 m/s. After drying, samples were immediately tempered at 60°C or grain temperature (GT) for 0 to 120 min. The long-grain cultivar Wells was dried from 21.9% MC to 12% MC in as little as 1 to 5 min. HRY was slightly increased above that of the low-temperature-dried (21.2°C) control under certain conditions, possibly due to partial gelatinization and/or starch-denatured protein interactions. When drying at 60 to 90°C to 13% MC or tempering at 60°C instead of GT, however, HRY was drastically reduced, as can be explained by the glass transition hypothesis. Whiteness and DOM generally decreased as drying condition severity (defined by increasing drying air temperatures, increasing tempering durations, increasing tempering temperature, and lower final MC) increased. This may have resulted from incomplete bran removal as the rice kernels were more resistant to milling due to increased kernel integrity from partial gelatinization and/or protein denaturation. Although resistance to bran removal might increase protein content of the milled rice, generally lower protein content values were observed for most samples dried with heated air. A shift to higher gelatinization temperatures at drying conditions of 120 to 150°C due to partial gelatinization during drying and lower peak and final viscosities at 150°C possibly due to interactions of starch with denatured proteins were observed. Partial gelatinization at drying conditions of 120 to 150°C ranged from 0.97 to 7.70% as determined by an enzymatic method and 11.1 to 29.6% as determined by differential scanning calorimetry; GTs were between 92 and 100°C. Fluidized bed drying may provide benefits to the rice industry due to decreased drying durations and potential increased HRYs while maintaining rice quality under certain drying conditions.

Effects of Nighttime Temperature during Kernel Development on Rice Physicochemical Properties

Cooper, N.T.W., Siebenmorgen, T.J., and Counce, P.A.

Rice quality can inexplicably vary from one lot to another and from year to year. One possible reason could be variable temperatures experienced during the nighttime hours of rice kernel development. A controlled temperature study was conducted at the RiceTec, Inc. headquarters in Alvin, Texas during the fall of 2004. Four nighttime temperatures of 18, 22, 26, and 30^{o}C, as well as six rice cultivars, chosen based on their processing characteristics, (Cypress, LaGrue, XP710, XL8, M204, and Bengal) were tested in four separate phytotrons, or large growth chambers, with each phytotron being randomly assigned a nighttime air temperature. The rice cultivars were grown in greenhouses until just before kernels began to develop and then were transferred into one of the phytotrons. Treatment temperatures were applied from 12 am to 5 am. As nighttime temperature increased, head rice yield significantly decreased for all cultivars except for Cypress and Bengal, which did not vary significantly between nighttime temperature treatments. 1000-kernel mass decreased significantly with an increase in nighttime temperature for cultivars XL8, XP710, and M204 but not for the two long-grain cultivars and Bengal. The occurrence of chalky kernels increased with an increase in nighttime temperature for all cultivars but Cypress. The amylose content of Cypress and LaGrue significantly decreased at the nighttime temperature of 30^{o}C.

Small Sample Mill Protocol Development: Evaluation of a Genogrinder 2000

Bautista, R.C., Siebenmorgen, T.J., Mauromustakos, A., and Burgos, R.M.

This study is part of a continuing effort to develop a protocol for milling small-quantity brown rice samples typically produced from breeding lines. A laboratory mill, the Genogrinder 2000, was evaluated for milling small-quantity samples of Bengal (medium-grain) and Francis (long-grain) brown rice. Operating parameters, including the milling duration, oscillation speed, tube size, and brown rice mass, were used to determine the milling performance of the mill in terms of brown rice mass loss percentage (MLP). Mass loss percentage indicates the amount of bran removed during milling. Results indicated that milling with the Genogrinder 2000 was significantly affected by brown rice mass, milling duration, and oscillation speed. Mass loss percentage was greater for rough rice samples at 15% moisture content (MC) than 12% MC for both varieties. Mass loss percentage was linearly correlated with milling duration and oscillation speed. The Genogrinder 2000 was found suitable for milling small-quantity samples of brown rice with minor modifications of the tube holders and could thus serve as an effective tool for breeders and physiologists.

Abstracts of Posters on Processing, Storage, and Quality
Panel Chair: O. Sanford

Association between Rice Grain Quality, Grain Moisture, and Soil Characteristics

Marchesi, C.E, Mutters, R.G., Thompson, J.F., and Plant, R.E.

This was an oral presentation also and the abstract can be found in the **Abstracts of Papers on Processing, Storage, and Quality** section.

Effect of Drying Conditions on Milling and Taste Quality of Rice

Zheng, X. and Lan, Y.

Paddy rice, as a grain sensitive to high temperature, is apt to display degradation phenomena, including cracking and inferior taste during the drying process. It is necessary to analyse and calculate the taste value of the post-drying paddy for paddy processing and dryer designing.

Some terms, such as crack rate, head rice yield, and taste value, based on individually desired requirement from researchers are used to evaluate rice quality. In this research, rice quality in terms of head rice yield, and taste value were synthetically analyzed during post-harvest drying.

The samples of paddy rice, from two varieties, were processed on a thin-layer drying table under different drying conditions, including initial moisture content, drying temperature, and surface velocity. Milling quality and taste value was obtained according to the standards method from the Chinese Department of Agriculture. Near Infrared Radiation (NIR) technology and Neural Network (NN) method were applied to measure rice constituents and predicate rice quality.

The conclusions were obtained as following:

The essential factors affecting rice quality were analyzed after drying paddy. A regression equation was developed to express the relation between drying constant K and drying parameters in terms of drying temperature, surface velocity, relative humidity, and initial moisture content, which describes the effect of each parameter on drying rate during paddy rice drying process.

The significant effects of drying conditions on rice milling quality were found that milling quality in terms of whole kernel amount, total rice yield, and head rice yield decreases with the increase of drying temperature and surface velocity under high initial moisture content. The result from taste analysis of dried rice indicated that the rice taste value is subject to the main constituents, which included the moisture, protein, amylase, fat acid, and drying temperature.

On the basis of the experiment, the rice taste value of post-drying paddy was evaluated. The main constituents content (A) of the rice was measured in near-infrared grain analyzer. Then, the rice taste value (B) was determined in panel sensory evaluation. The mathematical model was built involving the A and B base on the Neural Network software (NeuroShell2,V3.0), which has one input layer (five input nodes), three hidden layers, and one output layer (one output node).

A validated experiment indicates that the synthesis grade from neural network model for the dried rice make a good agreement with experimental results. The analysis of results leads to a conclusion that neural network model can evaluate the rice taste value of the post-drying paddy.

Effect of Post-Milling Conditions on Milled Rice Quality

Pan, Z., Gebreil, R., Amaratunga, K.S.P., Thompson, J.F., Zhu, Y., and Shih, C.

Rice milling quality is typically appraised based on the milling results, such as total rice yield and head rice yield, of a small rice sample. Even though fissure rate of milled rice kernels has not been considered as a quality parameter in rice quality appraisal, it could be a very important quality parameter in applications. The current standard rice sample milling procedures do not specify the post-milling handling procedures, which could affect the fissure rate of milled rice. The objective of this research was to determine the effect of cooling methods after milling on the fissure rate of milled rice. Medium-grain rice, M202, with 11.5% moisture was used for the study. The rice samples were milled with McGill No.3 mill at four different conditions to achieve different temperatures of milled rice from 56 to 80°C. Then, the milled rice samples were cooled in closed containers with three different environment temperatures, 15, 23, and 35°C. Selected samples were also cooled in open containers and as a thin layer in pans. The results showed that high temperature milling caused high fissure rates of milled whole rice kernels. The cooling in open containers and pans resulted in the loss of about 0.4 percentage points of total rice yield, which was primarily due to the moisture loss occurred during cooling.

Stackburn in a Test Tube

Belefant-Miller, H., Kay, M.G., and Lee, F.L.

Rice endosperm often develops a yellow discoloration during commercial storage in conditions of high temperature and moisture, thereby reducing the value of the grain. This postharvest yellowing (PHY) appears to be coincidental with fungal presence. In order to study the yellowing process in a controlled manner, we developed a technique to induce PHY on a small, laboratory scale. Milled rice kernels were rinsed with water and incubated in clear test tubes or microfuge tubes at 65 to 80°C. This allowed direct observation of the color change and measurement using a colorimeter. Every rice cultivar tested, which included long- and medium-grain japonicas and indicas, showed some level of PHY. Yellowing increased with temperature yielding a maximum color change at 79^{o}C. Most of the color change occurred within 1 day. The moisture parameters required for yellowing to occur were measured. Using sterilization and culture techniques, we found no indications of direct fungal involvement in the yellowing process.

Possibility of the Development of High Protein Rice with Acceptable Grain Quality for West African People in Interspecific Breeding Between *Oryza sativa* and *O. glaberrima*

Futakuchi, K., Watanabe, H., and Jones, M.P.

This was an oral presentation also and the abstract can be found in the **Abstracts of Papers on Processing, Storage, and Quality** section.

Rice Bread Quality as Affected by Yeast and Bran

Kadan, R.S. and Grim, C.

Whole rice bread (WRB) has been developed in our laboratory for people suffering from Celiac disease and other food allergies. The WRB has texture and related qualities comparable with white or whole wheat breads. This paper reports the results of three levels of yeast, defatted rice bran on the texture of WRC. The results showed by increasing both the amounts of the yeast and defatted bran, the texture can be altered to prepare different kinds of WRB. The aroma and the volatiles increased qualitatively by increasing the amounts of both yeast and bran.

Abstracts of Papers on Rice Culture
Panel Chair: L. Tarpley

Multiple-Inlet Plus Intermittent Rice Irrigation Reduces Water Use While Maintaining Acceptable Yields

Smith, M.C., Massey, J.H., Johnson, A., Thomas, J., Tacker, P.L., Vories, E.D.,
Lancaster, S., Andrews, A.A., and Ampim, P.

Research was conducted in 2004 and 2005 to determine the potential for water savings using multiple-inlet irrigation plus intermittent flooding compared with continuously flooded rice. Experiments were conducted at five farms, ranging from the southern-most Mississippi Delta to the northeast corner of Arkansas. The control field at each location was continuously flooded using the grower's traditional practices. The experimental field used multiple-inlet irrigation plus intermittent flooding, whereby the flood was established at the appropriate time using 38-cm diameter disposable plastic pipe to deliver water to each paddy simultaneously. After 2 weeks of continuous flooding, the experimental field was allowed to dry until about half of each paddy had exposed soil. At this point, the field was reflooded to an average depth of 7.6 to 10.2 cm. This cycle was repeated on a 5- to 9-day interval throughout the growing season. Rain gauges and flow-meters recorded all water inputs. Water-depth loggers recorded flood depth every 10 min in at least four paddies within each field. Flagleaf samples were collected at the booting stage and analyzed for nutrient content. Weed, insect, and disease control was excellent at all locations and unaffected by water management. Flagleaf samples averaged 3.1 and 3.7% nitrogen in 2004 and 2005, respectively, and were not affected by water management. Averaged over locations and years, rice yielded 8316 kg/ha and was unaffected by water management. Intermittently flooded rice used 61 cm water compared with 81cm with continuously flooded rice. A rice irrigation model was developed using the water depth logger data. The model was run using 25-year historical daily rainfall measurement from four Mississippi locations and five Arkansas locations. The model predicted intermittently flooded rice to consume 56 cm irrigation and continuously flooded rice to consume 86 cm irrigation.

Multiple-Inlet Plus Intermittent Rice Irrigation Increases Rainfall Capture and Reduces Non-Point Source Runoff

Massey, J.H., Smith, M.C., Johnson, A., Thomas, J., Tacker, P.L., Vories, E.D.,
Lancaster, S., Andrews, A.A., and Ampim, P.

Research was conducted in 2004 to determine the potential for water savings and reduced nonpoint source runoff using multiple-inlet irrigation plus intermittent flooding as compared with continuously flooded rice. Experiments were conducted at five farms, ranging from the southern-most Mississippi Delta to the northeast corner of Arkansas. Each location consisted of two adjacent fields averaging 16 ha each. The two fields only differed in water management practice. The control field at each location was continuously flooded using the grower's traditional practices. The experimental field used multiple-inlet irrigation plus intermittent flooding, whereby the flood was established at the appropriate time using 38-cm diameter plastic pipe to deliver water to each paddy simultaneously. After 2 weeks of continuous flooding, the experimental field was allowed to dry until about half of each paddy had exposed soil. At this point, the 8 to 10 cm flood was reestablished. This cycle was repeated every 5 to 9 days throughout the growing season. All water inputs and flood depths were recorded. Water samples were collected on a weekly basis for nutrient and pesticide analysis. Intermittent flooding did not affect pest pressure, plant-nutrient content, or rice yield. However, intermittently flooded rice used 56 cm water per ha compared with 81 cm per ha with continuously flooded rice, representing a 30% savings in irrigation inputs. This savings was due to increased rainfall-holding capacity, and reduced over-pumping and subsequent tailwater runoff. Based on 25-year historical rainfall data, our model predicts an average increase in rainfall capture of 67% and a 60% reduction in tailwater runoff for the intermittent flood as compared with the conventional flood system. Water samples are currently being analyzed for pesticide and nutrient concentrations and will be used to estimate surface water loadings from each irrigation treatment.

Water Use Measurements from the Arkansas Rice Research Verification Program

Vories, E.D., Tacker, P.L., Wilson, C., Runsick, S., and Branson, J.

In 1983, the Cooperative Extension Service established an interdisciplinary rice educational program that stresses management intensity and integrated pest management to maximize returns. The purpose of the Rice Research Verification Program (RRVP) was to verify the profitability of University of Arkansas recommendations in fields with less than optimum yields or returns. The goals of the program are: (1) to educate producers on the benefits of utilizing University of Arkansas recommendations to improve yields and/or net returns, (2) to conduct on-farm field trials to verify research-based recommendations, (3) to aid researchers in identifying areas of production that require further study; (4) to improve or refine existing recommendations which contribute to more profitable production, and (5) to incorporate data from RRVP into Extension educational programs at the county and state level.

The RRVP is supported by producer checkoff funds through the Arkansas Rice Research and Promotion Board. Since 1983, the RRVP has been conducted on over 240 commercial rice fields in more than 30 rice-producing counties in Arkansas. 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 made based on current University of Arkansas recommendations.

During the first 8 years of the program (1983 - 1990), flowmeters were placed on the water supplies of 42 of the program fields and water use was recorded during the permanent flood period (i.e., excluding any flushes necessary for germination and/or herbicide activation). Irrigation water use ranged from 381 to 1714 mm (15 to 67.5 in), with an average of 879 mm (34.6 in). Water use did not vary greatly among predominant soil types, with nine clay fields using an average of 902 mm (35.5 in), while 25 silt loam fields used an average of 907 mm (35.7 in).

After 8 years, the water-use data were collected less frequently. However, beginning in 2003, a new effort was begun to see whether water use had changed very much over the years. In addition to 20 years of the RRVP, there were other reasons to believe that water use may have decreased: many of the cultivars being produced had shorter growing seasons than older cultivars; and following a multi-year educational program, many producers had adopted multiple-inlet irrigation, which had been shown to reduce water use by 24% below that of conventional flooding. Water-use data were collected from 10 fields in 2003, along with 10 in 2004 and 13 in 2005. Irrigation water use ranged from 460 to 1435 mm (18.1 to 56.5 in), with an average of 780 mm (30.7 in). Again, water use did not vary greatly among predominant soil types, with 17 clay fields using an average of 781 mm (30.8 in), while 13 silt loam fields used an average of 763 mm (30.1 in).

Finally, long-term water use may be more improved than the 3-year (2003 - 2005) averages suggest. The 2005 rice growing season was extremely dry. Most producers had to flush their fields at least once before applying the flood, after not needing to flush during the two previous seasons. In addition, several producers commented that they had a harder time maintaining a flood in 2005 than they could ever remember. The annual averages were 724 mm (28.5 in) for 10 fields in 2003, 621 mm (24.4 in) for 10 fields in 2004, and 946 mm (37.2 in) for 13 fields in 2005. Additional data collected in future growing seasons should indicate whether the values for 2005 were unusually high and how much irrigation water use for rice production has changed over the life of the RRVP.

Improved Water Management with Multiple Inlet Rice Irrigation

Tacker, P.L., Vories, E.D., Hogan, R., and Smith, L.W.

Rice production is an important component of Arkansas' and other southern states' agriculture. In 2003, rice accounted for over $1.2 billion in total cash receipts, almost 10% of the state totals for all commodities for both Arkansas (9.7%) and Louisiana (8.3%). When combined with the rice processing, agricultural equipment, and other businesses supporting rice production, it is apparent that rice is important to the overall economy and not just in the rice-producing states.

While rice is produced in some parts of the world in an upland, rain fed culture, almost all U.S.-produced rice is grown in a flooded culture. In the dry-seeding system the crop is usually flooded at approximately the V-4 growth stage and, unless a disease or fertility problem requires the field to be dried, a continuous flood is maintained until after heading. Reported values for the amount of irrigation water applied to rice in Arkansas ranges from 610 to 1220 mm. Even at the 610 mm amount, rice production in Arkansas requires an average of at least 3.8 million m^3 of irrigation water per year.

The large amount of water applied to rice has resulted in two problems. The energy costs associated with pumping make up a significant portion of the rice production budget, especially with the significant increase in diesel fuel. In addition, groundwater shortages are being observed in parts of Arkansas and other rice-producing areas and similar problems with surface water sources have been encountered. Reducing the water requirements for rice has been a goal of farmers and researchers for many years. Multiple Inlet Rice Irrigation (MIRI) is an alternative method for applying flood water that has the potential to help address these problems.

The research objective was to investigate whether MIRI would reduce the water being pumped for rice production, without reducing yields, when used on production-scale fields by the regular farm employees. In order to study water requirements for rice on a production scale, on-farm water use studies were conducted during the 1999 through 2002 growing seasons. The studies consisted of paired fields located close together, with the same cultivar, soil type, planting date and management practices. One of the fields was randomly assigned as a conventionally flooded field (CONV) and the other was assigned as MIRI. Propeller-type flow meters were installed in both fields to measure the amount of water pumped and the farmer provided yield data for the fields.

During the 4-year study period, data for comparisons were collected from 14 pairs of fields ranging in size from 12.5 to 32.4 ha. The farms represented the northern, central, and southern portions of the rice-growing region in Arkansas, and the range of soil types used for rice production. The MIRI method required an average of 24% less irrigation water than conventional flooding, with 930 and 703 mm for CONV and MIRI, respectively. In addition, the MIRI field used less water for each of the 14 farms, ranging from 10% less to 42% less. Rice grain yields were 3.4% greater for MIRI, with 7.41 and 7.66 Mg/ha for CONV and MIRI, respectively. Differences ranged from 13% greater for MIRI to 3% greater for CONV. Since both the irrigation water applied and yield favored MIRI, the irrigation water use efficiency (WUE) (i.e., yield produced per unit of irrigation water applied) favored MIRI. In fact, an average 36% WUE increase was associated with MIRI, with 8.74 and 11.89 kg/ha-mm for CONV and MIRI, respectively. Differences ranged from 15% greater to 81% greater for MIRI.

Two possible factors affecting yield were the "cold water effect" and nitrogen efficiency. The cold water effect from groundwater and conventional flooding refers to the area around the well or riser that is typically later maturing and lower yielding than the rest of the field. This is a function of water temperature effect on the plants and the calcium precipitate that occurs from the water being exposed to the air and warmed. Introducing the water at several points in the field appears to reduce the cold water effect. The recommendation for minimizing nitrogen losses is to apply the initial flood within 5 days of the fertilizer application. This time frame is often exceeded with conventional flooding; however, most cooperators report less time being required to cover the field with water when using MIRI.

In addition to the water savings and potential yield increase, most producers indicate that MIRI results in a reduction in labor of approximately 25%. A notable quote from one producer concerning MIRI is, “It makes it possible for me to manage the water instead of the water managing me.”

Web-Based Rice Water Conservation Analyzer (RiceWCA)

Yang, Y., Wilson, L.T., Stansel, J., Wang, J., Gallegos, M., and Lu, P.

The San Antonio Water System (SAWS) is funding a project to study the feasibility of piping water to San Antonio from the Lower Colorado River. The water would be made available through conservation efforts in the Lower Colorado River Authority (LCRA) irrigation districts in Matagorda, Wharton, and Colorado counties. The development of a web-based Rice Water Conservation Analyzer (RiceWCA) is one of several studies involved in the LCRA/SAWS project. The focus of the research is to develop a decision tool to analyze the potential water savings and costs that could accrue from adoption of different on-farm water conservation measures. The five conservation practices include 1) precision grading, 2) multiple inlets, 3) conservation tillage, 4) tail water recovery systems, and 5) lateral improvement.

The RiceWCA will be able to rapidly estimate the costs and water savings associated with implementing a wide range of rice on-farm conservation measures. The web-based program will provide estimates of water use as a function of currently used on-farm water management practices and will estimate the potential water savings and costs associated with varying degrees of implementation of on-farm water conserving measures throughout the LCRA districts. Users will be able to analyze the benefits (water savings and in some cases yield increases) and costs (land improvements, labor, and in a few cases, yield decreases or increased fertilizer use), for a range of precision grading options, lateral improvements (weed control and buried pipe), multiple inlet systems, tail-water recovery systems, and conservation tillage practices.

RiceWCA will provide water use and cost analysis 1) at the levels of districts, sub-districts, canals and turnouts; 2) for baseline conditions of laterals and fields; 3) for multiple agronomic practices; and 4) for different weather scenarios. It will allow users to create, edit, and run multiple water conservation profiles and present graphic displays of results. It also provides dynamic access to field-specific weather and soil data.

The *Water Use Analysis* feature will allow users to view and analyze water use estimates for a conservation profile. The water use analysis page will allow users to choose a specific profile and select options for conservation practices, results display, and parameter settings. The available options depend on the configuration of the profile when it is created. The *Conservation Options* will allow users to examine water use with *No Improvement*, *Improve Field Only*, *Improve Lateral Only*, or *Improve both Field and Lateral*. The *Display Options* will allow users to view the water use and cumulative water use (ET, Flood, Flush, Percolation, Rainfall, Tail Water, Water Demand, Supply & Demand) at the intervals of daily, weekly, monthly, and yearly in either tabular or graphic format.

The *Cost/Benefit Analysis* feature will allow users to view and analyze the costs and benefits for each conservation profile. The available options are also dependent on the configuration of the profile when it is created. The layout of the cost benefit analysis page is similar to the water user analysis page. It has an additional option for users to customize the values for the cost/benefit parameters. The *Display Options* will allow users to view costs and benefits in three different formats: *Itemized Cost/Benefit*, *Summarized Cost/Benefit*, and *Cost/Benefit Comparison*. The *Itemized Cost/Benefit* will allow users to look at the costs/benefits for each measure of the conservation practices. The *Summarized Cost/Benefit* will allow users to look at the cost/benefit for field and lateral improvement as a whole. The *Cost/Benefit Comparison* will allow users to look at the cost/benefit of water conservation practices with regards to baseline conditions (i.e. existing conservation practices). Users can also check the cost and benefit of conservation practices with or without the Environmental Quality Incentives Program (EQIP).

The future of agriculture is tightly tied to water. As urban center continues to expand, society will be increasingly faced with the challenge of optimizing water allocation between agriculture, urban, and industry needs. An ever pressing challenge will be to meet the dual demands of maintaining or possibly enhancing agricultural production to feed our growing population and providing safe and abundant water for human consumption. RiceWCA will be one of the strategic planning tools used by LCRA to determine how to best conserve water to meet demands for water in the Lower Colorado River basin and surrounding cities.

Development of a Foundation Class Climatic Database for the U.S. Rice Producing States: An Example of Its Use in Analyzing the Impact of Weather Patterns on Rice Productivity

Wilson, L.T., Yang, Y., Lu, P., and Wang, J.

In July 2005, the Texas A&M University, Agricultural Research and Extension Center at Beaumont published a comprehensive spatially referenced web–based climatic database (http://beaumont.tamu.edu/WeatherData/). The database is dynamically linked to over 4,000 climatic stations distributed across the six major U.S. rice producing states. Several stations contain climatic records dating back over 100 years.

The foundation class climatic database provides underlying data that can be used to forecast the timing of current-year crop phenological progression for different planting dates, varieties, and counties (as with RiceDevA), the management of pest species (as with RiceSSWeb), the analyses of the impact of climatic changes on seasonal crop growth and development across years and/or locations, and the analysis of year-to-year variations in yield performance. As part of this paper, we present results from an analyses aimed at quantifying whether the 2005 crop season represented a climatic extreme. Climatic data from two stations for each of the six major rice-producing states were summarized. Four climate-based parameters were calculated for each year in the database for each of the 12 selected climatic stations, for the period from March 1 to October 20 each year. The variables which were summarized were degree-days > 10˚C, which is the estimated developmental threshold for rice, the number of days the daily maximum temperature was greater than 33.3˚C (92˚F), a temperature above which pollen inviability, grain embryo abortion, and rice plant cellular metabolic respiration all begin to rapidly increase, and the number of days the daily minimum temperature was greater than 22.2˚C (74˚F), signaling increased expenditure on metabolic respiration during the night, which decreases the net efficiency of the plant's photosynthesis machinery.
The summer of 2005 was the second hottest summer on record for Eagle Lake, TX, as measured by total degree-days accumulated during the season, missing the seasonal highest cumulative degree-day estimate by 3 and missing the highest number of days greater than 33.3˚C by 3. Nighttime maximum temperature was the third highest on record, suggesting a major metabolic cost to the crop during 2005. For Beaumont, 2005 had the eighth highest total degree-days accumulated, the second highest number of days where the maximum temperature was greater than 33.3˚C, and the seventh highest number of days where the minimum temperature was greater than 22.2˚C. Because the Beaumont Center has only maintained maximum relative humidity records for 3 years, the statistics for that variable are not definitive. Similar trends were observed for the majority of locations included in the analysis in the other five major rice-producing states. An important component of our analysis is a statistical examination of the impact of long-term weather patterns on Texas rice yield performance.

Ratoon Rice Response to Main-Crop Harvest Practices

Bond, J.A. and Dunand, R.T.

Ratoon rice production is very important along the Gulf Coast of Louisiana and Texas. A ratoon rice crop generally produces grain yields approximately only one-third of the main crop; however, production costs for the ratoon crop can be significantly lower than for the main crop. A ratoon rice crop can be produced with less labor because no land preparation or planting is required, and the ratoon crop requires less water than the main crop because of the short period from main-crop harvest until ratoon-crop maturity.

The ratoon rice harvest should be carefully considered throughout the growing season because every management decision made for the main crop impacts the development and yield of the ratoon crop. Main-crop harvest heights ranging from 0 to 50 cm have been utilized for ratoon rice production, and different optimum main-crop harvest heights are widely reported. However, research has indicated that lower main-crop harvest heights (15 to 30 cm) could produce higher ratoon rice grain yields than conventional main-crop harvest heights (45 to 60 cm).

Research conducted in Louisiana from 2001 through 2004 demonstrated an inconsistent response of ratoon grain yield to nontraditional main-crop harvest practices, including harvesting the main crop at 15 cm or rolling main-crop straw following harvest. Definite conclusions could not be reached on which to base a recommendation for main-crop harvest practices. However, positive yield responses to these varied harvest practices occurred often enough for the research to continue over several years, indicating that these alternative management practices may have application.

Rice has been ratooned along the Gulf Coast since the early 1960s, but research focused on improving recommendations for ratoon rice production in this area is limited. Research addressing management of the ratoon rice crop is vital to improving total rice production in the rice-growing areas of the Gulf Coast.

Studies were conducted in 2005 at the Louisiana State University AgCenter Rice Research Station to examine the ratoon rice response to main-crop harvest practices. One study compared ratoon rice yields when main-crop straw was flail-mowed, rolled flat following harvest, cut at 30 cm with the combine's sickle bar, or left at conventional harvest height (45 to 50 cm). This research was compromised because of damage from Hurricane Rita during ratoon-crop development.

A second study compared ratoon growth, development, and yield of Jupiter, Trenasse, and XP723 when the main crop was harvested at 23 and 46 cm. The rate of reproductive growth and development was affected by main-crop cutting height. When the main crop was harvested at 46 cm, panicle emergence was slightly earlier and number of panicles higher 6 weeks after main-crop harvest. Grain moisture (an indicator of crop maturity) averaged 21, 18, and 19% for Jupiter, Trenasse, and XP723, respectively. On average, grain moisture increased (18 vs. 20%) as cutting height decreased. Panicle emergence and ratoon harvest moisture results indicate delays in maturity when cutting height is lowered to 23 cm. On average, ratoon grain yields (adjusted to 12% moisture) were 2252, 1436, and 1796 kg/ha for Jupiter, Trenasse, and XP723, respectively, and grain yields were 1325 and 2332 lb/A for the 23- and 46-cm cutting heights, respectively. With the change in cutting height, grain yield increased more in XP723 (from 1000 to 2593 kg/ha), followed by Jupiter (from 1646 to 2858 lb/A) and Trenasse (from 1328 to 1544 lb/A).

Influence of Row Spacing and Seeding Rate on Rice Grain Yield

Frizzell, D.L., Wilson Jr., C.E., Norman, R.J., Slaton N.A., Richards, T.L., Branson, J.W., and Runsick, S.K.

Dry-seeded rice (*Oryza sativa*, L.) has historically been seeded in Arkansas with drills set with an 18- to 19-cm row spacing. However, 25-cm row spacing has become increasing popular because of the reduced financial investment involved in purchasing the drill. However, producers have expressed interest in agronomic differences that may exist between the two row spacing scenarios. Therefore, a study was conducted in 2004 and 2005 to examine the effect of drill row spacing and seeding rates on grain and milling yield of three rice cultivars.

Field studies were implemented at three locations during 2004 and four locations during 2005. During 2004, the study was conducted at the Rice Research and Extension Center (RREC), near Stuttgart, AR, on a DeWitt silt loam (fine, smectitic, thermic Typic Albaqualfs), at Lake Hogue, Poinsett County, AR, on a Hillemann silt loam (fine-silty, mixed, thermic Albic Glossic Natraqualfs), and at the Southeast Research and Extension Center (SEREC), near Rohwer, AR, on a Perry clay (very-fine, smectitic, thermic, Typic Epiaquert). In 2005, an additional location was added at the Northeast Research and Extension Center (NEREC), near Keiser, AR on a Sharkey clay (very fine, smectitic, thermic, Chromic Epiaquert). Three rice cultivars (Francis, Banks, and Cybonnet) were seeded at rates of 50, 76, 101, 126, or 151 kg ha^{-1} into 4.88 m-long plots with either 18- or 25-cm drill row spacing in 2004. Because of producer requests, a broadcast seeding method was added at each location during 2005. Stand densities were measured at the 3-leaf growth stage. Grain yields were determined by harvesting the center rows of each plot (5 rows for 18-cm, 3 rows for 25-cm, and 76-cm header width for broadcast treatments) and adjusting to 120 g kg^{-1} moisture content. Milling yields were determined on a 125-g sample with a McGill No. 2 rice mill and total milled rice and head rice are reported on a percentage of rough rice.

Grain yield was significantly higher for 18-cm row spacing versus 25-cm row spacing at all locations during 2004. The yield difference ranged from 320 kg ha^{-1} to 1,100 kg ha^{-1}. During 2004, on the clay at SEREC, Francis and Banks had significantly greater grain yield with 18-cm row spacing than 25-cm row spacing. However, Cybonnet was not affected by row spacing at this location. Grain yield was also significantly higher during 2005 for the 18-cm row spacing at RREC and NEREC and for the broadcast method at Lake Hogue. Although not significant, the 18-cm row spacing at SEREC produced numerically higher yields compared with the other two treatments, with yield differences ranging from 111 kg ha^{-1} to 1230 kg ha^{-1}. During 2005 on the clay at NEREC, Francis, Banks, and Cybonnet each had greater grain yield with the 18-cm row spacing versus the 25-cm row spacing or the broadcast method.

For the silt loam locations, the data suggest that the optimum seeding rate for these three rice cultivars is 76 kg ha^{-1} compared with the current recommended rate of 101 kg ha^{-1}. It also appears that if weather conditions are favorable, reduced seeding rates may also be feasible on clay soils as well. Consistent yield differences among locations and years suggest the dry-seeded rice should be drill-seeded on 18-cm row spacing.

Effect of Tillage on Nitrogen Uptake in Three Rice Rotations

Anders, M.M. and Olk, D.C.

Nitrogen is regarded as the element most responsible for determining rice grain yield. A great deal of research on nitrogen management in rice production has focused on N rates and the number of applications necessary to achieve maximum grain yield in a standard tillage and rotation scenario. As production costs increase and social concerns on environmental quality rise, there is more pressure on rice farmers to adopt tillage practices that reduce input costs and result in less environmental damage. In responding to these changes, it may be necessary to move to rotations with different crop species or intensify rice production. Direct comparisons of tillage and rotation effects on N uptake in rice could not be found, thus this work was established to evaluate how N management might need to be changed if no-till rice production was used in three different rotations.

In 1999, a long-term cropping systems study was initiated at the University of Arkansas Rice Research and Extension Center, Stuttgart, Arkansas. Main plots measuring 76 m by 12 m were divided into strips across each rotation into no-till and conventional-till treatments. Each tillage treatment plot was further divided into fertility (2) and variety (2) treatments. Each main plot represented a single phase of the seven rotations found in the study. Three rotations (continuous rice, rice-soybean, rice-corn) were selected for sampling. A single variety (Wells) and N application rate (168 kg ha^{-1}; 150 lb/A^{-1}) were sampled from each tillage and rotation. Data were collected in 2002 and 2004. Uptake comparisons for the rice-corn rotation were made only in 2004. This provided comparisons of tillage and rotation effects for a single variety and N rate. Shortly after rice emergence, 0.6-m diameter steel rings (4) were placed in each plot. Enriched urea (5 atomic percent ^{15}N) at a rate of 168 kg ha^{-1} was added to each ring when the rice reached the 4-leaf stage. Each ring was immediately filled with water to a depth of 10 cm. All plant material and soil samples were collected from a ring in each plot at 2 weeks following N application, green ring, flowering, and harvest. Soil bulk density samples were collected 2 weeks following N application and at green ring. The 15N atom percentages of the plant and soil samples were determined by continuous flow isotope ratio mass spectrometry, using a Fisons NA 1500 NC elemental analyzer coupled to a Finnigan Delta S mass spectrometer.

Tillage and rotation treatments resulted in changes in fertilizer and soil N uptake. Fertilizer N uptake was lower in the no-till treatment compared with the conventional-till treatment for all three rotations. Mean values for fertilizer N uptake were 42 kg ha^{-1}, 26 kg ha^{-1}, and 23 kg ha^{-1} for the rice-soybean, continuous rice, and rice-corn rotations, respectively. For the rice-soybean rotation, there was a average reduction of 2 kg ha^{-1} in fertilizer N uptake while that same comparison resulted in a 12 kg ha^{-1} reduction in the continuous rice rotation. Soil N uptake increased in the no-till plots for two rotations (rice-soybean, continuous rice) and decreased in the rice-corn rotation. Increased N uptake in the rice-soybean rotation resulted in an 8 kg ha^{-1} total N uptake increase while the increase in soil N uptake in the continuous rice rotation was not sufficient to offset the decrease in fertilizer N uptake; resulting in a 2 kg ha^{-1} decrease in total N uptake. These results suggest that a grower might reduce fertilizer N application levels in a rice-soybean rotation that was no-till managed in comparison with one that is conventional-till managed but would need to increase fertilizer N if a continuous rice or rice-corn rotation was changed from conventional-till to no-till.

Influence of Seeding Rate on Grain Yield and Milling Yield of Five Rice Cultivars in Arkansas

Runsick, S.K., Wilson Jr., C.E., Richards, A.L., and Branson, J.W.

Optimum seeding rates are important for uniform stand establishment in drill-seeded rice (*Oryza sativa* L.) production. However, over-compensation for potential problems associated with establishing and maintaining an optimum stand can result in overpopulation. Excessive stand densities result in increased disease pressure, increased competition among rice plants, and increased lodging. Therefore, finding the optimum rate allows for reduced risk from overpopulation but minimizes risk of insufficient stand density. Previous research conducted during the 1970s suggests an optimum seeding rate of 430 seeds/m^2 was needed to obtain a final target stand density of 160 to 215 plants/m^2. However, this work was conducted using taller-statured cultivars. Little research has been conducted to evaluate the optimum seeding rates for the shorter-statured cultivars currently grown in the southern U.S.A. rice belt. The general hypothesis is that many producers plant excessively high seeding rates and reduced seeding rates can be utilized to decrease lodging, disease pressure, and input costs, and still maintain high yields. Therefore, the objective of the study was to determine the optimum seeding rate for five commercially-produced rice cultivars in a drill-seeded cultural system.

Field studies were established in 2004 and 2005 in Chicot, Poinsett, Prairie, and Woodruff counties to evaluate grain yield and milling yield of five modern rice cultivars at five seeding rates under various field conditions. Two standard-statured conventional long-grain cultivars (Wells and Francis), a semidwarf, imidazolinone-tolerant long-grain cultivar (CL161), and two semidwarf medium-grain cultivars (Bengal and Medark) were evaluated at each location. Each cultivar was seeded at rates of 50.4, 75.6, 100.8, 126, and 151.2 kg/ha in 7.6-m long plots in eight rows on 18-cm row spacings. The study was designed as a randomized complete block with a factorial arrangement of cultivars and seeding rates and replicated three times. The studies were implemented at on-farm locations and were managed according to the remaining field. Rice plant populations were determined by taking stand counts at the 3- to 4-leaf stage in three locations within each plot. Grain yield was determined by harvesting the four center rows and adjusting the weights to constant 120 g/kg moisture content. Milling yields were determined by analyzing a 125-g sample in a McGill No. 2 rice mill. Head rice and total milled rice are reported as a percentage of rough rice. Economic analyses were conducted to compare the effect of input costs and potential net returns.

Grain yields were not different when comparing the currently recommended seeding rate of 100.8 kg/ha to 75.6 kg/ha for any of the cultivars evaluated. Consistent across all locations and years, a seeding rate of 75.6 kg/ha achieved optimum stand density and maintained grain yields. Economic analysis suggests that net returns can be increased by as much as $37/ha when comparing the 75.6 kg/ha seeding rate to 100.8 kg/ha seeding rate. Reducing the seeding rate to 50.4 kg/ha seeding rate was equal to 100.8 kg/ha seeding rate in yield at some locations, but reduced yields were observed at Woodruff County in 2004 and 2005 with the lowest seeding rate.

What is the Value of Applying Early-Season N to Rice on Clay Soils?

Walker, T.W., Norman, R.J., and Ottis, B.V.

A common practice for many midsouthern U.S.A. rice producers is to apply N when rice reaches the 1- to 3-leaf growth stage. Growers, extension personnel, and certified crop advisors have utilized this practice as a management tool with the goal of promoting enough vegetative growth so that a flood can be established as rapidly after emergence as possible. Researchers have noted differences in the appearance of rice treated with early-season (ES) N, but seldom have detected any measurable differences in rice grain yield. Additionally, this application of N has never been counted toward the total N budget. An experiment was conducted on clay soils in Arkansas (AR), Missouri (MO), and Mississippi (MS) to determine the effects of applying ES N on rice at the 1- to 2-leaf growth stage. More specifically, the objectives of this study were to quantify the differences in biomass production and N-uptake at the 5-leaf and panicle emergence (PE) rice growth stages, and yield among treatments.

The treatment structure at each location was a factorial with four ES N sources {ammonium sulfate (AMS), diammonium phosphate (DAP), urea (U), and none} applied at the rate of 22.4 kg N ha^{-1} and three PF N rates (101, 134, and 168 kg N ha^{-1}). The treatments were arranged in a randomized complete block and replicated four times. Cocodrie was drill-seeded in AR, MO, and MS. Early-season N was applied to rice at each location when the rice reached the 1- to 2-leaf growth stage. Plots were flush irrigated within 2 d after application. Plant samples were collected from the second inside row at the 5-leaf rice growth stage, oven-dried, weighed, and digested to determine total biomass and total N-uptake. This was repeated at panicle emergence. In addition to biomass, plant heights were measured at the 5-leaf growth stage. Finally, at physiological maturity, rice plots were harvested with small plot combines at each location and yields were adjusted to 12% moisture content. Analysis of variance procedures were used to determine treatment effects. Means were separated using Fisher's LSD at the 0.05 level of significance.

Plant height and biomass at the 5-leaf stage were greater when ES N was applied at all locations. In AR, plant height was greatest when DAP was used as the ES N source and resulted in a 1.3, 4.7, and 5.8 cm increase when compared with AMS, U, and none, respectively. In MO and MS, no differences were detected among ES N source; however, when averaged across ES N sources, plant height was increased by approximately 5 cm compared with none at both locations. All ES N sources produced greater biomass compared with none; however, DAP produced greater biomass than U. In MS, ES biomass production, though not significant (P=0.0818), was greater for all ES N sources compared with none. Additionally, when averaging all ES N sources, approximately 36% greater N-uptake occurred compared with when no starter was applied (P=0.0872). Treatments did not affect ES biomass or N-uptake in MO. Late-season biomass was not affected by ES N treatments in AR and MO; however, when averaged across PF rates and ES N sources, 12% more biomass was produced compared with no ES N. Furthermore, total N uptake was greater for the ES N treatments compared with when none was applied (P=0.0526). More specifically, DAP-, AMS-, and U-treated plots absorbed and average 18, 25, and 27 kg N ha^{-1} more compared with when no ES N was applied. When averaged across ES N applications, the PF N rate affected total N uptake (P=<0.0001), biomass (P=0.0002), plant height (P=<0.0001), and rice grain yield (P=<0.0001) in MS. Total N uptake and plant height increased with increasing PF N rate reaching a maximum of 198 kg N ha^{-1} and 96 cm, respectively, at the highest PF N rate. Biomass and rice grain yield responses were similar for AR and MS in that 134 kg N ha^{-1} produced biomass equal to 168 kg N ha^{-1}, but both were greater than the 101 kg N ha^{-1} rate. Rice grain yields were greatest when 168 kg N ha^{-1} was applied for AR and MS. Essentially, no treatment differences were observed for the MO location. Because rice had never been cultivated on the soil in MO, relatively large amounts of native N masked differences in N treatments.

From these data, it appears that the value of ES N applications is realized in producing greater biomass and taller plants at the 5-leaf growth stage, which will allow growers to establish a flood sooner. Additionally, based on the preliminary N-uptake data from MS, potentially all of the ES N is being absorbed by the plants, and hence could be counted towards the total N budget that could save growers approximately $35 ha^{-1} in N cost.

Ratoon Rice Yield Advantage from Flail Mowing is Due to Decreased Straw Matting –
Not Decreased Physiological Inhibition

Tarpley, L., Mohammed, A.R., and Rounds, E.W.

A relative increase in rice ratoon yield is often associated with low cutting height of the main crop. Research was conducted to determine if this association was due to a) a decrease in shading due to removal of upper vegetative material and wind-rowed straw, b) a relative increase in photosynthetic capacity of the developing ratoon crop, c) a progressive removal of inhibition that is caused by the presence of upper growth on the main crop stems, and/or d) a more optimal proportion of tillers near the base of the plant with good supporting resources and a longer developmental period.

Study 1: All plots were cut to 5 to 6 cm (2") by flail mowing. Some plots were harvested beforehand as usual with a combine. For other plots, the whole plant, including grain, was mowed under. Ratoon stand was much worse for those plots for which the grain was not harvested first; therefore, the additional straw is physically or chemically inhibiting the ratoon crop growth or the extra material that has to be mowed is preventing an efficient chop by the flail mower and either the presence of the relatively large pieces of the straw or the duller cut of the stalk is somehow inhibiting the ratoon crop growth. Very vigorous genotypes, such as XL-7, were better able to grow out of the stand inhibition due to cutting the entire plant, weakly suggesting that the inhibition is not due to a duller cut of the stalk because such a physical injury would usually result in a proportional decrease in potential yield rather than a setback to vigor.

Study 2: For all plots, the entire plants, including grain, were flail mowed, but to three different cutting heights [6-cm (2-inch), 10-cm (4-inch), and 15-cm (6-inch)]. The plots cut highest had a much better ratoon stand, and the intermediate cut had an intermediate stand. These results suggest that a chemical inhibition due to the presence of the extra straw was probably not a factor because the proportional differences in the mass of vegetation cut were much less than the differences in ratoon stand. The probable explanation is that the 15-cm (6”) cutting height was tall enough to be above the mat of straw. Results obtained by producers support this notion.

Results from the above two studies further suggest that the advantage of flail mowing is not due to removal of an inhibitory signal sent down the stem from the panicle.

The primary advantages of flail mowing for ratoon yield appear to lie in the system, namely a clean low cut with a good chop so that mainly basal tillers are formed (basal tillers typically form a larger panicle but take longer to develop). The good chop helps prevent straw matting and wind-rowing, which can either physically inhibit the developing tillers or can shade them excessively. The clean cut minimizes any harm to the tillers and also provides a uniform cut to the field. Uniformity indirectly benefits yield in several ways – by allowing relatively good uniformity in grain at harvest, this means less greens or over-mature grain, and better timing of agrochemical treatments and other management practices because of the better uniformity of plant development.

Some tentative conclusions can be drawn concerning the use of flail mowing following harvest of the main crop as a tool for enhancing ratoon crop yield: 1) if a 15-cm (6-inch) cutting height performs as well as a lower cutting height, the 15-cm height would be preferred because it is more tolerant against possible inhibition due to straw matting; 2) because neither chemical nor physiological (inhibition signal) inhibition appears to be a major factor corrected by flail mowing, agrochemical treatments or management schemes that encourage vigorous growth of the developing ratoon tillers would be complementary to the benefits from flail mowing; and 3) the advantage of the low cutting height is probably physiological, but the advantage of using the flail mower to achieve the low cutting height is probably in its ability to minimize the matting. The studies described above did not allow us to determine if the matting primarily caused shading or a physical inhibition of tiller growth.

Poultry Litter Induces Rice Tillering

Miller, H.

Poultry litter (PL) is used as a soil amendment for numerous crops, including rice. While it is known that rice growth is improved by PL, little study has been carried out to identify the specific growth parameters that are altered. We have identified a marked increase in the number of tillers (shoots) in rice plants grown in soil containing PL. The tests have been done in the greenhouse and confirmed in the field. The beneficial effect of PL has been ascribed to its nutrient composition. However, we have found that the tiller number of plants grown in soil amended with both PL and complete fertilizer exceeds that of plants grown in soil amended with fertilizer alone. Thus, PL appears to contain a factor in addition to any fertilizer components that improves rice growth by inducing tillering.

Hybrid Rice Competition

Minter, C., Cuevas, F., and Wallace, D.M.

Hybrid vigor is often expressed as improved competitiveness. Replacement series experiments with commercial rice hybrid XL723 and rice variety Cheniere were conducted in Texas and Arkansas to assess this principle. Seed blending rates used were 5, 10, 15, 20, 25, and 50% with pure hybrid and pure variety stands control plots. Final blended rates were adjusted after stand counts when plants of variety Cheniere (glabrous leaves and green stems) were flagged; allowing for separated hand harvesting and yield determination of variety and hybrid. Hybrid and variety contributions to total yield were then calculated on a percent basis. XL723 showed competitive advantage over Cheniere at both locations. The data suggested the need to blend Cheniere as 70% of the seed mixture to achieve a 50% contribution to yield when blended with XL723. This competitive advantage could result in improved weed control.

A Computer Program for Prediction of Safe Growth Stages for Draining Rice Fields

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

A computer model was developed consisting of (1) water use predictions by stage of development, (2) thermal time interval predictions between successive stages of development, and (3) water available to the crop from the soil after draining. The model runs as on a Microsoft Excel program. To calculate the safe stage of growth for draining a rice field using the model, several inputs are needed. These inputs include: location, cultivar, 50% heading date, and depth of rooting in the soil. One assumption embedded within the model is that water use will be maximum based on published water use data for rice. This is to assure adequate water for the crop's needs after draining. To test the model's predictions, two field, randomized complete block experiments were conducted in 2005. One field experiment was established at Stuttgart, Arkansas, and the other at Gillett, Arkansas.

To accurately predict water use, the model first predicts the time in days to reach different stages of development. To predict stages of development, thermal units or growing degree days (DD50) are calculated from the average of the high and low temperatures for a day minus 10ºC (50ºF). Further calculation "rules" are that when the minimum temperature is greater than 21ºC (70ºF), it is set equal to 21ºC and that when the maximum temperature is greater than 34ºC (94ºF) it is set equal to 34ºC. Further, the minimum DD50 accumulated for a day is 0. Daily DD50 values are cumulated between reproductive development stages and compared with observed cumulated DD50 values for particular growth stages. Historic temperatures for a location and date of 50% heading (R3 stage of development) for a given field allow days for each growth stage to be estimated. Maximum water use per growth stage is calculated from multiplying the predicted days in each growth stage by maximum water use. The amount of water from saturation to wilting point is determined for a particular soil. The amount of water available to the crop from the drained soil is calculated by multiplying the rooting depth by the mm water available/mm of soil. Then, counting backward from grain maturity at R9, water use is calculated for R8 to R9, then R7 to R9, R6 to R9, etc. When the amount of water available to the crop is greater than the water used from a particular stage to R9, it is safe to drain.

At Stuttgart, the rice cultivar was Wells. The rooting depth for the soil at the Stuttgart site was estimated to be 100 mm (4 inches). There were two treatments in the experiment at Stuttgart: (1) Draining by the growth stage as determined by the model program and (2) Draining at 28 days after heading. The program projected the safe stage of growth for draining the rice at Stuttgart was R8 (one brown seed on the main stem panicle). Treatment 1 was drained 14 days after 50% heading (field Growth Stage R7.8 with 80% of plants at R8) and Treatment 2 was drained 28 days after 50% heading. Treatment 1 yielded 9.6 MG ha^{-1} (191 bu/A) with a head rice yield of 62%. Treatment 2 yielded 9.7 MG ha^{-1} (192 bu/A) with a head rice yield of 63%. Neither grain yields nor head rice yields differed statistically. Water savings in the Stuttgart would have amounted to approximately 50 mm (2 inches) with an economic value of \$20 to \$25 ha^{-1} (\$8 to \$10/A) based on a nearby cooperating farmer's irrigation costs.

The rice cultivar at the Gillett experiment was Francis. The rooting depth at the Gillett site was 200 mm (8 inches) based on penetrometer measurements. We utilized 1.22 X 2.5 m (4 X 8 ft) metal frames to create a drained rice field plot within a flooded rice field. The frames were driven into the soil to the depth of the impervious layer. There were three treatments: (1) Drain by growth stage as determined by the growth stage model computer program with plot area surrounded by the metal frame, (2) A control with the frame around the rice (as in Treatment 1) but simply drained at the time the field was drained to see if the frame affected yield and (3) A second control was established without a frame with the same plot dimensions as Treatments 1 and 2. Treatment 1 was drained 10 days after 50% heading (field Growth Stage R6) and Treatments 2 and 3 were drained 23 days after 50% heading. At the Gillett field the predicted safe stage of growth for draining rice was R6. Treatment 1 yielded 11.5 MG ha^{-1} (228 bu/A) with head rice yield of 65.4%. Treatment 2 yielded 10.7 MG ha^{-1} (213 bu/A) with a head rice yield of 65.5%. Treatment 3 yielded 10.9 MG ha^{-1} (217 bu/A) with a head rice yield of 66.1%. Neither rough rice yields nor head rice yields differed among treatments Water savings were approximately 100 mm with an economic value of \$25 to \$30 ha^{-1} (\$10 to \$12/A) in the Gillett experiment as estimated by the cooperator (the rice field was irrigated once more after we drained Treatment 1). The program provides a comprehensive way to consider decisions on rice draining. Our goal is to allow rice producers to save money and conserve irrigation water without reducing rice yield or quality. These water savings have ranged from \$20 to \$30 ha^{-1} with further savings from reduced tillage to repair ruts in some cases.

Effects of Planting Date on Grain Dimensions and Grain Weight of Selected Rice Varieties

Sha, X.Y., Theunissen, S.J., and Linscombe, S.D.

Planting date has a significant effect on rice yield and milling. However, there is little information on the effects of planting date on grain size and dimension of water-seeded rice. Studies were conducted in 2004 at the LSU AgCenter's Rice Research Station to investigate the effects of different planting dates on grain length, width, L/W ratio, and grain weight of rough, brown, and milled rice.

Twelve rice genotypes were evaluated, including conventional long-, medium- and short-grain varieties, Clearfield varieties, and hybrids. A split-plot design was applied with different planting dates as main plots and genotypes as subplots. Each subplot was water-seeded and repeated three times. The seven planting dates were February 27, April 1, April 15, May 2, May 14, May 28, and July 4. A milling sample was individually taken at the right maturity from the first two reps. Each milling sample was divided into six sub-samples (50 grains each), two for the fully filled rough rice, two for whole brown rice, and two for milled whole white rice. Grain dimension was measured by the WinSeedle™ system. All data were analyzed by the SAS program (version 9.0).

Our preliminary results indicated that planting date had significant effects on the grain size, shape, and weight of rough, brown, and milled rice. Rice planted on May 2 and February 27 produced the longest grains (rough, brown, and milled) among all planting dates, while July 4 planting consistently had the shortest grains. In contrast to the grain length, May 2 and February 27 plantings produced the narrowest grain among all plantings. As the result, rice planted on May 2 and February 27 was more slender (larger L/W ratio) than planted on other planting dates. Same trend was found for the grain weight, with heaviest grains appeared on May 2, February 27, and April 15 planting dates. This test will be repeated in 2005.

Can We Predict Rice Yields Using Spectral Reflectance at Midseason?

Dunn, D.J., Ottis, B.V., Wrather, J.A., Stevens, W.E., Beighley, D., and Aide, M.T.

Production costs continue to increase and rough rice prices have remained constant or declined. One of the greatest sources of cost increase is N fertilizer. In field N management is difficult and time consuming for rice producers and crop consultants. In an ideal situation, drill-seeded rice is fertilized with urea immediately before flooding. In less than ideal situations, field size and irrigation well pump capacity may lead to delays in flood establishment. Under these conditions, urea can be lost by volatilization while a field is being flooded. Several methods have been developed to determine if additional N supplied post-flood can increase rice yields. Arkansas Plant Area Board measurements (plant height multiplied by row width) have been well correlated to rice yield response and midseason N. Many rice producers and crop consultants are reluctant to use it because of time constraints and complicated calculations. Minolta SPAD 502 chlorophyll meters have also been used successfully by university researchers but are too expensive for most rice producers and crop consultants. Tissue testing for N status of rice fields may be useful, but additional expenses and time lag constraints may limit its utility. Field maps produced with remote sensing technology offer an alternative solution. These maps, based on spectral reflectance, are commercially available to cotton producers. Adaptation of this technology to N status of rice fields is currently being investigated. The objective of this paper is to compare the ability of five traditional methods of assessing plant N status and one spectral reflectance method to predict rice yields at internode elongation.

In this 3-year experiment, reference strips with four different N fertility regimes were produced. In 2003 and 2004, these strips were located at the Missouri Rice Research Farm near Qulin, MO, on a Crowley silt loam. In 2005, the study was conducted at the University of Missouri-Delta Center near Portageville on a Sharkey clay soil, which had recently been graded. The rice variety Cocodrie was planted in early-May of each year. At tillering, plots were treated with 0, 84, 168, or 252 kg ha^{-1} N. Each plot was 20 feet wide and 400 feet long. Each treatment was replicated three times. At internode elongation, a spectral reflectance image of the rice was collected with aircraft mounted sensors at a 0.5 mile altitude. In 2003, data were collected by Spectral Visions (Champaign, IL), and in 2004 and 2005, data were collected by InTime Corporation (Cleveland, MS). Plant height, plant color, and SPAD 502 measurements of chlorophyll in leaves were collected from the center area of eight locations in each strip along with tissue samples for N and potassium analysis. Rice yields for each of the eight locations in the 12 strips were collected. The data were analyzed and means separated using ANOVA in SAS.

In all 3 years, the preflood N treatments produced significantly different rice yields. In 2003, four methods were highly correlated to yield (Pearson coefficient>0.50). These methods were GNDVI (0.8515), plant biomass (0.7275), plant height (0.6897), and SPAD 502 (0.5455). Tissue analysis for N was able to explain only 36% of the variation in yield while K analysis explained 30%. In 2004, five methods were highly correlated to yield. These methods were plant biomass (0.9188), plant height (0.9114), plant color (0.7669), SPAD 502 (0.6151), and GNDVI (0.5314). Tissue analysis for N was able to explain only 39% of the variation in yield while K analysis explained less than 1%. In 2005, only two methods were highly correlated to yield. These methods were GNDVI (0.6020) and plant height (0.5390). Tissue analysis for N was able to explain only 45% of the variation in yield while K analysis explained 36%.

The spectral reflectance and plant height measurement were the only two methods successful at predicting rice grain yields each of the 3 years in this experiment. These two methods represent the best choices among the available methods. The spectral reflectance method gave the greatest correlation two of the three years studied. Given the amount of time required to measure plant height in the field and the commercial availability of spectral reflectance data maps, more research and development should be applied to this technique for rice.

A Century of Rice Production in Arkansas

Wilson Jr., C.E.

Rice (Oryza sativa L.) has become a major commodity in the Arkansas agricultural economy. Arkansas is currently the leading rice-producing state, producing nearly half of the rice produced in the United States. Rice production in Arkansas has progressed from none produced prior to 1900 to over 600,000 hectares annually at the beginning of the 21st century. Several events and scientific advancements were instrumental in Arkansas becoming a major factor in the U.S. rice market.

Rice production began in Arkansas with one acre grown in Lonoke County in 1902. Official state records on yields, acreage, and seasonal prices have been kept since 1905. Rice acreage expanded in Arkansas until 1955 when the first government acreage controls were implemented, stabilizing acreage at approximately 200,000 hectares. These quotas were lifted in 1974 and rice acreage increased, peaking at a record of 670,000 hectares in 2005. Arkansas has ranked number one in production since 1973, corresponding to when the acreage quotas were lifted.

The history of rice production reveals three recent phases when yields increased dramatically over a 2- to 3-year period. Each phase coincides with the release, subsequent acceptance, and widespread growth of a new variety or varieties. The first phase started in 1967 when Starbonnet was first released by the University of Arkansas. Prior to 1967, the highest average rice yield was 96 bu/A. Record yields were produced in 4 of the next 5 years. In 1969, Starbonnet replaced Bluebonnet as the most popular rice variety and remained the number one variety through 1984. In 1985, yields again increased several bushels per acre. Newbonnet and Lemont were released in 1983, and in 1985, Newbonnet replaced Starbonnet as the most widely grown variety. In 1984, Starbonnet, Lebonnet and Labelle were planted on 80.7% of the state's acres. In 1985, these three varieties were planted on less than 13% of the state's acreage. In comparison, Newbonnet and Lemont acreage increased from 6.5% in 1984 to almost 77% in 1985. During the 1990's, varieties like Bengal, Cypress, Drew, Kaybonnet and LaGrue increased the overall state average yields. A new era of rice varieties and new yield records has been realized during the first part of the 21st century. In 1999, Wells and Cocodrie were released and rapidly increased to combine for more than 65% of the acreage. Since the release of these varieties, record yields have been achieved each year between 2001 and 2004. New technology is poised to again raise the bar for rice yields in Arkansas. Hybrid rice with excellent yield potential is currently limited by seed production. The expansion of Clearfield rice is certain to have a positive impact by allowing red rice-infested acres to be unaffected by the yield and quality-liming effects of this weed.

Between 1967 and 1985, rice acreage increased from 202,000 hectares to over 600,000 hectares. This increase in rice acreage may have contributed to the lower yields of the late 1970s and early 1980s. Two additional factors contributing to lower yields were marginal land being placed in production and producers adjusting to managing more acres. In addition to the availability of improved varieties, other events have significantly impacted Arkansas rice production over the past 30 years. In 1975, 53 rice growers in 11 counties field tested an alternate method of timing midseason nitrogen fertilizer applications. The program, now known as the computerized DD50 program, helps farmers with 28 management decisions and is used on 50% or more of the state's acreage. Other important events and dates in Arkansas rice production include the opening of the Rice Branch Experiment Station in 1926, the introduction of propanil to commercial rice fields in 1961, the introduction of molinate to commercial rice fields in 1968, the release of Katy as a blast-resistant variety in 1989, the introduction of gibberellic acid seed treatment in 1990, the introduction of Facet to commercial rice fields in 1992, the introduction of Quadris, the first strobulin-type fungicide, to commercial rice fields in 1997, the completion of the Dale Bumpers National Germplasm Center completed in 1998, the introduction of Command for use in commercial rice fields in 2000, and the introduction of Clearfield rice and Newpath for controlling red rice.

The future of rice production is dependent upon conservation of our natural resources. Most rice production in Arkansas has been dependent upon groundwater for irrigation, but this valuable resource is rapidly diminishing. Irrigation districts, surface water impoundments, and other technological advances are needed to allow Arkansas rice farmers to continue to be successful for future generations. Research and Extension programs have played a pivotal role in the success of rice production in Arkansas during the 20th century. This institution should continue to seek answers to improve the sustainability of rice production for the 21st century.

Blast Field Resistance Utilized in Arkansas during Record Rice Production Years 2001-2005

Lee, F.N., Cartwright, R.D., and Wilson Jr., C.E.

Rice (*Oryza sativa* L.) is a critical commodity in the Arkansas agricultural economy. A sustained period of historic per-acre rice production was realized for Arkansas during years 2001 to 2005. Modern cultivars grown during this period possessed a very high yield potential packaged with multiple desirable agronomic characteristics. One key component of the package was the control of the erratic niche disease, rice blast, incited by *Magnaporthe grisea* Cav. During this period, rice producers utilized flood-induced field resistance for efficacious blast control when growing susceptible cultivars including Wells, Cocodrie, LaGrue, Francis and CL161.

Although available, less than 15% of the state acres were planted to cultivars containing major resistance genes during the 5-year period. In the absence of effective major genes, producers rely upon inherent field resistance for blast control. Field resistance is impacted by cultural practices, primarily fertility and irrigation, and, at times, must be complimented by fungicides. Flood-induced field resistance develops as root zone dissolved oxygen is depleted to establish anaerobic conditions. Anaerobic conditions determine availability and form of plant nutrients associated with blast susceptibility, enhance production of hormones linked with disease resistance mechanisms, and induce morphological modifications that facilitate oxygen transport to the roots and restrict pathogen growth.

Test data from replicated greenhouse and field pathogenicity tests show blast to be much more severe when susceptible rice cultivars are moisture stressed than when growing in a continuous flood. Research and field observations show flood-induced resistance to be cumulative with duration and depth of flood. The magnitude of resistance in certain susceptible cultivars becomes comparable with that expressed by major R genes. In tests conducted to date, some degree of flood-induced field resistance has been detected in all rice cultivars inoculated with a virulent race.

On the whole, blast susceptible cultivars where planted to more that 80% of planted acres during 2001–2005. These cultivars exhibit flood-induced blast field resistance but are susceptible to panicle blast when growing in drought-stressed blast field nurseries where panicle blast ratings of moderately susceptible (MS) to very susceptible (VS) are common. These susceptible cultivars typically escape severe blast in statewide disease test plots and production fields, especially if growers are careful about field selection and irrigation schedules. LaGrue and Frances placement is restricted by rice blast.

The cultivar Cocodrie has a nursery panicle blast rating of MS to S, has good field resistance, and was planted to 10% of state acres in 2001, peaked at 29.3% in 2003 but declined to 9.4% in 2005. Wells has nursery panicle blast ratings of MS to VS, was planted to 29.7% of state acres in 2001, peaked at 46.8% in 2003, and declined to 37.3% in 2005. The more susceptible LaGrue has a nursery panicle blast rating of VS, was planted to 10% of state acres in 2001 and then gradually replaced by the higher yielding but equally susceptible Francis, planted to 10.6% of state acres 2005. Field resistance is undetermined for CL161 which was planted to 19.2% of state acres in 2005.

Historically, field resistant cultivars have performed exceptionally well in Arkansas. Two outstanding examples are Starbonnet and Cypress. The very popular Starbonnet, which replaced Bluebonnet to become the number one cultivar from 1969 through 1984, was planted to 42 to 65% of state acres. Cypress was planted to 15 to 39% of state acres from 1994 through 2000. In inoculated greenhouse tests, Starbonnet and Cypress rated susceptible to multiple blast races commonly found in Arkansas. However, unless placed under significant drought stress, neither cultivar was considered to be blast susceptible in production fields.

Challenges of the Arsenic Crisis to Rice Production

Loeppert, R.H.

Arsenic, especially inorganic arsenic as As^{III} (arsenite) and As^{V} (arsenate), is toxic to both plants and animals. But, recently, there has been considerable national and international attention to arsenic, especially within the environmental and health sectors in response to toxicological evidence and the increased understanding of the carcinogenic and mutagenic characteristics of arsenic. These concerns have prompted the USEPA to lower the maximum allowable concentration of arsenic in municipal drinking water from 50 µg/L to 10 µg/L. These concerns also directly and indirectly impact the entire agricultural industry, but especially the rice industry. Concern within the rice industry has been prompted by several recent reports of relatively high concentrations of arsenic in several samples of U.S. rice grain.

The objective of the current paper is to review what is currently known (and not known) about arsenic in rice, with emphasis on (i) the possible cause of genetic variability in arsenic concentration and speciation in rice grain and (ii) the impact of soil and crop management variables on rice grain arsenic concentration.

The arsenic concentration in rice is highly variable. The predominant forms of arsenic in rice grain are inorganic As(III) and As(V), monomethyl arsonic acid (MMA), and dimethyl arsinic acid (DMA). Inorganic forms of arsenic are approximately 20 times more toxic to humans than are MMA and DMA. The few published studies on arsenic speciation of USA rice have shown that between 10 and 90% of the total arsenic content is inorganic, with the remainder predominantly methyl arsenic forms. This wide range reinforces the need to assess inorganic as well total arsenic contents of rice. These same forms of arsenic will exist naturally in the soil, though usually the inorganic forms are in much higher concentration and generally are more readily taken up by the rice plant. Rice varieties appear to differ considerably in their tendency to transport arsenic to the rice grain. There is some contradiction in the literature, though it appears that major proportion of methyl arsenic in rice grain is present as a result of biological methylation of inorganic arsenic within the plant. These observations suggest that rice varieties can be selected for reduced arsenic translocation to grain and reduced inorganic to total arsenic ratio.

Previous studies have indicated that high arsenic concentrations in soil can induce the physiologic disorder 'straighthead' and thus result in significant reductions in grain yield. High arsenic levels from soil impact reproductive tissues and cause panicle abnormalities, resulting in sterility and reduced grain yields. Rice varieties differ considerably in their susceptibility to straighthead. However, in the case of arsenic-induced straighthead, it is not known whether straighthead resistance involves an avoidance mechanism (i.e., reduced arsenic uptake and translocation) or a tolerance mechanism (i.e., tolerance to high arsenic). The physiologic basis for (i) straighthead resistance and (ii) the relationship between grain arsenic concentration and speciation and straighthead susceptibility have yet to be established.

Arsenic is especially problematic with rice due to the higher solubility of arsenic in soil under the reduced conditions of flooded rice culture. The phenomenon is due predominantly to the dissolution of soil iron oxides under reduced conditions and the subsequent release of arsenic. Under these conditions, arsenic is potentially more bioavailable for uptake by plant roots and subsequent transport to grain. Arsenic concentrations of soil can vary considerably and, in the southern United States, are strongly impacted by the historical use of rice lands for cotton production for which arsenicals had previously been used as defoliants and desiccants. Arsenic toxicity and its bioavailability are more strongly related to the concentration of dissolved pore water arsenic than to total soil arsenic concentration. For a given soil under flooded conditions, a positive correlation between dissolved arsenic concentration and total soil arsenic concentration might be expected. Several other soil factors could also strongly impact arsenic solubility: (i) organic matter, (ii) Fe oxide mineralogy, and (iii) soil phosphate status. Organic matter can play a dominant role because of it impact on microbially induced oxygen depletion, soil redox potential, and the resulting solubility of soil arsenic. Soil iron oxides impact arsenic dynamics and solubility because of their role in arsenic retention in soil and in iron plaque development at the surface of rice roots. Of these three factors above, organic matter might be especially relevant to rice production systems in the southern United States because of the use of organic amendments in the production of organic rice. A major, possibly dominant, factor that impacts soil arsenic bioavailability is soil water status, predominantly because of its impact on soil redox potential and arsenic solubility. Flooding usually results in an increased concentration of dissolved phosphate and arsenic. Water management might be an important "tool" to minimize arsenic hazard.

Rice Response to Potassium Fertilization Rate on Silt Loam Soils in Arkansas

Slaton, N.A., DeLong, R.E., Norman, R.J., Wilson Jr., C.E., Golden, B.R., and Baquireza, C.J.

Flood-irrigated rice (*Oryza sativa* L.) is considered to be a scavenger of soil potassium (K) due to its prolific fibrous root system and increased K availability following flooding. Potassium fertilization recommendations for rice grown on silt and sandy loam soils have been questioned during the last 15 years because of the increased yield potential of rice and rotational crops and the increased frequency of K deficiencies of rice. The primary objectives of this research were to 1) conduct K fertilization trials to correlate Mehlich-3 soil-test K to rice yield, 2) calibrate K fertilization rate to soil-test K level, and 3) evaluate rice and soybean responses to annual K fertilization rate across time. The ultimate goal of this project is to provide accurate soil-test based K fertilization recommendations that maximize yield potential of rice grown on silt and sandy loam soils.

Annual K fertilization trials were conducted with rice during 2004 and 2005 on silt loam soils in eastern Arkansas at 16 sites. Composite soil samples from each site were collected before fertilizer application and extracted with Mehlich-3 solution to estimate K availability. Mehlich-3 soil K ranged from 63 to 164 mg K/kg. Muriate of potash fertilizer was applied to the soil surface at rates ranging from 0 to 148 kg K/ha. Whole-plant samples were collected at panicle differentiation and early heading to monitor tissue K concentrations and plant uptake. Grain yield was measured at maturity.

A long-term study was established on a Calhoun silt loam to monitor rice and soybean [*Glycine max* (Merr.) L] responses to annual K fertilization rate in 2000. Wells rice was grown in 2000, 2002, and 2004 and soybean was grown in 2001, 2003, and 2005. Annual K rates of 0, 28, 56, 84, and 112 kg K/ha have been applied each year since 2000. Soil and plant measurements as described for the annual K trials have been collected each year.

Rice grain yields in 10 of 16 K fertilization trials have responded positively and significantly to K fertilization. Relative yields of the unfertilized control were 68 to 103% of the highest yielding K application rate. The correlation between relative rice yield and Mehlich-3 soil K was significant ($P = 0.0790$) and nonlinear, but soil-test K explained only 32% of the variation in relative rice yield. The relationships between whole-plant K concentrations at the panicle differentiation (PD) and early heading stages (HDG) with Mehlich-3 K were also significant ($P < 0.05$) and nonlinear at PD and linear at HDG. Whole plant K concentration explained 81 and 66% of the variability in whole-plant K concentrations at PD and HDG, respectively. Correlation data suggest that Mehlich-3 soil K is a good predictor of rice tissue K concentrations, but Mehlich-3 K alone does not accurately assess whether rice yield increases will occur from K fertilization. The relationships between whole-plant K concentrations and relative yield were significant, but similar to Mehlich-3 soil K, explained less than 32% of the variability in yields.

For the long-term K rate study, soil samples collected in 2000 showed the research area contained uniform concentrations of soil-test K at the start of the study. For the first two crop rotation cycles, rice yields (2000 and 2002) were similar among K application rates. Soybean yields in 2001 were significantly increased by application of K fertilizer, regardless of rate. In 2003, soybean receiving K produced numerically higher yields than the unfertilized control, but the differences were not statistically significant. Beginning with the third crop rotation cycle, significant yield differences due to K fertilization rate occurred for rice (2004) and soybean (2005). Crop yields receiving K fertilizer have produced greater yields than the unfertilized control. In general, rice and soybean yield response increased linearly as K fertilizer rate increased with the greatest yields produced by application of 112 kg K/ha. Although annual Mehlich-3 K concentrations often differed among the annual K rates, the K availability index of the unfertilized control has not declined as rapidly as expected.

Data suggest that soil-test K is not a highly accurate predictor of whether rice will respond to K fertilization. Significant rice yield increases from K fertilization occurred about 60% of the trials when Mehlich-3 soil-test K was <100 mg K/kg. The availability or size of another pool of soil K (e.g., non-exchangeable K), not assessed by the Mehlich-3 extractant, may play an important role in K availability for flood-irrigated rice. Alternatively, soil and crop management (e.g., previous crop yields and fertilization practices, rice yield potential, cultivar, etc.) factors may also play significant roles in determining whether rice responds to K fertilization. Additional trials and soil analyses are required to more accurately identify K-deficient soils used for flood-irrigated rice production.

Rice Response to P Application Rates and Timing

Walker, T.W.

The chemical changes that rice soils undergo after flooding have historically decreased the potential for rice grain yields to be increased by P application. In Mississippi (MS), the native levels of P and soil pH are adequate for optimum rice production. However, as native soils are disturbed by land-leveling and inundated with irrigation water high in calcium, the potential to obtain positive yield response from P-fertilizer increases. The percentage of fields that are precision-leveled has increased dramatically in recent years. Furthermore, the liming effect that irrigation water has on rice soils has not been balanced by equal amounts of acidity. Therefore, problems associated with P deficiency have increased. Research has been conducted in MS since 2002 with the overall objectives of better predicting those areas where rice yields would be increased and determining the optimum rates and application timings for various soil environments.

Experiments were conducted at four sites in 2004 (Aguzzi04, Boone, Richard, and Steele) and in 2005 (Aguzzi05-1, Aguzzi05-2, Gentry05-1, and Gentry05-2). Five of the experiments consisted of factorial combination of treatments including three P rates (12, 25, and 50 kg P ha^{-1}) and two application timings (1- and 5-leaf) with an untreated control. The Aguzzi04 location contained the same rates but two additional timings {panicle differentiation (PD) and boot (BT)} were included. The three rates of P and the untreated check were the only treatments evaluated at the Richard location. In addition to the 1- and 5-leaf timings, there was a fall timing included at the Aguzzi05-1 location. Applications made at 1- and 5-leaf were made using a custom-manufactured, self-propelled fertilizer distributor equipped with a Hege belt cone and a zero-max. Phosphorus treatments made after permanent flood establishment were broadcasted onto the flooded plots by hand. Tissue samples were collected from 0.9 m of row on the first inside row of the plots on 14-d intervals beginning 14 d after permanent flood establishment. The samples were analyzed for total P with appropriate methods by the Mississippi State University Soil Testing and Plant Analysis Laboratory. Nitrogen fertilizer applications and pest management practices were conducted by the cooperator and were similar to those recommended by the Mississippi State University Extension Service. At maturity, plots were harvested with a small plot combine, and yields were adjusted to 12% moisture. Data were subjected to analysis of variance to determine any differences among treatments. Means were separated using Fisher's LSD at the 0.05 level of significance.

Over the 8 site years, significant grain yield responses were obtained at five locations. Application timing significantly affected rice grain yields at Aguzzi04, Boone, Aguzzi05-1, and Aguzzi05-2. Averaged across P rates, the 1-leaf timing was superior to all other timings except for the Aguzzi05-2 location, where the 5-leaf timing produced the greatest yields. The yield responses were 5, 8, 8, and 54%, for the Aguzzi05-2, Aguzzi05-1, Boone, and Aguzzi04 locations, respectively. Phosphorus rate significantly impacted yields at the Aguzzi04 and Boone locations. At the Boone location and averaged across application timings, 25 kg P ha^{-1} produced greater yields than 12 kg P ha^{-1}; however, the untreated check though numerically lower than the two highest rates where not significantly different. At the Aguzzi04 location and averaged across application timings, 25 kg P ha^{-1} produced the highest yield which was 33% greater than the untreated check. Finally, 12 kg P ha^{-1} produced equal yields to the higher rates but 16% greater yields than the untreated check at the Richard location. Though the tissue data are not reported in this paper, a significant positive correlation (r^2=0.65) was obtained between the tissue concentration from the whole plant collected 2 weeks after permanent flood establishment and rice grain yield for the 2004 locations that responded to P fertilizer.

These data suggest that applications made near planting but before permanent flood establishment produce the greatest yield response. Additionally, rates appear to be dependent on soil test P, pH, and history of P applications. These data will be combined with previously reported data in addition to soil and tissue data with the goal of improving the precision and accuracy of the current P recommendations. As growers and crop input providers adopt precision agriculture technologies, this research is critical so that nutrients such as P can be applied in areas where an economical response is probable.

Rapid Response Research Addressing Acute Salt Contamination of Rice Soils Following Hurricane Rita

Bond, J.A., Blanche, S.B., Saichuk, J.K., and Breitenbeck, G.A.

On September 23 and 24, 2005, Hurricane Rita struck the coast of southwestern Louisiana and southeastern Texas as a Category IV storm on the Saffir-Simpson Hurricane Scale. In the days following landfall of Hurricane Rita, an unprecedented storm surge inundated the coastal parishes of southwestern Louisiana, including part of Calcasieu, Cameron, Jefferson Davis, Vermilion, and Iberia parishes. The storm surge covered approximately 7,500 square kilometers (2,900 square miles) with water containing varying levels of soluble salt. Some flooded areas were covered with freshwater from lakes and bayous pushed out of these bodies by the force of brackish and saltwater from coastal marshes and the Gulf of Mexico. However, other areas were covered by concentrated saltwater from the Gulf of Mexico. The flood persisted as long as 3 weeks in some areas. The storm surge affected a myriad of agricultural lands, but a majority of the impacted areas are located in the rice-growing region of southwestern Louisiana. These extraordinary circumstances made clear definition of the effects of the storm surge extremely difficult. The levels of soluble salts remaining after the floodwater receded are cause for major concern and have left the productivity of large tracts of rice soils in serious question for the 2006 crop year.

Efforts are underway to define the extent and severity of salt contamination, to interpret results of soil tests revealing levels of salt contamination, and to offer recommendations for remediation of the contaminated soils. In a cooperative endeavor between Louisiana State University AgCenter personnel and private industry, grid soil samples were collected from the affected areas. Laboratory analyses indicated that soluble salt levels in saturated extracts of surface soil (0 to 8 cm) ranged from 0.23 to 49.1 dS/m (20 to 13,500 ppm); therefore, some areas were much more severely affected than others.

Greenhouse bioassays and laboratory analyses are under way to address rice production issues associated with the storm surge. Soil from seven sites in the affected areas was collected, and laboratory analyses determined that soluble salt levels in these soils ranged from 0.92 to 12.9 dS/m (590 to 8,270 ppm). A greenhouse bioassay showed that seedling emergence and plant dry weight 21 DAP were not affected in soils with EC_e values <1.5 dS/m (980 ppm), whereas seedling emergence was reduced at least 76% in soils with EC_e values >10 dS/m (6,430 ppm). Other greenhouse research will be conducted throughout the winter of 2005 and 2006 to address the issue of salt contamination in rice soils in Louisiana.

Causes of Localized Decline of Flooded Rice in South Louisiana

Breitenbeck, G.A. and Saichuk, J.K.

During the past decade, an unexplained disorder has been observed in numerous rice fields in southwestern Louisiana. Symptoms usually appear early in the season prior to internode elongation in localized areas where stunted stands fail to tiller. Unless the field is drained immediately, symptoms can rapidly spread across a field, but symptoms seldom, if ever, cross over a levee. Afflicted plants fail to mature and yields are substantially reduced. Because the cause of this disorder cannot be attributed to typical disease, insect, or nutrient problems, it has been dubbed the 'mystery malady.'

A study was initiated to (1) identify specific early-season symptoms of this disorder, (2) to test many of the hypotheses proposed to account for its cause, and (3) to identify treatments that could reliably induce symptoms under greenhouse conditions. In 2005, producers were encouraged to promptly report a suspected occurrence of the disorder to county agents. More than 60 occurrences were reported and site visits identified 29 of these sites as highly representative of the disorder. At each of these 29 sites, samples of soil, above and below ground biomass, and irrigation water were collected. For comparison, a corresponding set of samples were collected from a nearby area under similar management identified by the grower as 'healthy.' A detailed survey was also completed for each site to determine whether the disorder was associated with crop variety, prior land use, or other specific production practices.

Afflicted areas typically consisted of thin stands of stunted plants. Plant heights averaged 56% of those in adjacent healthy areas. Above and below ground biomasses were reduced 82 and 65%, respectively. In addition to stunted growth, stands were reduced by the failure of afflicted plants to tiller. Occasionally, a large percentage of seedlings had died as well. Viewed from a distance, an afflicted area displays a reddish-brown hue. The most definitive symptom was the presence of reddish spots on the lowest erect leaf. Microscopic investigation shows that the cuticle remains intact, and the discoloration arises as blotches of reddish color within the underlying leaf tissue. These symptoms are more indicative of a metabolic disorder induced by herbicides or nutrient imbalance than of an infection caused by a pathogen.

Plant tissue analyses strongly suggest that this disorder is induced by a combination of excessive iron (Fe) and deficient zinc (Zn) uptake. Fe concentrations in the aboveground portion of afflicted plants averaged 1645 mg/kg whereas the corresponding tissue of healthy plants contained 426 mg/kg. Zn concentrations averaged 17 and 26 mg/kg in afflicted and healthy plants, respectively. Published values suggest that concentrations of >500 mg Fe/kg are toxic to rice plants, whereas <20 mg Zn/kg indicates deficiency. Moreover, high levels of Fe interfere with the ability of the plant to utilize Zn. Sulfur tended to be very low in both above and below ground tissue in all samples, eliminating sulfide toxicity as a possible cause of the disorder. Phosphorus uptake was good in all samples, but potassium tended to be near deficiency levels. N was consistently far below deficiency levels in both afflicted and healthy plants at this critical vegetative stage.

Producer survey responses did not suggest herbicide use as a cause. High rice water weevil larval populations were found at a few sites but not at most. There was no other evidence of significant insect damage. The disorder was observed in conventional till, no-till, and stale seedbed systems. It occurred in drill- and water-seeded and broadcast rice. It occurred in fields previously used for crawfish, soybeans, and rice and in fields fallowed the previous year. For nearly half the afflicted sites, symptoms were first evident near the riser in the top field. While this suggests a connection with irrigation water, analysis of both the water and soils failed to establish a clear linkage.

A greenhouse study showed that the characteristic symptoms of this disorder could be induced by incorporating readily decomposable organic matter (6.7 Mg/ha; 3 T/A) or trace amounts of sodium molybdate to inhibit sulfate reduction. Additions of Zn-EDTA plus potassium sulfate prevented symptoms from occurring in soils with a history of this disorder and led to substantial increases in both seedling growth and tillering.

Evaluation of Several Indices of Potentially Mineralizable Soil Nitrogen on Arkansas Silt Loam Rice Soils

Bushong, J.T., Norman, R.J., Ross, W.J., Slaton, N.A., and Wilson Jr., C.E.

A reliable nitrogen (N) soil test that accurately predicts N mineralization in rice soils has long been sought. Currently, in Arkansas, N fertilizer recommendations are based upon crop/cultivar needs, soil texture, and/or previous crop and do not take into account the N mineralized from the soil organic fraction. Not taking into account the N mineralization of the soil organic fraction can lead to over- and under-N fertilization. It is known that under-fertilizing can decrease rice grain yields; however, over-fertilizing with N can decrease yields due to increases in disease, mutual shading, and lodging. In addition, over-fertilizing with N increases fertilizer and application costs and could potentially contaminate nearby surface and groundwater. Over the years, numerous analytical methods have been proposed, but no one method has been widely accepted. Biological or incubation studies have been shown to have the highest correlation with N uptake in field studies; however, the time needed for incubation does not lend them to be practical for soil testing use. Research conducted at the University of Arkansas back in 1994 concluded that a 14-d anaerobic incubation accurately predicted N uptake in greenhouse-grown rice. Other researchers have evaluated quick analytical procedures that utilize some form of a chemical reaction to predict N mineralization. Procedures of interest are acid oxidation, ultraviolet absorption of soils extracted with a mild salt, and diffusion of amino sugar-N. Therefore, the objective of this study was to compare the aforementioned analytical methods for predicting N mineralization with the NH_4-N mineralized after a 14-d anaerobic incubation utilizing Arkansas silt loam rice soils.

Sixteen silt loam soil samples were collected from the rice-growing region of Arkansas. Samples were initially oven-dried and crushed to pass a 2-mm sieve. The anaerobic incubation procedure, which acted as the standard in this study, was carried out by incubating the soils anaerobically, for 14 d at 40^{o}C. After incubation, NH_4-N concentration was determined using steam distillation techniques. For the acid oxidation procedure, soils were extracted with H_2SO_4 + $KMnO_4$, and the amount of NH_4-N extracted was determined using steam distillation techniques. The diffusion of amino sugar-N was conducted according to the Illinois Soil N Test (ISNT), in which soils were heated in NaOH solution and the amount of NH_4-N released was measured using mason-jar diffusion techniques. Ultraviolet methods were conducted by extracting the soil with KCl and the extract was either analyzed at 260 nm or the NO_3 reduced using Devarda's alloy and analyzed at 210 and 260 nm. Simple linear regressions were utilized to determine which method most accurately predicted the NH_4-N mineralized after a 14-d anaerobic incubation.

For all analytical methods evaluated, significant relationships were observed with the anaerobic incubation procedure. However, some methods performed better than others. The acid oxidation method performed the best of all methods, by displaying a coefficient of determination of 0.83. It was observed the diffusion of amino sugar-N using the ISNT method also accurately predicted anaerobic incubation values with a coefficient of determination of 0.71. The ultraviolet method with NO_3 measured at 260 nm performed fairly well with a coefficient of determination of 0.63. However, the extractions in which NO_3 was reduced and the absorbances measured at 210 and 260 nm displayed unacceptably low coefficients of determination (R^2 = 0.48 and 0.38, respectively).

In conclusion, if the concentration of NH_4-N mineralized after a 14-d anaerobic incubation is a reliable indicator of the native soil N mineralized and taken up in field-grown rice, then it can be assumed that the acid oxidation followed by diffusion of amino sugar-N using the ISNT to be the accurate methods for predicting N mineralization in the field.

Evaluation of the Illinois Soil N Test to Determine Mineralizable N in Arkansas Rice Production

Ross, W.J., Norman, R.J., Wilson Jr., C.E., Slaton, N.A., and Bushong, J.T.

Routine soil testing is used to predict the need for applications of P, K, and other essential elements for rice (*Oryza sativa* L.) production in Arkansas. However, N applications are often based on soil texture, rotation, and variety. This method of N recommendation may cause an under or over fertilization of rice since native soil N availability is not taken into account. Lack of N due to insufficient application of N fertilizers can result in economic loss due to reduced yields, while over application of N can result in loss due to crop lodging and increased susceptibility to diseases. Another concern of the over application of N fertilizers has been environmental pollution of ground and surface water. Because of these concerns, a quick and accurate soil testing method for predicting N fertilizer recommendations is needed.

Ideally, a soil test for N availability should be quick, easy, and have a high correlation with crop N uptake. Determination of plant available soil N is difficult due to the dynamic nature of soil N, which is effected by soil temperature and moisture. Both biological and chemical methods have been investigated as a measure of soil N availability, but none have been accepted as a routine soil N test. Recently, it was reported in Illinois that the amino sugar-N in the soil could be used to predict the amount of soil mineralizable N. The objective of this study was to evaluate the ability of the Illinois Soil N Test (ISNT) to predict the total N uptake of rice and ultimately the N fertility rates required by rice to optimize grain yield.

Rice N rate studies were conducted at five locations in 2003 and 2004. Locations were divided into silt loam and clay soil locations. The silt loam soil locations were the Pine Tree Experiment Station, Colt, AR; Rice Research and Extension Center, Stuttgart, AR; and the White River Ecosystem, Waldenburg, AR. The clay soil locations were the Northeast Research and Extension Center, Keiser, AR, and the Southeast Research and Extension Center, Rohwer, AR. The studies were arranged in a randomized complete block design. The rice studies were planted with the Medark cultivar at normal plant populations according to soil texture and planting date. The N rates were 0, 67, 101, 135, 168, and 202 kg N ha^{-1} for the silt loam soil locations and 0, 101, 135, 168, 202, and 236 kg N ha^{-1} for the clay soil locations. Recommended P, K and other nutrients were applied according to soil test results. Soil samples were taken prior to preflood N fertilizer application. Eighteen to 20 soil cores at a depth of 10 cm were combined from each unfertilized check plot at each location. Soil samples were oven-dried, ground to pass through a 2 mm sieve, and stored for analysis. Rice tissue samples were collected at 50% heading by removing the aboveground portions of a 1-m section of an inner row from each plot. The tissue samples were oven dried to a constant weight, weighed, ground, and analyzed for total N determined by combustion.

The ISNT was performed by diffusing 1 g of dry soil with 10 ml of 2 *M* NaOH in a modified Mason jar. A Pyrex Petri dish containing 5 ml of a 4% H_3BO_3 indicator solution was placed in the modified Mason jar to capture the liberated NH_4. The diffusion unit was heated at 48 to 50ºC on a modified hot plate for 5 hours. After completion of the diffusion, the Petri dish was removed from the jar, 5 ml of deionized water was added, and NH_4-N in the H_3BO_3 solution was determined by titration with 0.01 *M* H_2SO_4 using an automatic titrator. Rice and wheat tissue samples were collected at 50% heading by removing the aboveground portions of a 1-m section of an inner row from each plot. The tissue samples were oven dried to a constant weight, weighed, ground, and analyzed for total N determined by combustion.

Rice grain yields when no N fertilizer was applied ranged from 1789 to 6972 kg ha^{-1} and 1778 to 9343 kg ha^{-1} in 2003 and 2004, respectively. Total N uptake when no N fertilizer was applied ranged from 27 to 125 kg N ha^{-1} and 21 to 117 kg N ha^{-1} in 2003 and 2004, respectively. The values obtained from the ISNT ranged from 100 to 196 mg NH_4-N kg^{-1} for both years. Using straight-line regression techniques, a poor relationship between NH_4-N from the ISNT and total N uptake of rice was seen (R^2=0.04).

The ISNT method was not sensitive enough to predict rice N uptake or grain yield with 2 years of data. Since the soils in Illinois are very different than the soils in the rice producing portion of Arkansas, the ISNT may not be a good predictor of rice N fertilization requirements in Arkansas. Additional studies are currently underway to examine the acid hydrolysable fractions of the soils used in this study.

The Urea-Nitrogen Equivalence of Fresh and Pelleted Poultry Litter for Flood-Irrigated Rice

Golden, B.R., Slaton, N.A., Norman, R.J., Gbur, E.E., Brye, K.R., and Delong, R.E.

Long-term application of high poultry litter rates to pastures near the point of its production has sustained excellent forage yields in western Arkansas, but soil phosphorus has accumulated to excessive levels and is considered a non-point source of nutrient pollution to surface waters in some areas. One alternative use for poultry litter 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 recently leveled fields, but its value as a 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 objectives of this research project were to determine the N-fertilizer value of fresh and pelletized poultry litter applied preplant to soils used for the direct-seeded, delayed flood rice production system.

Experiments were established during 2003 and 2004 at the Rice Research and Extension Center (RREC) on a Dewitt silt loam and the Pine Tree Branch Station (PTBS) on a Calhoun silt loam. At the PTBS, a single experiment was established in 2003, but, in 2004, two adjacent studies that differed only in floodwater management were established. The permanent flood was established at the normal time (NF, 5-leaf stage) or delayed (DF, 5-leaf + 9 d). The flood was applied at the normal time for all studies conducted during 2003 and at the RREC in 2004. Soybean [*Glycine max* (Merr.) L.] was the previous crop grown at all site-years. 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^{-1}, and mechanically incorporated within 3 hours of application. Wells rice was drill seeded at 112 kg ha^{-1}. 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^{-1} 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 to a constant weight, weighed, ground to pass a 1-mm sieve, and whole-plant N concentration was determined by combustion. Net N uptake was calculated by multiplying %N concentration by dry matter and subtracting the untreated control and expressed as kg N ha^{-1}. 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. The net-N uptake and grain yields were initially regressed on N-rate allowing for both linear and quadratic terms with coefficients depending on N-source and site-year. Non-significant model terms were removed sequentially and the model was refit until a satisfactory model was obtained. Differences among all remaining coefficients, which varied by N source, site-year, or both, were determined using single degree of freedom contrasts. All statistical analyses were conducted using SAS version 9.1.

Regression analyses indicated that the N source % rate interaction was highly significant for net N uptake at PD and HDG and grain yield. Rice grain yield and net N uptake increased linearly or non-linearly as N rate increased within each N source. The linear and/or non-linear slope coefficients were always similar between litter sources among site-years, but significantly lower than the coefficients for urea applied preflood. Averaged across litter-N application rates, rice recovered <10% of litter N by PD and <25% of litter N by HDG compared to >40% recovery of urea-N. On average, preplant incorporated poultry litter applied at rates of 5,000 to 6,000 kg ha^{-1} resulted in similar rice N uptake and grain yield as about 68 kg N ha^{-1} applied as urea to a dry soil surface preflood.

Net-N uptake data showed that recovery of urea N at PD and HDG was about six times more efficient as the recovery of total litter N. Poultry litter applied at 1500 to 2500 kg ha^{-1} would supply adequate P or K for most silt-loam soils that receive recommendations for P or K and would generally supply 50 to 100 kg total N ha^{-1}. For this range of poultry litter application rates, poultry litter would contribute only 7 to 14 kg N ha^{-1} towards fertilizer-N uptake by HDG. Net-grain yield data indicated that the urea-N equivalence of the total-N in poultry litter was about 25%. Therefore, preflood urea-N rates should be reduced by 25% of the total-N applied as poultry litter.

Increasing N Uptake Efficiency through Banded Fluid Fertilizer in Texas Rice Production: A 3-Year Summary

Turner, F.T., Tarpley, L., Jund, M.F., Hebert, M., and Hagler, D.R.

Historically, most fertilizer has been aerial applied to drill-seeded rice in the southern U.S. in two to four applications during the growing season because aerial application is quick, fields are flooded, and multiple applications increase efficiency of topdressed N. Banded fluid fertilizer has the potential to reduce fertilizer application cost by applying 75 to 100% of total N at planting and increase N uptake efficiency by reducing ammonia volatilization and denitrification. Our objective was to determine if subsurface banding of fluid fertilizer while planting can improve the economics of rice production by increasing N fertilizer uptake, improving yield, and reducing fertilizer application cost. Studies were conducted on clay soil near Beaumont, Texas, in 2003, 2004, and 2005 and on silt loam soil near Eagle Lake, Texas, in 2004 and 2005. The fluid treatments received 75 or 100% of the 168 kg N ha^{-1} at planting, with the remainder being applied as dry urea at midseason. Fluid fertilizer was banded 5 to 10 cm below the soil surface between every other drill row spaced 20 cm apart. Dry fertilizer treatments received 17 to 100% of the 168 kg N ha^{-1} as dry urea broadcast on the soil surface just prior to planting. Remaining N was applied at pre-flood and midseason. Fertilizer treatments were superimposed on flood irrigation treatments consisting of establishing the flood at the 4- or 6-leaf growth stage.

Plant N content and rice yield were measured under the two irrigation systems. Banding of fluid fertilizer and early flood increased N content of rice plants receiving all N at planting. Applying 100% of total N as fluid at planting also produced numerically greater N contents when compared with 2-way (112 kg N ha^{-1} as fluid at planting + 56 kg ha^{-1} dry at midseason) and 3-way (28 kg ha^{-1} preplant, 84 kg ha^{-1} preflood, 56 kg ha^{-1} midseason) splits on clay soil.

Rice yields averaged across the 3 years show fluid fertilizer, when applied at 168 kg N ha^{-1} at planting, had only a 362 kg ha^{-1} yield advantage over dry urea when flooded at the 4-leaf growth stage on clay soil. When flooded at 6-leaf growth stage, yield advantage of fluid increased to 1081 kg ha^{-1}. The increased yield advantage for fluid at the 6-leaf flood was likely a result of decreased N efficiency for dry fertilizer when delaying flood to 6-leaf growth stage.

Applying fluid fertilizer all at planting had only a 280 kg ha^{-1} yield advantage over 2- and 3-way splits. However, the economic advantage of fluid was $101/ha ($41/A) and $131/ha ($53/A) for 2- and 3-way splits when flooded at 6-leaf stage on clay soil. On silt loam soils, fluid's yield advantage was less than that for clay soil resulting in economic advantages of $12/ha ($5/A) and $86/ha ($35/A) for 2- and 3-way splits, respectively. The better economics for fluid fertilizer is primarily a result of reduced application cost.

This study illustrates the pronounced effect of N fertilizer placement and timely flood establishment on N uptake efficiency and rice yield, especially on clay soil.

Evaluation of Several Nitrogen Fertilizers Applied Preflood to a Wet and Dry Soil in Delayed Flood Rice

Norman, R.J., Wilson Jr., C.E., Slaton, N.A., Frizzell, D.L., Griggs, B.R.,
Bushong, J.T., Ross, W.J., and Richards, T.L.

In the delayed, flood rice culture system, it is recommended that urea be the N source for the large, early N application and it be applied immediately before establishment of the permanent flood. Urea has many fine qualities, but it also has an undesirable characteristic in that it's 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. Most commercial rice fields require 5 to 10 days to get the floodwater across the field, and thus, there is potential for substantial ammonia volatilization losses of urea. In addition, the soil is not always dry when the preflood N fertilizer has to be applied and urea applied to muddy soil could aggravate 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 loss. Urease inhibitors have been promoted as a means to significantly slow ammonia volatilization losses from urea fertilizer and Agrotain is a urea fertilizer which contains the urease inhibitor NBPT. In light of these other two N fertilizers that are less susceptible to ammonia volatilization compared with urea, coupled with the difficulties of flooding a commercial rice field timely following application of the preflood N fertilizer and/or applying the urea fertilizer onto a dry soil surface; the objectives of this study were to evaluate urea, Agrotain, and ammonium sulfate applied to dry and muddy soil surfaces as to their ammonia volatility and influence on the grain yield of drill-seeded, delayed flood rice.

The studies were conducted in 2004 and 2005 at the University of Arkansas Rice Research and Extension Center on a Dewitt silt loam (Typic Albaqualfs) having a soil pH from 5.8 to 6.3. The cultivar Wells was seeded at 100 kg ha^{-1} 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. A split-plot experimental design with four replications was utilized with preflood soil moisture as the main plot and the subplot arranged in a factorial with N source, N rate, and N application time as the factors. In 2004, the fertilizer N sources were urea, Agrotain, and ammonium sulfate applied at rates of 0, 67.2, and 134.4 kg N/ha to a dry soil 3 and 7 days prior to flooding and a muddy soil 3 days prior to flooding. In 2005, the same N rates as in 2004 were used and the two N fertilizers were urea and Agrotain applied to a dry and muddy soil 1 and 5 days prior to flooding. Also, in 2005, ammonia volatilization of urea and Agrotain applied to the dry and muddy soil was measured using static chambers. At maturity, the plots were harvested with a small plot combine. Statistical analyses were conducted on grain yield and ammonia volatilization data with SAS and mean separations were based upon protected LSD where appropriate.

In 2004, the 67.2 kg N/ha fertilizer rate resulted in maximum grain yield for the best treatments and was better than the 134.4 kg N/ha rate in differentiating the three N sources. All three N sources applied to a dry soil 3 days prior to flooding resulted in a similar grain yield of around 10, 000 kg/ha. When the time between N application and flooding was increased to 7 days, grain yields significantly decreased compared with those measured at 3 days prior to flooding for urea. Agrotain and ammonium sulfate resulted in similar grain yields when applied 3 or 7 days prior to flooding. When the three N sources where applied to a muddy soil 3 days prior to flooding grain yields for urea, ammonium sulfate, and Agrotain were 7510, 8417, and 8618 kg/ha. Thus, grain yields were significantly less when the N sources were applied to a muddy soil compared with a dry soil, but Agrotain and ammonium sulfate resulted in significantly higher yields compared to urea when applied to a muddy soil. In 2005, urea and Agrotain were applied to a dry and muddy soil 5 days prior to flooding. The amount of N fertilizer lost via ammonia volatilization over the 5 days between N fertilizer application and flooding when urea was applied to a dry and muddy soil was 13 and >25%, respectively, while Agrotain applied to a dry and muddy soil only lost <2 and 8%, respectively. Highest grain yields were measured with the 134.4 kg N/ha fertilizer application for both sources. When urea and Agrotain were applied on a dry soil 1 day prior to flooding, grain yields of around 10,800 kg/ha were obtained. When the two N sources were applied to a dry soil 5 days prior to flooding, a yield of 10,634 kg/ha was obtained with Agrotain while urea produced a lower yield of 9677 kg/ha. Yields decreased when the two N sources were applied to a muddy soil compared with a dry soil, however, yields decreased much less when Agrotain was the N source. When the N sources were applied to a muddy soil 1 day before flooding, urea and Agrotain produced grain yields of 8690 and 9727 kg/ha, respectively. When the N sources were applied to a muddy soil 5 days before flooding, urea and Agrotain produced grain yields of 7484 and 9122 kg/ha, respectively. In conclusion, Agrotain or ammonium sulfate should be used if the preflood N has to be applied to a muddy soil. If the preflood N can be applied to a dry soil then Agrotain or ammonium sulfate should be used if greater than 3 days are required to establish a flood.

Abstracts of Posters on Rice Culture
Panel Chair: L. Tarpley

Measurement of Canopy Level Photosynthesis of Three Rice Cultivars in a Portable Field Chamber

Medley, J.C. and Wilson, L.T.

A canopy chamber was designed and constructed that could be utilized with the LiCor LI-6400 Photosynthesis Meter for measuring photosynthesis of rice plants in a flooded field. The chamber encompassed two rows of rice plants (20.3 cm row spacing), 1 m in length. The chamber was built in three sections so that height could be adjusted to accommodate plant height over the growing season. The field chamber was used to measure the canopy gas exchange of three rice varieties, Francis, Jupiter and Cocodrie on August 2, 3, and 4, 2005, respectively. Data was logged every 5 minutes from approximately 10:30 AM to 2:00 PM on each day. Data collected includes the photosynthetic rate, PAR (Photosynthetic Active Radiation), ambient CO_2, and chamber temperature. Average photosynthetic rates were 13.6, 11.2, and 11.7 µM CO_2 m^{-2} s^{-1} for Francis, Cocodrie, and Jupiter, respectively. The low gas exchange rates are due to the measurements being taken late in the season during soft-dough or milk stage. Average PAR values were similar for August 2 and 3 when measurements were taken on Francis and Jupiter (1209 and 1189 MJ m^{-2} s^{-1}), but August 4, when measurements were taken on Cocodrie, was a very hazy day and the average value was 951 MJ m^{-2} s^{-1}. Chamber temperatures were also lower on August 4 because of the hazy conditions. Average temperatures were 31.93, 31.50, and 30.03^{o}C for Jupiter, Francis, and Cocodrie, respectively.

Development of a Growth Model for the Phenology of California Rice Cultivars

Wennig, R.L., Mutters, R.G., Greer, C.A., and Hill, J.E.

Rice degree day phenology models are not widely utilized for scheduling field management decisions in California. Degree day models developed for California are 10 to 15 years old and need to updated and modernized to improve user access. The DD50 model, used extensively in the southern states, may need to be modified for use in California. The purpose of this study is to collect morphologically accurate phenological data for the two most commonly grown medium-grain rice cultivars in the Sacramento Valley.

Initial field studies were conducted in 2005 in commercial fields at the southern and northern ends of the Sacramento Valley. Two medium-grain Calrose cultivars, M-202 and M-206, were grown in replicated plots at the two sites. The plots were direct seeded by hand into a continuously flooded field environment. The northern Butte County (warmer) site was planted 24 days later than the cooler Sutter County site. Water and air temperatures were recorded at both sites from planting to grain maturity. The Counce 'Uniform, Objective, and Adaptive System for Expressing Rice Development' was used to record leaf and reproductive stage development.

Initial results indicate that the rate of leaf development was similar for both cultivars at each site. However, the delayed planting date at Butte increased the daily accumulation of degree day (DD) heat units available for leaf development and reduced days to fourth leaf by 2 days compared with the Sutter site. The degree days required from fourth leaf to flag leaf were similar for both cultivars at both sites. At the Butte site, M-206 reached 50% heading (DTH) 7 days earlier and with 170 fewer DD units than M-202. At the Sutter site, M-206 only had a 2-day DTH and a 60 DD advantage. Both cultivars required a similar number of DD units to reach stage R9 (all grains are brown colored) at Sutter while M-206 needed significantly fewer DD units than M-202 to reach stage R9 at Butte. Degree day accumulation and the duration of daily temperatures within the growing limits will influence the number of days required to reach specific stages of rice development.

Instrumentation Enabling Study of Rice Plant Response to Elevated Nighttime Temperature

Tarpley, L., Mohammed, A.R., and Rounds, E.W.

High nighttime temperatures have been implicated in disappointing rice yields in the southern United States and throughout the world. The effects are diverse but can include: (1) coincidence of the period of unusually high nighttime temperatures with sensitive reproductive stages leading to poor seed set; (2) decline in vegetative carbohydrate and reduced nitrogen reserves associated with increased respiration which itself is commonly associated with high temperatures; and (3) alteration in developmental pattern or rate of development. The currently available apparatuses to study these effects are limited in either the ability to carefully control the elevated temperature, the ability to conduct replicated study of populations of plants, or in the ability to minimize perturbation of other environmental factors.

The additional heat needed to elevate temperature is provided through infrared heaters. The use of infrared heating for controlled elevated temperature is not new in plant biology, although most usage has been to mimic the effect of global warming of natural vegetation plots, i.e. Free Air Temperature Increase (FATI). Fairly unique to our described instrumentation is the level of control incorporated and, thus, the accuracy and precision with which the temperature can be maintained:

*The infrared heaters use a calomel sheath for the heating element, which has been documented to provide physiologically safe low output below 800 nm. In addition, the power to the lamps are supplied through a power semi-conductor (SCR) with "phase-angled fired" proportional control, thus the heaters and the power controllers have a long anticipated life; and smooth, rapid (in milliseconds), proportional heating action is obtained.

*The signal translated by the power controller is provided by a temperature controller with embedded internet and serial communications, thus allowing remote data acquisition and control (DAC) and flexible programming via OPC (OLE for Process Control) software on remote PCs. Combined with the high accuracy and temperature stability provided by these temperature controllers, this setup allows unique temperature studies, e.g., 0.5% increase with near-real time continuous adjustment over current ambient conditions. The RS-485 communications protocol allows a number of instruments such as the temperature controllers to be connected through a single industrial microserver.

* Temperature input is flexible, and can be through thermocouple, RTD, or process voltage/current. We've used thermocouples, thus providing flexibility for use of infrared (non-contact), rapid response (air temperature), or hypodermic needle-type (internal temperature of desired plant part) thermocouples. Thermocouples also allow flexibility in the types of measurements, for example, some of the global warming studies conduct a differential temperature measurement to constantly elevate treatment plots by a constant degree difference compared to controls.

The described apparatus can hold a nighttime setpoint +/- 0.5 deg K within the physiologically relevant ranges of 26 to 35°C as monitored using independent temperature acquisition units over the course of several studies of several nights duration. A natural vertical temperature gradient can be mimicked.

The apparatus is currently being used to study the effects of high nighttime temperature on several factors potentially affecting rice productivity. Results are being used to suggest novel management schemes or screenable traits in support of varietal improvement.

Validation of the Rice DD50 Threshold Establishment at Two Locations in Arkansas

Duren, M.W., Wilson Jr., C.E., Norman, R.J., Frizzell, D.L., Richards, A.L, and Slaton, N.A.

The University of Arkansas Rice Computerized DD-50 Program was established as a decision-making aid by predicting the timing of various rice (*Oryza sativa* L.) management practices. The program is utilized by farmers on approximately 50% of the rice acreage in Arkansas since 1974 and has been adapted by other southern U.S. rice-producing states. As new cultivars are developed and released, thresholds for the program must be determined by field testing. This field testing has historically been conducted at the Rice Research and Extension Center (RREC), near Stuttgart, AR. These field studies are used to determine the thresholds for 1.3-cm internode elongation and 50% heading. All other predictions are made relative to these primary growth stages. The data developed from these studies are then utilized to update the existing program to include these new cultivars. Recently, questions have been raised by producers in northeast Arkansas regarding the accuracy of the program since the thresholds are developed in a single location and adapted for the entire state. Therefore, the current study was conducted to compare actual thresholds determined in northeast Arkansas with those determined at RREC.

Field studies were implemented during 2003, 2004, and 2005 at the Northeast Research and Extension Center (NEREC), located near Keiser, AR, on a Sharkey clay (very-fine, smectitic, thermic Chromic Epiaquerts) and at RREC on a DeWitt silt loam (fine, smectitic, thermic Typic Albaaqualfs). Twenty cultivars were seeded each year at four seeding dates into 9-row plots that are 4.9 m long. The study was arranged in a randomized complete block design with four replications. Measurements of internode length were made as the rice approaches midseason to determine the day the plots reach 13-mm internode length. The date of heading (50% heading) was recorded. DD-50 thermal unit accumulation that was required to reach 13-mm internode elongation and 50% heading is then calculated beginning the day after emergence. Comparisons were then made utilizing linear regression between the accumulations required to reach P.D. and 50% heading at NEREC and RREC. In 2003, internode measurements were made on seven cultivars (Bengal, Cocodrie, Francis, Wells, XL-8, CL161, and Medark). In 2004, internode measurements were made on six cultivars (Bengal, CL161, Rice Tec CL XL8, Cocodrie, Francis, and Wells). In 2005, internode measurements were made on two cultivars (CL161 and Wells). Date of heading was determined on six cultivars in 2003, six cultivars in 2004, and four cultivars in 2005.

Standard thresholds currently utilized to update the Rice DD50 Computerized Program are developed at RREC. Linear regression was utilized to compare the thresholds determined at NEREC with those obtained at RREC between 2003 and 2005. The accumulations measured at NEREC were also compared by regression to the current thresholds utilized by the program. Results show that a strong positive linear relationship existed between the thresholds determined at the two locations for P.D. The slope was near 1 and the R^2 was 0.78. However, an intercept greater than zero indicates that the thresholds for NEREC may need to be adjusted slightly higher to more accurately predict rice growth rates in northeast Arkansas. When the thresholds determined at NEREC were compared with the standard thresholds, a strong linear relationship was observed with a slope near one and R^2 of 0.88. Again, a positive intercept suggested that higher DD50 accumulations are necessary at NEREC than at RREC to achieve the same growth stage. When the accumulations need to reach heading were evaluated, no relationship between the two locations were observed.

Seeding date studies conducted at NEREC suggest that the optimum planting window may be smaller for northeast Arkansas. More studies are needed to assess the differences in DD50 accumulations necessary to reach specific growth stages between various regions of Arkansas. The apparent requirement for more DD50 thermal units to reach specific growth stages may have some impact on differences observed in optimum planting dates. However, these questions need to be examined further.

Seeding Date Effect on Kernel Smut and Grain Yield of Rice in Arkansas

DeLong, R.E., Boothe, D.L., Slaton, N.A., Norman, R.J., Cartwright, R.D., Wilson Jr., C.E., and Duren, M.W.

Kernel smut, *Tilletia barclayana* (Bref.) Sacc. and Syd., of rice (*Oryza sativa* L.) has been a persistent fungal disease in Arkansas for more than 50 year. The effect of rice seeding date on the frequency and severity of kernel smut has not been thoroughly reported. Literature suggests that later-planted rice has a greater occurrence of disease. The presence of moisture near anthesis may be linked to the severity of kernel smut of rice. Management of kernel smut includes selecting the least susceptible cultivar, properly managing N fertilization, and timely applications of a fungicide to very susceptible rice cultivars. Cultural control of the rice disease is preferable since the symptoms of kernel smut are not visible until the grain-filling stage. A fungicide may need to be sprayed preventively or it may be too late for efficacious control of the disease. The objectives of our research were to evaluate the effect of seeding date and cultivar on the incidence and severity of kernel smut and grain yield of rice in Arkansas.

In 2003 and 2004, six long-grain rice cultivars ranging from moderately to very susceptible to kernel smut were direct-seeded in a Dewitt silt loam at the RREC (Stuttgart, AR) and a Sharkey clay at the NEREC (Keiser, AR). Rice cultivars susceptibilities to kernel smut were: 'Very Susceptible', Cocodrie, Francis, and LaGrue; 'Susceptible', CL161; and 'Moderately Susceptible', Ahrent and Wells. The experimental design was a randomized complete block with a split-plot factorial treatment structure. Three (RREC) or four (NEREC) replicates were used per treatment. Each plot contained nine, 4.9-m long rows with 18-cm row widths. Plots were seeded in April, May, and June. Urea-N application rates of 135 kg N ha^{-1} at the RREC and 165 kg N ha^{-1} at the NEREC were applied at the 5-leaf stage before a 10-cm deep flood was applied and maintained until near maturity. Thirty days after anthesis, 25 panicles were collected from each plot. Rice panicles were immersed in 0.27*M* KOH overnight, rinsed three times with water, and inspected over a light box to identify smutted kernels. Kernel smut incidence (sum of number of panicles with at least one smutted kernel divided by the total number of panicles multiplied by 100) and severity (total number of smutted kernels divided by the total number of kernels multiplied by 100) of the rice panicles were evaluated. Grain yield was determined at maturity.

For all site-years, grain yields were usually greatest when rice was seeded in April or early May and declined when seeding was delayed until late May or June. In general, rice grain yields were greatest for Francis and Wells, intermediate for Cocodrie and LaGrue, and lowest for Ahrent and CL161. Kernel smut incidence and severity data for each cultivar generally agreed with cultivar susceptibility ratings. For all site years, except NEREC in 2004, Francis and/or Cocodrie consistently had the greatest incidence of kernel smut. Relatively low incidences of kernel smut were measured across all seeding dates at the NEREC in 2004 compared with the other site-years. Kernel smut incidence, averaged across cultivars and examined across site-years, showed no consistent evidence that kernel smut increased as seeding date was delayed. The greatest number of smutted kernels was measured at NEREC in 2003 where disease severity did not differ significantly among cultivars seeded on 18 April, 30 April, and 10 June. Cultivars rated as 'Highly Susceptible' tended to have greater kernel smut incidence and severity values compared with less susceptible cultivars, especially on seeding dates with the highest levels of kernel smut. In 2003, kernel smut tended to increase as seeding was delayed. However, in 2004, kernel smut incidence and severity were uniform across seeding dates. Few rainfall events occurred between the late boot stage and maturity in 2004. Kernel smut incidence showed similar patterns as disease severity. For example, seeding dates that produced high disease incidence also had the greatest severity.

Incidence and severity of kernel smut of rice appears to be dependent upon environmental conditions that are favorable for infection rather than seeding date. Seeding date trials were established at three Arkansas sites in 2005 using similar procedures. Environmental conditions favorable for infection may occur more frequently on late-seeded rice when air temperatures decline, dew periods are extended, precipitation increases, and plant growth from anthesis to maturity is slowed. Air temperature and precipitation data have been collected for each site-year and will be used to help identify the environmental conditions that are favorable for the development of kernel smut of rice. When environmental conditions are more conducive for disease development, kernel smut incidence and severity occurs at a greater level for 'Very Susceptible' cultivars than less susceptible cultivars. Selecting less susceptible cultivars and avoiding excessive N fertilization help reduce economic losses attributed to kernel smut of rice. Use of fungicides to reduce kernel smut appears warranted only on 'Very Susceptible' cultivars when environmental conditions are favorable for the occurrence of kernel smut of rice.

Rice Variety Yields in Southeast Missouri as Influenced by Seeding Date

Beighley, D., Dickens, C., Dickens, R., 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 are 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 between April 15 and the first week of May. 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 than April 15 or later than the second week of May.

Preliminary data indicates 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. After the early-May planting, yields begin to taper off through mid-June.

The highest milling quality across varieties and planting dates have been those of the late-May and mid-June planting dates followed closely by the early-April planting date. There is a decrease in the head yield observed at the mid-April planting milling quality.

Preliminary Studies on Effects of Planting Dates on Seedling Stand of Water-Seeded Rice

Sha, X.Y., Linscombe, S.D., Theunissen, S.J., and Conner, C.A.

Seedling stand can be improved for the drill-seeded rice by delayed planting simply because the soil temperature increases as the growing season progresses. However, environment conditions are different for water-seeded rice that will sustain the low water temperature at the beginning of the season but hot water temperature at the end of the season. The effects of delayed planting on seedling stands for the water-seeded rice were rarely documented. In this study, seedling stands of different rice varieties (long-grain, medium-grain, Clearfield, and hybrids) water-seeded at five different dates from mid-March to early July were collected. The data were analyzed to reveal the effects of different planting dates on seedling stands of different rice genotypes under the water-seeded condition.

Fifteen rice genotypes, including six conventional long-grain, two long-grain Clearfield, four medium- or short-grain, and three hybrids, were water-seeded on March 15, April 15, May 15, June 1, and July 1, 2005, at the LSU AgCenter's Rice Research Station at Crowley, LA. The seeding rate was 42 kg/ha for hybrids and 112 kg/ha for all the other genotypes. A split-plot design was used, with planting dates as main plots and genotypes as subplots. Subplots were randomized and repeated three times. Seedling stands were counted at 4- to 5-leaf stage, right before permanent flooding. All data were analyzed with the SAS program (version 9.0).

The preliminary results suggested that CL131, a newly released Clearfield rice variety, had the highest seedling stand count among all long-grain rices, followed by Cheniere and Cybonnet. Jupiter, a new Louisiana release, had the highest seedling stand count among all four medium grains. All three hybrids performed similarly across all planting dates. Of the five planting dates, May 15 planting had the highest seedling stand count, followed by March 15 and June 1 plantings. July 1 planting produced the worst stand for all genotypes.

Performance of CL161, Wells, and XL8 at Reduced Seeding Rates

Ottis, B.V. and Talbert, R.E.

New rice (*Oryza sativa* L.) cultivars have been released that possess yield potential greater than 10,000 kg ha^{-1}. Some of these new cultivars have increased costs associated with them due to patented input traits and/or hybrid technology. Previous research has been conducted analyzing the potential of reduced seeding rates in rice production; however, this research was conducted using older cultivars no longer in production.

Research analyzing the effects of seeding rate on yield components with modern cultivars is not well-documented. Therefore, field trials were conducted near Stuttgart, AR, in 2002 through 2004 with the objective of determining the effect of rice seeding rate on yield components of three modern, long-grain rice cultivars. This research was done in an effort to determine if lower-than-recommended seeding rates would produce yields similar to currently recommended rates.

Rice seeding rates from 57 to 500 seeds m^{-2} did not affect rice aboveground biomass production, panicle density, harvest index (HI), or rice yield, regardless of cultivar. Wells produced higher panicle weights and had a higher harvest index than CL161 across the range of rice densities. XL8 and Wells produced similar yields, and these yields were higher than CL161. Cultivar, rice density, and thermal time were significant factors affecting rice canopy coverage. XL8 achieved canopy coverage sooner than CL161 or Wells. As rice density increased, canopy coverage increased by 3% for every additional 100 plants m^{-2}. As degree days (DD50) accumulated, canopy coverage increased 0.4% $^{o}Cd^{-1}$.

Results from this study indicate that seeding rates for CL161, Wells, and XL8 can be reduced while maintaining yield levels similar to those achieved at currently recommended seeding rates.

What is the Value of Applying Early-Season N to Rice on Clay Soils?

Walker, T.W., Norman, R.J., and Ottis, B.V.

A common practice for many mid-southern U.S.A. rice producers is to apply N when rice reaches the 1- to 3-leaf growth stage. Growers, extension personnel, and certified crop advisors have utilized this practice as a management tool with the goal of promoting enough vegetative growth so that a flood can be established as rapidly after emergence as possible. Researchers have noted differences in the appearance of rice treated with early-season (ES) N but seldom have detected any measurable differences in rice grain yield. Additionally, this application of N has never been counted toward the total N budget. An experiment was conducted on clay soils in Arkansas (AR), Missouri (MO), and Mississippi (MS) to determine the effects of applying ES N on rice at the 1- to 2-leaf growth stage. More specifically, the objectives of this study were to quantify the differences in biomass production and N-uptake at the 5-leaf and panicle emergence (PE) rice growth stages, and yield among treatments.

The treatment structure at each location was a factorial with four ES N sources {ammonium sulfate (AMS), diammonium phosphate (DAP), urea (U), and none} applied at the rate of 22.4 kg N ha^{-1} and three PF N rates (101, 134, and 168 kg N ha^{-1}). The treatments were arranged in a randomized complete block and replicated four times. Cocodrie was drill-seeded in AR, MO, and MS. Early-season N was applied to rice at each location when the rice reached the 1- to 2-leaf growth stage. Plots were flush irrigated within 2 d after application. Plant samples were collected from the second inside row at the 5-leaf rice growth stage, oven-dried, weighed, and digested to determine total biomass and total N-uptake. This was repeated at panicle emergence. In addition to biomass, plant heights were measured at the 5-leaf growth stage. Finally, at physiological maturity, rice plots were harvested with small plot combines at each location and yields were adjusted to 12% moisture content. Analysis of variance procedures were used to determine treatment effects. Means were separated using Fisher's LSD at the 0.05 level of significance.

Plant height and biomass at the 5-leaf stage was greater when ES N was applied at all locations. In AR, plant height was greatest when DAP was used as the ES N source and resulted in a 1.3, 4.7, and 5.8 cm increase when compared with AMS, U, and none, respectively. In MO and MS, no differences were detected among ES N source; however, when averaged across ES N sources, plant height was increased by approximately 5 cm compared with none at both locations. All ES N sources produced greater biomass compared with none; however, DAP produced greater biomass than U. In MS, ES biomass production, though not significant (P=0.0818), was greater for all ES N sources compared with none. Additionally, when averaging all ES N sources, approximately 36% greater N-uptake occurred compared with when no starter was applied (P=0.0872). Treatments did not affect ES biomass or N-uptake in MO. Late-season biomass was not affected by ES N treatments in AR and MO; however, when averaged across PF rates and ES N sources, 12% more biomass was produced compared with no ES N. Furthermore, total N uptake was greater for the ES N treatments compared with when none was applied (P=0.0526). More specifically, DAP, AMS, and U treated plots absorbed and average 18, 25, and 27 kg N ha^{-1} more compared to when no ES N was applied. When averaged across ES N applications, the PF N rate affected total N uptake (P=<0.0001), biomass (P=0.0002), plant height (P=<0.0001), and rice grain yield (P=<0.0001) in MS. Total N uptake and plant height increased with increasing PF N rate reaching a maximum of 198 kg N ha^{-1} and 96 cm, respectively, at the highest PF N rate. Biomass and rice grain yield responses were similar for AR and MS in that 134 kg N ha^{-1} produced biomass equal to 168 kg N ha^{-1}, but both were greater than the 101 kg N ha^{-1} rate. Rice grain yields were greatest when 168 kg N ha^{-1} was applied for AR and MS. Essentially, no treatment differences were observed for the MO location. Because rice had never been cultivated on the soil in MO, relatively large amounts of native N masked differences in N treatments.

From these data, it appears that the value of ES N applications is realized in producing greater biomass and taller plants at the 5-leaf growth stage, which will allow growers to establish a flood sooner. Additionally, based on the preliminary N-uptake data from MS, potentially all of the ES N is being absorbed by the plants and, hence, could be counted towards the total N budget which could save growers approximately \$35 ha^{-1} in N cost.

The Evaluation of an Alternative N Source and Method of Application

Walker, T.W. and Martin, S.W.

Recent increases in the price of fuel and fertilizer have further decreased the profitability of rice production. Nitrogen fertilizer is applied by aircraft for much of the hectarage in the southern USA rice producing area. These applications can cost a grower anywhere from \$35 to \$50 ha^{-1} based on the rate of fertilizer applied and amount the aerial-applicator charges. Considerable cost savings could be achieved if growers could reduce the amount of fertilizer applied by air. The objectives of this experiment were to compare rice grain yield and the economic return of using an alternative N source and application method.

A factorial combination of four N rates (101, 134, 168, and 202 kg N ha^{-1}), two N sources {fluid urea (22% N) and granular urea (46% N)} and two internode elongation (IE) rates (0 and 52 kg N ha^{-1} as urea) were arranged in a randomized complete block design and replicated four times. Two comparison treatments were included that consisted of an untreated check and a standard treatment. The standard treatment was a preflood (PF) application of 134 kg N ha^{-1} followed by 67 kg N ha^{-1} applied at IE. A Great Plains 1520 drill was adapted with a John Blue pump and knives placed in the center of every other drill row so that the fluid could be banded approximately 5 cm below the soil surface and 10 cm from each drill row during planting. Granular urea treatments were broadcasted onto the soil surface and incorporated with a rotary tiller immediately prior to planting. Internode elongation N treatments were broadcast by hand onto the plots in the flood. Cheniere rice was planted and N treatments were applied on 4 May 2005 at the Delta Research and Extension Center. The soil type was Sharkey clay. Plots were flooded on 8 June 2005. At maturity, rice plots were harvested with a small-plot combine. Analysis of variance procedures were used to determine treatment effects and means were separated using Fisher's LSD at the 0.05 level of significance. Costs associated the various treatment combinations were considered and a net return after fertilizer and application costs was calculated for each treatment. Fluid urea on an N basis was \$0.80 kg^{-1}, while granular urea was \$0.72 kg^{-1}. The price for fluid application was \$7.50 ha^{-1}, which was approximately half the cost of using a spin-spreader because of the soil incorporation costs associated with using granular urea. An aerial application cost of \$0.27 kg^{-1} N was charged to all of the applied N in the standard treatment as well as to the IE N treatments. A market value of \$7.64 cwt^{-1} was used in determining gross returns.

A rate by source interaction (P=0.0384) occurred for rice grain yield. At the 202 kg N ha^{-1} rate, the fluid source produced 6.4% greater yield compared with the granular source. The IE factor also affected yield (P=0.0001). Averaged across N rates and sources, an IE application increased yields 6.6%. All treatment combinations produced greater yields than the untreated, but the standard treatment produced the greatest yield (7776 kg ha^{-1}). The standard treatment also produced the highest net returns over N costs ($1130.50 ha^{-1}), which was $137.33 ha^{-1} greater than the second best treatment combination of 202 kg N ha^{-1} as fluid followed by an IE application of urea.

This study will be repeated; however, based on these data and the conditions in which this study was conducted, the alternative N application method is not an economically viable option for rice growers. Practices that will aid in reducing N loss for the proposed alternative methods will be tested in the future. Two such practices include the addition of N-Serve and decreasing the amount of time from planting to flooding.

Rice Response to a Nitrogen Fortified Granular Poultry Litter Fertilizer

Reiter, M.S., Slaton, N.A., Daniel, T.D., and Norman, R.J.

Approximately 1.2 billion broilers, worth $2 billion, are produced primarily in the western one-half of Arkansas each year. The poultry industry produces about 1.9 billion kg of poultry litter (PL) annually. Meanwhile, N fertilizer is applied to about 0.7 million hectares of rice (*Oryza sativa* L.) in the eastern half of the state. Transporting PL long distances for application to soils used for row-crop production is not economically feasible due to litter's low N, P, and K concentrations and difficulties in spreading. Development of litter-based fertilizers with elevated N concentrations may make transport and application of litter to soils used for row-crop production in eastern Arkansas more feasible. Our research objective was to evaluate fortified, poultry-litter based granulated fertilizers applied preplant as potential N sources for flood-irrigated rice. The granulated fertilizers were compared with the standard method of urea applied preflood.

The developed N sources were i) fresh PL (3.2% N), ii) granulated PL fortified with N as urea (PLU, 15.2% N), and iii) PLU with the dicyandiamide nitrification inhibitor (PLUDCD, 15.8% N). The PL-based fertilizers were preplant incorporated and compared with urea fertilizer (46% N), which was applied to the soil surface approximately 4 weeks after emergence and followed immediately by flooding. All N sources were applied at 67, 112, 157, and 202 kg N ha^{-1} (60, 100, 140, and 180 lb N/A) and when combined with N sources gave a 4 (N source) × 4 (N rate) factorial arrangement plus an unfertilized control in a completely randomized block design. The study was conducted on Dewitt silt loam (Fine, smectitic, thermic, typic Albaqualfs) at the Rice Research and Extension Center near Stuttgart, AR, during 2004 and 2005. Wells rice was seeded into a conventionally tilled seedbed following blanket applications of P and K fertilizers. Data were analyzed using the PROC GLM procedure with SAS and means separated using least significant difference (LSD) at an alpha level of 0.10.

Rice biomass production in 2004 was affected only by N source. When averaged across N rates, PLU (9660 kg ha^{-1}), PLUDCD (9569 kg ha^{-1}), and preflood urea (8224 kg ha^{-1}) produced the greatest biomass among N sources ($LSD_{0.10}$ = 1555 kg ha^{-1}). Fresh PL (7553 kg ha^{-1}) and preflood urea produced similar biomass, which were higher than the unfertilized control (5156 kg ha^{-1}). A N source × N rate interaction in 2005 indicated that urea (13,709 kg ha^{-1}) and PLUDCD (14,427 kg ha^{-1}) produced the highest biomass at 157 and 202 kg N ha^{-1}, respectively ($LSD_{0.10}$ = 2217 kg biomass ha^{-1}). Fresh PL and PLU produced the lowest biomass but were higher than the 0-N control plots (3964 kg ha^{-1}).

In 2004, rice N uptake at heading was affected only by N source and N rate. Nitrogen uptake, averaged across N rates, from urea (141 kg N ha^{-1}), PLU (138 kg N ha^{-1}), and PLUDCD (136 kg N ha^{-1}) were similar ($LSD_{0.10}$ = 23 kg N ha^{-1}), while N uptake from PL averaged 98 kg N ha^{-1}. Rice receiving 0 kg N ha^{-1} contained 68 kg N ha^{-1}. Rice recovered about 30 kg N ha^{-1} from PL compared with 73 kg N ha^{-1} from preflood urea. Assuming an average application rate of 135 kg N ha^{-1}, 22 and 54% of applied fertilizer N was recovered from PL and urea, respectively. For the N rate main effect, 157 and 202 kg N ha^{-1} had similar N uptakes (143 and 152 kg N ha^{-1}, respectively; $LSD_{0.10}$ = 23 kg N ha^{-1}) compared with the lower N rates of 67 and 112 kg N ha^{-1} (101 and 117 kg N ha^{-1}, respectively), averaged across N sources.

In 2004, a N source × N rate interaction indicated that the highest yields for PL (7068 kg ha^{-1}) and PLU (7261 kg ha^{-1}) were obtained with 202 kg N ha^{-1} ($LSD_{0.10}$ = 344 kg ha^{-1}). In comparison, rice receiving PLUDCD required 157 kg N ha^{-1} (7255 kg ha^{-1}) to produce its highest yield. Preflood urea yields peaked at 6718 kg ha^{-1} when 112 kg N ha^{-1} was applied. We speculate that N was lost through volatilization of urea due to an unusually wet spring. In 2005, grain yield was also affected by the N source × N rate interaction. The highest yields for the PL fertilizers were obtained with 112, 157, and 202 kg N ha^{-1} for PL (4924 kg ha^{-1}), PLU (5672 kg ha^{-1}), and PLUDCD (8235 kg ha^{-1}; $LSD_{0.10}$ = 894 kg ha^{-1}). Preflood urea produced the highest mean yield (11406 kg ha^{-1}) when 157 kg N ha^{-1} was applied. Rice receiving PLUDCD produced greater yields than PLU, while PLU produced yields that were generally similar to fresh PL. Fertilizing rice preplant with fortified granular products appears to be a viable option to urea applied preflood but requires additional research before recommendations can be developed for its use.

Iron Toxicity in the Lowlands

Diatta, S., Sie, M., Sahrawat, K.L., and Audebert, A.

Iron toxicity is caused by the microbial reduction in flooded conditions of insoluble Fe^{3+} into soluble Fe^{2+} that can be taken up by rice plant in excess amounts. It has been described as a multiple nutritional disorder enhanced by deficiency of other nutrients such as P, K, Ca, Zn. Iron toxicity occurs when large amounts of ferrous iron (Fe^{2+}) are mobilized *in-situ* in soil solution or through interflow of Fe^{2+} through adjacent slopes. Iron toxicity has a negative effect on lowland rice growth, reducing plant height and number of tillers. Surveys carried out by WARDA on the distribution and yield loss due to iron toxicity in three countries (Ghana, Guinea, and Cote d'Ivoire) indicated that 60% of the area could be at risk to Fe^{2+} toxicity. In West Africa, iron toxicity can reduce grain yield by 10 to 100%, depending on the intensity of the stress and the tolerance of the rice cultivars. Combined application of N, P, K, and Zn can mitigate the grain yield of susceptible rice cultivars. The use of tolerant varieties is recommended on iron toxic soils. Cultural practices, such as ridges, can leach out Fe^{2+} from the affected soil horizons. Inland valley management at watershed level can be also an alternative for mitigating iron toxicity effect.

Effect of Irrigation Termination Timing Effects on Rice Grain Yield and Milling Quality

Richards, A.L., Wilson Jr., C.E., Slaton, N.A., Frizzell, D.L., Norman, R.J., and Brye, K.

Irrigation is an important aspect of successful rice (*Oryza sativa*, L.) production in the southern United States. Due to reduced water availability and demand for water for other crops, interest has been expressed in determining the optimum time for terminating irrigation in rice. Previous studies suggest that the flood may be removed 14 d after 50% heading, but this study considered the effects of only one cultivar. Therefore, a study was initiated during 2004 at two locations to determine the optimum timing for irrigation termination on two medium-grain rice cultivars (Medark and Bengal) and two long-grain rice cultivars (Cocodrie and Wells).

Field studies were implemented during 2004 and 2005 at the Rice Research and Extension Center (RREC), near Stuttgart, AR, and at the Pine Tree Branch Experiment Station (PTBS), near Colt, AR. The study was conducted on a DeWitt silt loam (fine, smectitic, thermic Typic Albaqualfs) at RREC and a Calloway silt loam (fine-silty-mixed, active, thermic Glossaquic Fragiudalfs) at PTBS. Two medium-grain rice cultivars (Medark and Bengal) and two long-grain rice cultivars (Cocodrie and Wells) were seeded into 9-row plots 4.88 m long and managed according to recommended production practices for Arkansas. Irrigation treatments imposed were draining the flood 14, 21, 28, or 35 days after 50% heading. Soil moisture readings were conducted with a soil resistance probe every 2 d after flood removal. Grain yield was determined by harvesting the four center rows and adjusting to 120 g/kg moisture content. Milling yields were determined on a 125-gram sample with a McGill No. 2 rice mill and reported as total milled rice and head rice as a percentage of rough rice.

Terminating irrigation 14 days after 50% heading resulted in significant yield reduction compared with the recommended 28 days after 50% heading at both locations during 2004. At RREC, volumentric water content declined from 0.45 m^3/m^3 1 day after draining the 14-day treatment to 0.13 m^3/m^3 after 14 days of drying. This moisture content is low enough to cause severe drought stress during the grain filling process. This corresponds to the normal drain time. At the PTBS, the volumetric water content declined to same extent but rainfall received after the 14-day drain treatment prevented the soil to dry as quickly. However, in both cases, the moisture was apparently deficient enough to result in reduced grain yields. At the RREC, during 2005, the soil moisture content declined from 0.48 m^3/m^3 to 0.16 m^3/m^3 following the 14-day drain treatment. Again, the soil moisture deficit was apparently sufficient to cause the yields to be reduced when the flood was removed 14 days after 50% heading. The yields were not significantly reduced when the flood was removed 21 days after 50% heading compared with the recommended 28 days after 50% heading. However, sufficient rainfall was received to maintain soil moisture contents near saturation for the first week after the flood was removed. Subsequently, the soil did not begin drying after the 21-day flood removal until the normal drain time of 28 days after heading.

Current recommendations call for the flood to be drained 35 days after 50% heading for medium-grain cultivars. Data from this study suggest that medium-grain cultivars may be drained at the same time as long grains with no detrimental effects on yields or milling yields.

Tillage and Crop Rotation Effects on Soil Aggregate Stability in a Rice Soil of Eastern Arkansas

Schmid, B.T., Anders, M.M., Brye, K., and McNew, R.

Rice production in the south-central United States is tillage intensive. This is due, in part, to facilitate the movement of water on and off fields. Adoption of conservation or no-till rice farming in these areas has been one of the lowest in the nation. This low rate of adoption has been attributed to factors such as land tenure, problems with water management, a soil type that does not respond favorably to conservation tillage practices, and an intransigent 'plow' culture. In 1999, a long-term rotation study was initiated at the University of Arkansas Rice Research and Extension Center, Stuttgart, AR. This study consists of seven rotations managed as conventional or no-till systems. Rotations consist of rice (*Oryza sativa* L.), soybeans (*Glycine max* L.), corn (*Zea mays* L.), and wheat (*Triticum aestivum* L.). Each rotation contains two cultivars and two fertility levels (standard and enhanced), with data collected from a single variety and the standard fertility level. Aggregate stability samples were taken to depths of 0 to 5 cm and 5 to 10 cm with most significant differences showing in the 0- to 5-cm depth. Data collected in 2004 and 2005 on soil resistance at the station site showed significant reductions in soil resistance and increased soil moisture content in the no-till plots compared with conventional till plots. Reductions in soil resistance were dependent on the crop grown with soybeans being most effective in reducing soil resistance and corn less effective. Results indicate that percent total water stable aggregates increased with increasing frequency of rice in rotation. Statistical analysis indicated that the largest, most stable aggregates in the 0- to 5-cm sampling depth were concentrated in the continuous rice with winter wheat rotation, followed by continuous rice without wheat. These results indicate that in soils commonly used for rice production, soil health as measured by the percentage of water stable aggregates and resistance improves over time.

Polymer Fertilizer Coatings: Can They Increase Phosphorus Efficiency in Rice?

Dunn, D.J.

Proper Phosphorus (P) nutrition is critical for producing maximum rice grain yields. Phosphorus promotes strong early plant growth and development of a strong root system. Maximum tillering is also dependent on P. Not all of the P contained in fertilizers is available to plants. When phosphorus fertilizers are applied to soils, a percentage of the P may be tightly bonded to soil minerals. Phosphorus may also strongly bond with soil calcium to form insoluble compounds. This percentage may range from 25 to 90%, depending on soil composition, pH, and calcium level. Surface coating of P fertilizers with polymer additives, which interfere with P bonding to calcium, have been investigated. Avail manufactured by Specialty Fertilizers Products Inc., Belton, MO, is one such product. Avail is a water-soluble, biodegradable dicarboxylic co-polymer with a very high cation exchange capacity (1800 milliequivalents per 100 grams of polymer). Polymeric structure is very specific to adsorption of divalent and trivalent cations. This polymer functionality is not affected by temperature, pH, or ionic strength. This material functions by preferentially bonding with soil calcium. This leaves P free to be used by plants for early-season growth. Typically 1/4 lb of Avail is added to 100 lb of P fertilizer. The added cost of Avail is approximately $2- to $4/ha. The objective of this study was to compare the response of P uptake and rice yields with non-coated and Avail-coated triple super phosphate (TSP).

This 2-year small plot evaluation was conducted at the Missouri Rice Research Farm near Qulin, MO. The soil type is a Crowley silt loam. A different research area was used each year. Both years the soil pH was 6.2, organic matter 1.8%, and CEC of 10.0 meq/100 gr. In 2004, soil test found 19 kg ha^{-1} P and 72 kg ha^{-1} K. In 2005, soil test found 5 kg ha^{-1} P and 57 mg kg^{-1} of K. A randomized complete block experimental design with four replications was employed each year. Three preplant P_2O_5 rates of both non-coated and Avail-coated TSP (28, 56, and 112 kg ha^{-1}) were compared with an untreated control. These treatments were applied by hand in early-May of each year and immediately incorporated. Supplemental N (168 kg ha^{-1} N) was applied at first tiller and a permanent flood established and maintained until maturity. Grain was harvested from the center of each plot, moisture percentage measured and yields adjusted to a 12.5% basis. Soil samples (0-15 cm) were collected from each plot five times during the growing season (preflood, flood + 2 weeks, internode elongation, 10% heading, and harvest) and were analyzed for P by Bray 1. Plant tissue samples were also collected at these times. Sixty cm of row was collected from the second drill row from the outside edge of each plot. These samples were dried, weighed, analyzed for P content, and P uptake was calculated. All data was analyzed using the Proc GLM statement.

In both years, rice yields were significantly increased by all P treatments except the 28 kg ha^{-1} uncoated TSP in 2004. This treatment was statistically and numerically equivalent to the untreated check. Each year the 28 kg ha^{-1} coated TSP and 56 kg ha^{-1} uncoated TSP treatments produced statistically equivalent yields (2004 coated 28 = 8770 and uncoated 56 = 8770, lsd 0.05 = 242; 2005 coated 28 = 6653 and uncoated 58 = 6854, lsd 0.05 = 711). The 58 $kgha^{-1}$ coated TSP treatment produced statistically equivalent yields to 112 $kgha^{-1}$ coated or uncoated TSP (2004 coated 56 = 9022, uncoated 112 = 9223 and coated 112 = 9173; 2005 coated 56 = 6804, uncoated 112 = 6955 and coated 112 = 6805). These yield differences could be due to increased availability of P early in the growing season.

Phosphorus fertilization, coated or uncoated, generally produced significant differences in soil test and tissue levels of P. Both years, coated TSP treatments produced soil test and tissue P levels that were numerically greater but statistically equivalent to the corresponding uncoated TSP treatments. These numerical differences were greater during the early part of the season. Dry matter levels and P uptake were also were also significantly affected by P fertilization. The differences were also greater during the early part of the growing season. This may be due to increased tillering promoted by greater P availability.

This 2-year study found Avail-coated TSP was more effective at increasing yields than uncoated TSP. A 28 kg ha^{-1} application of coated TSP was as effective as 56 kg ha^{-1} of uncoated TSP. However, the 50 lb P_2O_5 rate of coated TSP continued to statistically increase grain yields and to produce an advantage over the same rate of the uncoated TSP. Soil and plant tissue data support this finding. The Avail coating increased P use efficiency and profitably increased overall yields. Higher yields lead to lower production costs per bushel and increase overall profitability.

Rate Effect of HM9754A, a Soil Amendment, on Rice Yields and Nutrient Uptake

Dunn, D.J., Bowman, R., and Helms, R.

Organic soil amendments have been used to increase nutrient uptake and crop yields for over 100 years. These amendments fall into several categories. One of these categories is humic acids. Humic acids are fully degraded water soluble constituents of organic matter. These organic acids are chemical complex and are arranged in a manner that provides plants with an improved environment for growth and nutrient uptake. Physical humic acids improver soil tilth, reduce crusting, and improve soil water holding capacity. Chemically humic acids improve N, P, and K availability, chelate micronutrients, and can buffer the toxicity of salt and heavy metals. Biologically humic acids stimulate root and beneficial microbial growth. In a previous study, it was demonstrated that HM9754A, a granular humic acid material, could be used to enhance rice production. This paper evaluates the performance of HM9754A at five application rates with respect to nutrient uptake and rice yield in two environments.

This evaluation was conducted at two separate locations at the Missouri Rice Research Farm near Qulin, MO, in 2005. The soil type for both was a Crowley silt loam. These locations differ in soil fertility. At the first location (F+), the soil fertility had been maintained at levels ideal for rice cultivation (pH= 6.0, OM = 2.2%, P = 28 mg kg^{-1}, K = 132 mg kg^{-1}, Zn = 1.7 mg kg^{-1}). No P, K, or Zn fertilization would be recommended. At the second location, (F-) the soil fertility has not been maintained (pH= 6.3, OM = 1.9%, P = 8 mg kg^{-1}, K = 57 mg kg^{-1}, Zn = 0.6 mg kg^{-1}). At F-, a fertilizer application of 45 kg ha^{-1} P_2O_5, 135 kg ha^{-1} K_2O, and 12 kg ha^{-1} Zn would be recommended.

Small plots with four replications were established in a randomized complete block design at each location. Four application rates of HM9754A (11.2, 22.4, 44.8, and 89.6 kg ha^{-1}) were compared with an untreated check. These treatments were applied by hand in and immediately incorporated prior to seeding. The rice variety CL161 was used at both locations. Supplemental N (168 kg ha^{-1} N) was applied at first tiller. A permanent flood established and maintained until maturity. Normal agronomic practices were followed throughout each season at each location. Plant tissue samples were also collected at 10% heading. Sixty cm of row was collected from the second drill row from the outside edge of each plot. These samples were dried, weighed, analyzed for nutrient content, and nutrient uptake was calculated. Grain was harvested from the center of each plot, moisture percentage measured and yields adjusted to a 12.5% basis. The yield, tissue concentration, and nutrient uptake data were analyzed using the Proc GLM statement for the 0.10 level.

As expected, there was greater dry matter accumulation at the F+ than the F- location. Dry matter accumulation was significantly increased (alpha = 0.10) with any HM9754A rate at both locations. The magnitude of this increase was linearly related to rate of HM9754A application. At the both sites, the 89.6 kg ha^{-1} rate had the greatest increase over the untreated check (F+: 6653 kg ha^{-1} vs. 9799 kg ha^{-1}, lsd 0.10 = 1565 kg ha^{-1}; F-: 5136 kg ha^{-1} vs. 6310 kg ha^{-1}, lsd 0.10 = 572 kg ha^{-1}) Tissue levels of N, P, K Ca, Mg, Zn, Fe, and Mn were not significantly affected by HM9754A applications at the F+ location. None of the average tissue levels for these nutrients were below the critical levels found in the literature. In terms of nutrient uptake, N, K, Zn, Fe, and Mn were significantly increased by HM9754A applications at the F+ location. Tissue levels of N, P, K Ca, and Mn were significantly affected by HM9754A applications at the F- location. Average tissue concentrations of P for the untreated check were below the published critical level, however, for the two highest HM9754A treatments P tissue concentrations were above the critical level. In terms of nutrient uptake, N, P, Ca, Zn, Fe, and Mn were significantly increased by HM9754A applications at the F- location.

As expected, rice grain yields were greater at the F+ than the F- location. Rice grain yields were not significantly affected by HM9754A applications at the F+ location. For the F+ location, the 22.4 $kgha^{-1}$ rate of HM9754A produced the greatest yield increase relative to the untreated check (7106 kg ha^{-1} vs. 7610 kg ha^{-1}, lsd 0.10 = 645 kg ha^{-1}). For the F- location, the 89.6 kg ha^{-1}rate of HM9754A produced the yields statistically greater than the untreated check (5569 kg ha^{-1} vs. 6199 kg ha^{-1}, lsd 0.10 = 549 kg ha^{-1}).

The results of this study suggest that HM9754A can be used to increase nutrient uptake by rice plants. In a low fertility situation, similar to recently graded fields, HM9754A can significantly increase rice yields. In maintained fertility situations, HM9754A numerically increased rice yields.

Impact of HM9754A on Rice Production on Leveled Ground

Kenty, M.M., Dunn, D.J., Helms, R.S., Bowman, R., and Walker, T.

Throughout the rice production areas of the United States leveling land for improved water management is a common occurrence. The grade or cut of the land may be as little as one centimeter to as much as two meters depending on the natural slope of the land. It has been generally accepted that the process of leveling the land for improved water management has a negative impact on inherent fertility and can reduce rice yields. In a previous study it was demonstrated that HM9754A, a granular organic acid material, could be used as an alternative to chicken litter as a tool to enhance rice production. This paper evaluates the performance of HM9754A at 44.8 kg ha^{-1} (40 lbs/A) with respect to rice yield in several environments over three years.

Experiments were conducted from 2003 to 2005 at eight locations, four in Arkansas, three in Missouri, and one in Mississippi. The locations were typical rice production areas with cuts from as low as a few centimeters up to approximately 2 m. Small replicated plots were established in a randomized complete block design at each location to evaluate HM9754A at varying rates versus other products or accepted practices. All treatments, including the untreated check, received the standard recommended fertility at each respective location. Normal agronomic practices were followed throughout each season at each location. At physiological maturity, the middle rows were harvested and weighed. For the purpose of this evaluation only the HM9754A at 44.8 kg ha^{-1} (40 lb/A) and the untreated check will be presented. The yield data was analyzed across locations using Proc OLM statement.

HM9754A applied at the recommended rate of 44.8 kg ha^{-1} (40 lb/A) yielded from 6.3 to 2028.6 kg ha^{-1} (0.125 to 40.25 bu/A) more rice than the untreated check at the eight locations. Averaged across locations HM9754A significantly ($\alpha = 0.05$) increased yield by 568.3 kg ha^{-1} (11.28 bu/A) over the untreated check. The results of this comparison suggest that HM9754A at 44.8 kg ha^{-1} (40 lb/A) can be used in conjunction with standard fertility practices to increase rice production on leveled ground.

The Utility of a Foliar Nitrogen Source in Rice Production

Kenty, M.M., Helms, R.S., Walker, T., McCann, J.K., Thomas, J.M., and Bowman, R.

Nitrogen is the main nutrient used in rice production. Since 2003, N prices have increased drastically causing growers to consider changes in their fertility management practices. Growers are also looking at ways to improve efficiency in their operations by combining operations thus reducing application costs. During the past six growing seasons, two foliar N sources, HM9310 and HM9827A, have been evaluated as supplements to fertility programs in corn, cotton, rice, soybeans, and wheat. The objective of this study was to evaluate the effects of HM9310 and HM9827A on rice production as compared with a standard N fertility program.

Three experiments were conducted in Arkansas (AR) in 2005 and one in Mississippi (MS) in 2004 and 2005. The locations were typical rice production areas representative of each state. Small replicated plots were established in a randomized complete block design at each location. At the AR locations, HM9310 and HM9827A at rates of 9.35, 18.70, 28.06, and 46.77 l ha^{-1} (1, 2, 3, and 5 gal/A) and combinations were evaluated versus standard accepted practices. Additionally, all treatments received either 224 kg ha^{-1} (200 lb/A) of urea (46% N) as the preflood N application. Two of the AR locations were inoculated with sheath blight in order to evaluate the effect of fungicides applied with HM9310 and HM9827A as part of a total fertility program. In MS, HM9310 and HM9827A at 18.70 l ha^{-1} (2 gal/A) were evaluated for the effect on yield when applied with and without a fungicide on plots inoculated with sheath blight. Additionally, all treatments received either 134.4 kg ha^{-1} (120 lb/A) of urea (46% N) as the preflood N application and 67.2 kg ha^{-1} (60 lb/A) at panicle determination. All treatments, including the untreated check, received the standard recommended fertility for all other nutrients at each respective location. Normal agronomic practices were followed throughout each season at each location. At physiological maturity, the middle rows were harvested and weighed. Since the treatments at the AR locations differed from the treatments at the MS location, the data from each state will be analyzed separately. Analysis of variance procedures were conducted to determine treatment effects and means were separated using Fisher's LSD at the 0.05 level of significance.

In the 2005 AR trials, there were no statistical differences among treatments in yield as compared with the standard N fertility program of 224 kg ha^{-1} (200 lb/A) at preflood followed by 89.6 kg ha^{-1} (80 lb/A) at ½ inch internode elongation for each trial. Since there were no differences detected even in the inoculated locations, the three trials were analyzed across locations to determine the fertility effect of HM9310 and HM9827A as compared with the standard. HM9310 and HM9827A treatments and combinations yielded 7547.4 to 7996.8 kg ha^{-1} (149.8 to 158.7 bu/A) as compared with the standard at 7690.2 kg ha^{-1} (152.6 bu/A). Numerically, the highest yielding treatment was the HM9310 at 46.77 l ha^{-1} (5 gal/A) applied at booting following the standard N fertility program with a yield of 7996.8 kg ha^{-1} (158.7 bu/A). These results indicate that HM9310 and/or HM9827A can be used in lieu of the standard 89.6 kg ha^{-1} (80 lb/A) at ½ inch internode elongation to produce acceptable yields.

In MS, HM9310 and HM9827A at 18.70 l ha^{-1} (2 gal/A) each were evaluated for the effect at the panicle differentiation + 14 day application timing applied with and without fungicides following the standard N applications. Averaged across years, all treatments except HM9310 alone were significantly greater than the standard; however, there was a numerical advantage of 898.7 kg ha^{-1} (18.1 bu/A). The addition of either fungicide, Quadris or Stratego, significantly improved yield as compared with the standard and the standard + HM9310 alone. However, only Stratego was significantly different than the standard + HM9827A with yields of 9608.3 kg ha^{-1} (190.6 bu/A) vs. 8652.2 kg ha^{-1} (171.7 bu/A), respectively. There were no statistical differences observed between treatments with either fungicide. The addition of either HM9310 or HM9827A with either fungicide increased yields only numerically with the greatest increase being achieved with Quadris + HM9827A at 9738.9 kg ha^{-1} (193.2 bu/A) as compared with Quadris alone which yielded 9469.9 kg ha^{-1} (187.9 bu/A) which was also the highest yielding treatment. These results indicate that in addition to fungicides HM9827A may offer some plant health value above a standard fertility program.

These data show that in AR, HM9310 or HM9827A can potentially be used as an alternative N source for rice production. In MS, if sheath blight is present, HM9310 and HM9827A can potentially increase yield; however, there is no additive effect by adding either product to a fungicide in a sheath blight-infested situation.

Fertilization of Ratoon Rice in Louisiana

Bond, J.A., Leonards, J.P., and Regan R.P.

Ratooning, the practice of harvesting grain from tillers originating from the stubble of a previously harvested crop (main crop), enhances rice grain yields without increasing land area because it provides higher resource use efficiency per unit of land area and per unit of time. Ratoon rice productivity is influenced by nitrogen (N) fertilization. Current Louisiana recommendations for ratoon rice production suggest application of N at 84 to 100 kg ha^{-1} immediately following main-crop harvest, if harvest occurs prior to August 15, and establishment of the ratoon-crop flood immediately following N fertilization. The objective of this research was to discover the N fertilizer application rate producing maximum ratoon rice grain yields.

An experiment to examine the response of four rice cultivars to ratoon N applications was conducted from 2003 through 2004 at the Louisiana State University AgCenter Rice Research Station near Crowley, LA, and an on-farm site near Lake Arthur, LA. Rice was cultured using a delayed-flood, drill-seeded production system. Main-crop rice was harvested in late-July to early-August each year. Treatments were replicated four times in a randomized complete block experimental design with a factorial arrangement of four rice cultivars (Cheniere, CL161, Cocodrie, and Cypress) and four ratoon N fertilizer rates (34, 68, 100, and 134 kg ha^{-1}). Nitrogen fertilizer treatments were applied as urea immediately following main-crop harvest and before ratoon flooding, which occurred 1 d following N fertilizer application. Ratoon days to 50% heading was determined as the time from main-crop harvest until 50% of rice had visible panicles. At maturity, ratoon rice was harvested at a moisture content of 200 g kg^{-1} and rough rice yields were adjusted to 120 g kg^{-1} moisture content.

Increasing the N fertilizer rate from 68 to 100 kg ha^{-1} delayed ratoon days to 50% heading by 1 d. While the influence of N fertilizer rate on ratoon days to 50% heading was slight, N fertilizer rate had a significant effect on ratoon rough rice yield. As N fertilizer rate increased from 34 to 100 kg ha^{-1}, ratoon rough rice yields increased from 2680 to 3030 kg ha^{-1}. Increasing N fertilizer rate from 100 to 134 kg ha^{-1} did not improve ratoon rough rice yields.

Although the delay in ratoon maturity with increasing N fertilizer application rate was significant, a 1-d delay in maturity would probably not influence harvestability or ratoon rice yields. However, longer delays in ratoon maturity could have some practical implication. Along the Gulf Coast where rice is ratooned, the growing season prior to the onset of unfavorable temperatures is not long enough in every year to allow maturation of the ratoon grain. Furthermore, the months of September and October, when the ratoon crop is developing, are also the months when the production area is most susceptible to tropical weather systems. Therefore, delays in ratoon maturity of 3 to 4 d could result in significant yield loss in years when low temperatures or tropical weather systems occur before the ratoon crop is fully developed.

In rice-growing areas along the Gulf Coast, a ratoon rice harvest is valuable to a producer's income because it increases total production on a given area with a limited amount of additional input. However, the income realized from the additional harvest must offset the added input costs of ratoon production. Verification that the N fertilizer application rate producing maximum ratoon rough rice yields for semidwarf cultivars was 100 kg ha^{-1} led to an increase in the recommended ratoon N fertilizer rate in Louisiana.

Rice Seeding Rates and Yield Response to Midseason Nitrogen

Rhine, M., Stevens, G., and Dunn, D.

Nitrogen fertilizer management in rice (*Oryza sativa*) is dependent on several variables, including genetics, soil properties, and crop rotations. Rice seeding density may also affect rice response to N. Additional N may be needed in low population rice fields to promote tillering which increases leaf canopy. A research project was begun in 2005 to study methods of measuring rice leaf canopy at green ring (GR) growth stage with different seeding rates and varying preflood and midseason N treatments. The objective was to determine the effect of rice seeding rates on response to N fertilization at preflood and midseason as well as the efficiency of two methods to determine whether midseason fertilizer applications are needed.

A field test was conducted at Portageville, Missouri, on a Sharkey clay soil. The field was graded in the spring of 2004 and planted in soybeans. In 2005, rice plots were drill seeded (19-cm row spacing) with Wells cultivar at seeding rates of 54, 162, 267, and 377 seeds m^2. Three preflood N treatments were applied at 50, 101, and 151 kg N/ha. One half of the treatments received midseason N while the other half received no midseason applications. Plots with midseason applications received 34 kg N/ha at internode elongation plus an additional 34 kg N ha^{-1} 1 week later. Plots were mechanically harvested with a combine.

Two methods of measuring leaf canopy were tested. For the first method, we used a macro developed at University of Arkansas for Sigma Scan image software to evaluate digital pictures based on the percentage of green leaf material in a given area. Digital photos were taken from each plot during the GR growth stage. A digital camera was positioned on 1.52-m rod held at a 45-degree angle above the plot. Photos were taken at a downward angle over the rice rows. Photos were analyzed using Sigma Scan to determine the percentage of pixels in each picture that appeared green in color (near 510 nm in wavelength). For the second method, visual observations with a yardstick were also made at GR growth stage. Two center rows from each plot were selected. A wooden yardstick was placed halfway between the rows on the surface of floodwater. (The yardstick was positioned parallel to the rows.) Standing between adjacent rows and leaning over the sampling rows, we counted the inch numbers showing on the yardstick (not hidden by rice leaves) out of the 36 places possible. Two digit-inch numbers were counted as one place. When a rice leaf obstructed the view of either of two digit numbers, we did not count that place.

Crop yield response to midseason N decreased as preflood N rates increased. Averaged across seeding rates, midseason N increased yields 1150 kg/ha at 50 kg N/ha preflood rates. However, at 151 kg N/ha preflood, midseason N caused yields to decrease 505 kg/ha. At the 54 seeds m^2 seeding rate, plots with 50 kg N/ha preflood yielded significantly less than the 101 and 151 kg N/ha preflood N rates. At the 377 seeds m^2 rate, no significant difference in yields was found between preflood N treatments. Also, no significant interaction between midseason N applications and seeding rates was found. At the 101 and 151 kg N/ha preflood N application rates, lodging increased as seeding rates increased. Lodging was 25% at the 151 kg N/ha preflood compared with 7% at 101 kg N/ha and 0% at 50 kg N/ha.

In rice plots, numbers showing on the yardstick and leaf area percentages measured with digital photos processed in Sigma Scan were strongly correlated ($R^2 = 0.998$). Averaged across N treatments, at the lowest seeding rate (54 seeds m^2) percent leaf canopy at GR from digital photos was 40%. At higher seeding rates, percent canopy at GR was 65 to 80%. The highest rice yields that we measured were when percent leaf canopy and yardstick numbers showing at GR were 60% and 15, respectively.

Yardstick Method for Assessing Rice Midseason Nitrogen

Stevens, G., Dunn, D., Wrather, A., Ottis, B., and Beighley, D.

Managing N fertilization in rice fields can be challenging for producers. In drill-seeded rice, urea fertilizer is usually broadcast immediately before flooding. Depending on irrigation well pump capacity, field size, and weather conditions, urea can be lost by volatilization while a field is being flooded. Optimum N rates vary by rice variety, soil texture, and previous crop rotations. Nitrogen can also be lost by denitrification if the urea is converted to nitrate in the soil.

For many years, rice agronomists have tried to develop an accurate method of determining whether supplemental N is needed at internode elongation growth stage. The Plant Area Board has shown good correlation to rice yield response to midseason N in experiments. However, few growers use it because it is time consuming and requires tedious calculations. Likewise, Minolta SPAD chlorophyll meters have been used successfully in N rice research projects but are too expensive for most growers and consultants.

In 2004, we developed and tested a new inexpensive method using an ordinary, wooden yardstick for monitoring rice plant N. Field tests were conducted at Glennonville, Missouri, on a Crowley silt loam soil and Portageville, Missouri, on a Sharkey clay soil. At each location, plots were drill seeded (19-cm row spacing) with Francis and Cheniere varieties. A split-plot design was used with varieties in main plots and N treatments in subplots. Five preflood N rates were applied at 0, 39, 78, 118, and 157 kg N/ha. One half of the subplot treatments received midseason N and one half did not receive additional N. Subplots with midseason N received 34 kg N/ha at internode elongation plus 34 kg N/ha 1 week later. Plots were mechanically harvested with a combine. Rice yields for each preflood N rate subplot without midseason N were subtracted from yields in preflood N rate subplots with midseason N.

Visual observations with a yardstick were made at green ring growth stage. Two center rows from each plot were selected. A wooden yardstick was placed halfway between the rice rows on the surface of floodwater. (The yardstick was positioned parallel to the rows.) Standing between adjacent rows and leaning over the sampling rows, we counted the inch numbers showing on the yardstick (not hidden by rice leaves) out of the 36 places possible. Two digit inch numbers were counted as one place. When a rice leaf obstructed the view of either of two digit numbers, we did not count that place.

Averaged across varieties, soils, and years, rice yields were highest when 157 kg N/ha was applied before flooding with no midseason N applications. In seven out of eight field observations, midseason N reduced rice yields in main plots with 157 kg N/ha applied preflood. On the Sharkey clay soil in 2004, midseason N increased Cheniere rice yields at all preflood N rates. The greatest yield reduction occurred with Cheniere on freshly graded Sharkey clay in 2005. Winds from the aftermath of Hurricane Katrina caused significant lodging in some treatments. Lodging in plots with midseason N following 157 kg N/ha preflood was 62% compared with only 3% in plots without midseason N. For all environments, rice yield increases from midseason N applications following 0 and 35 kg N/ha preflood ranged with +450 to 1150 kg /ha. In the mid-range of preflood N rates tested, rice yield responses from midseason N following 78 and 118 kg N/ha preflood varied by environment. Midseason N yield response in these treatments ranged from –1850 to +800 kg/ha.

Yield response to midseason N was correlated with yardstick observations made at green ring. We did not find a single critical yardstick number that predicted midseason N response for both varieties in all environments. In four out of the seven observations where midseason N response was found, rice yield increases from midseason N were not found when less than 12 numbers were showing on the yardstick. In 2005, on the Crowley silt loam soil, Francis yields were increased from midseason only when greater than 18 numbers were showing on a yardstick. In 2005, on the freshly graded Sharkey clay soil, Francis and Cheniere yields were increased only when greater than 23 numbers were showing on a yardstick.

In the study, a single application of 157 kg N/ha produced optimum yields. At lower preflood rates, field tests showed that the yardstick method did a fair job of predicting yield response to midseason N. In 3 ½ minutes per plot, leaf canopy was estimated by counting the inch numerals visible on a yardstick floating between rice row drills. In this management system, no calculations are needed to make a judgment on whether to apply midseason N.

Utilizing Multispectral Imagery to Support the Arkansas Rice Verification Program

Meggs, B.A., Baker, W.H., and Key, L.R.

The Rice Research Verification Program is an important part of the Arkansas Cooperative Extension Service. Each year, the program serves as a demonstration of the most current rice production recommendations based on University research. The objective of this work was to provide support to this program by making processed multispectral imagery available via the web. Ten fields were involved in the program for the 2005 year. Normalized difference vegetation index maps were classified into seven zones based on rice biomass. The initial response to these images was met with skepticism and confusion**.** But, once the interested parties began to scout the fields, interpretation of the imagery improved. These images helped to quantify strong and weak areas of rice and were found to be a useful aid with crop management decisions. No variable rate applications were attempted. A need for image processing and interpretation workshops was made clear. As variable rate technologies become available, more opportunity to utilize the information from the imagery will occur.

Trials and Tribulations of Processing Imagery for Variable Rate Applications in Rice

Key, L.R., Baker, W.H., and Meggs, B.A.

Multispectral imagery has shown significant results for identifying areas of plant stress. The first objective of this project was to refine the use of multispectral imagery and determine the benefit in making variable rate prescriptions and/or midseason decisions. The second objective of this study was to explore the profitability of variable rate (VR) applications in rice. This work was done in cooperation with KinCo Flying Service in Light, AR. Aerial imagery was used to produce a scout map and eventual VR prescription. Two aircrafts equipped for VR were used. All VR applications were kept within the labeled rates for the product used. The scout and/or the farmer made the decision about which rates to apply. Fertilizer, weed control, and fungicide VR applications were developed and applied to production fields. Weed control for nut grass, barnyard grass, and saw grass was not successful this year because of technical problems with the camera. More effort will be put into image processing for VR weed control because the work did show promise, especially with large patches of barnyard grass and nut grass. A fertilizer mix of diammonium phosphate was applied to cut areas in several fields based on bare soil imagery and Veris soil electrical conductivity. VR fungicide applications were found to save money after the cost of VR were included. Treatments for these inputs typically cost around $20 to $28/A, making foliar fungicides the most expensive input in rice production. Aerial imagery was used to map plant biomass and then relate biomass to sheath blight infestation. Each field was scouted to verify the occurrence of heavy sheath blight infestation where the rice biomass was thickest and low to no infestation where the rice was thin (usually cold water rice). The steps needed to process an image into a scout map are a time consuming process. It was very important that each image was to be reviewed by the scout or farmer to assure the VR application was valid. The rice crop changes very quickly week to week, thus, imagery was needed within a few days of an application to insure the conditions were still applicable. Cloud cover and haze were always a problem. The majority of the fields (over 30) evaluated for VR fungicide applications were found to save between $1 to $3/A after all costs were accounted for. Aerial imagery was found to be an efficient tool to map rice biomass, and, biomass was found to be related to sheath blight infestation levels.

Development of an Integrated Rice Crop Management Manual

Samonte, S.O.P.B., Wilson, L.T., and Cockrell, J.

An "Integrated Rice Crop Management Manual" is currently being developed at Texas A&M University System's Agricultural Research and Extension Center, with support from a Texas Department of Agriculture Integrated Pest Management Grant. The manual is not only intended for farmers in Texas, but also for agriculturists (consultants, educators, and students) interested in irrigated direct-seeded rice production and management. In addition to the detailed and clearly written texts that will discuss the chapters listed below, the manual will have easy-to-understand graphs or charts and detailed illustrations that explain the different principles and practices in integrated rice management. It will also include professional quality color photographs that can be used to identify pests (insects and weeds), diseases, and the damages due to biotic and abiotic factors. Contributions for this manual have come from rice researchers based at Texas, Arkansas, Kansas, Louisiana, and Missouri. Each of the 38 individuals will be an author or co-author of a chapter(s).

The current outline of the rice manual is as follows:

(1) Introduction
(2) Rice Plant
(3) Rice Environment
(4) Rice Agroecosystem
(5) Varietal Improvement
(6) Crop Production and Management
(7) Insect Pest Management
(8) Pathogen Pest Management
(9) Weed Management
(10) Harvesting and Threshing
(11) Rice Storage and Processing
(12) Economics of Rice Production
(13) Rice Research Methodology and Techniques
(14) Information and Technology Transfer

Efficacy of Carfentrazone-Ethyl and Quinclorac for Post Broadleaf and Grass Control in Arkansas Rice (*Oryza sativa* L.)

Doherty, R.C., Smith, K.L., Meier, J.R., and Kelly, M.B.

Two trials were conducted in 2005 at Rohwer, AR, to evaluate broadleaf and grass control in conventional rice (*Oryza sativa* L.) utilizing carfentrazone-ethyl and quinclorac combinations. Carfentrazone-ethyl applied at 0.013 and 0.017 kg ai/ha and quinclorac at 0.28 kg ai/ha plus carfentrazone-ethyl at 0.017 kg ai/ha applied to 3-inch weeds provided 99% control of hemp sesbania (*Sesbania exaltata* Raf.) at 8 days after treatment (DAT). Quinclorac at 0.28 kg ai/ha plus carfentrazone-ethyl at 0.017 kg ai/ha provided greater control (94%) of hemp sesbania at 18 DAT than provided by carfentrazone-ethyl at 0.017 kg ai/ha (89%) or quinclorac at 0.28 kg ai/ha (43%) applied at the same timing. Quinclorac at 0.43 kg ai/ha plus carfentrazone-ethyl at 0.017 kg ai/ha provided greater (80%) control of hemp sesbania 37 DAT than provided by carfentrazone-ethyl at 0.017 kg ai/ha (76%) or quinclorac at 0.43 kg ai/ha (55%).

In a separate trial, quinclorac at 0.43 kg ai/ha plus carfentrazone-ethyl at 0.018 kg ai/ha, quinclorac at 0.43 kg ai/ha, and quinclorac at 0.56 kg ai/ha failed to provided greater than 54% control of barnyardgrass (*Echinochloa crus-galli* L.) 13 DAT. Quinclorac at 0.43 kg ai/ha plus carfentrazone-ethyl at 0.018 kg ai/ha provided greater (90%) control of hemp sesbania than quinclorac at 0.43 kg ai/ha (86%) and quinclorac at 0.56 kg ai/ha (88%) at the same timing. The addition of carfentrazone-ethyl at 0.018 kg ai/ha to quinclorac at 0.43 kg ai/ha provided greater control of hemp sesbania (88%) than quinclorac at 0.43 kg ai/ha (78%) alone 20 DAT. Barnyardgrass control was equal between quinclorac at 0.43 kg ai/ha plus carfentrazone-ethyl at 0.018 kg ai/ha, quinclorac at 0.43 kg ai/ha, and quinclorac at 0.56 kg ai/ha 20 and 27 DAT. The application of quinclorac at 0.43 kg ai/ha plus carfentrazone-ethyl at 0.018 kg ai/ha 27 DAT provided 90% control of hemp sesbania compared with 81% provided by quinclorac at 0.43 kg ai/ha alone.

Clincher (Cyhalofop) and Propanil Formulation Interactions

Kendig, J.A., Heiser, J.W., Smith, C.S., and Ezell, P.M.

Low rates of the product Clincher (cyhalofop) are sometimes mixed with SuperWham (propanil) to improve the postemergence control of larger grasses. Several instances of increased control have been noted in research; however, they often tend to be inconsistent and inconclusive. It should be noted that there are strong size interactions with propanil-based treatments: susceptible grasses with three leaves or less are usually controlled while grasses with six leaves or more often survive.

Often, fast-acting photosynthetic inhibitors (like propanil) will cause foliar burn and reduce uptake and translocation of systemic herbicide (like cyhalofop) and result in antagonism. However, SuperWham is a relatively unique propanil formulation because it is water-based and because it is said to contain a small amount of carbaryl. Clincher is an emulsified-concentrate formulation. In some cases, emulsified concentrate solvents will have an adjuvant effect on herbicide active ingredients and improve weed control.

To evaluate Clincher and propanil formulation interactions; Clincher at 0, 0.1, 0.21, and 0.31 kg ai/ha (0, 5, 10, and 15 fl oz/A) was combined factorially with SuperWham at 3.36 and 5.6 kg ai /ha (3 or 5 quarts or pounds), Stam M-4 at 3.36 kg ai/ha (3 quarts or pounds), and Stam SC at 3.36 kg ai/ha (3 quarts or pounds) to barnyardgrass (*Echinochloa crus-galli*) that was at the 4- to 5-leaf stage.

Three additional treatments evaluated the effect of EC-types of solvents on SuperWham efficacy. In these treatments, 1.12 kg ai/ha of Stam M-4 was added to 2.24 and 4.48 kg ai/ha A of SuperWham (in effect substituting 0.95 L or 1 quart of an EC formulation into the water-based formulation). Crop oil concentrate was added at 1.25% v/v to the water-based propanils (SuperWham and Stam SC) but was not added to Stam M-4 EC (based on typical surfactant recommendations). Crop oil was added to the Stam EC + Superwham treatments.

Standard weed science methodology was used: treatments were applied with CO_2-pressurized backpack sprayers at 20 gpa application volume, using 8002VS flat fan spray tips at approximately 165 kPa (25 PSI). The experiment was a randomized complete block with four replications, and plots were planted with rice although experiments were terminated as the single treatments were not intended to represent a full-season weed control program. Colby expected control values were calculated for all mixtures based on the performance of each herbicide alone, and compared with the actual control values observed from tank-mix treatments.

Clincher statistically improved barnyardgrass control from propanil products in roughly one-half of the observations, with numerical improvements being observed in most of the remaining observations. Based on simple LSD tests, there were a few instances of significant synergism but also some instances of antagonistic responses. In one experiment, although Clincher improved the control observed with propanil, the control from Clincher alone was actually numerically higher. Substituting 1.12 kg ai/ha of Stam M-4 into Superwham had little effect on barnyardgrass control, indicating that the Clincher responses are probably not due simply to it being an EC-type formulation acting as an adjuvant.

Insight into Causes of Antagonism between Cyhalofop-Butyl and Other Rice Herbicides in Barnyardgrass

Ottis, B.V., Mattice, J.D., and Talbert, R.E.

Applying graminicides simultaneously with other herbicides would be of great benefit to rice producers because it would allow them to control a wide variety of weeds with one herbicide application; however, because control of barnyardgrass and other grass weeds can be reduced when graminicides are mixed with some herbicides, they must be applied separately in order to maximize control. This phenomenon necessitates multiple herbicide applications, which increases costs to the producer.

Herbicide antagonism is defined as the reduction of control of certain weeds as the result of applying mixtures of two or more herbicides. Cyhalofop-butyl (CB), a graminicide used for postemergence grass control in rice, is antagonized by some rice herbicides when applied simultaneously or within a few days. The result of this type of antagonism usually results in decreased control of grass weeds. Research has shown that herbicide antagonism between graminicides and other herbicides may be caused by different mechanisms as the result of activity of the tank-mix partner.

A study was conducted in 2004 to quantify CB and CB metabolites when applied alone or in combination with halosulfuron, propanil, or triclopyr in barnyardgrass tissue. Following herbicide application to 3-leaf barnyardgrass, tissue was excised at 0.5, 4, 10, and 18 h after treatment. Tissue was extracted and analyzed using High Performance Liquid Chromatography (HPLC).

The absorption of CB into barnyardgrass tissue and hydrolysis to its phytotoxic metabolite, cyhalofop-acid (CA), was rapid, and halosulfuron and triclopyr had no effect. At 0.5 h after treatment, 69 to 75% of detectable CB had been hydrolyzed to CA when CB was applied alone or in combination with halosulfuron or triclopyr. The fate of CB and CA between 4 and 18 h after treatment followed a similar trend among treatments of CB alone, CB + halosulfuron, and CB + triclopyr. CB was absorbed in greater amounts within the propanil tank mixture than the other treatments most likely due to the high solvent load in the propanil formulation we utilized, which aided in movement through the cuticle. However, beyond 0.5 h after treatment, the ratio of CB to CA remained constant due to a likely interaction of propanil with an apoplastic esterase enzyme, which reduced hydrolysis of CB.

Based on these findings, it appears that antagonism of CB by triclopyr occurs beyond 18 h after application and is not likely associated with reduced hydrolysis of CB to CA as a result of the presence of triclopyr. Research has shown that the auxinic herbicide, 2,4-D, inhibited the production of active oxygen species induced by the effects of diclofop-methyl in oat, thereby, reversing phytotoxicity associated with diclofop-methyl. It may be possible that the auxinic herbicide, triclopyr, has a similar effect on CB activity in barnyardgrass.

Herbicide antagonism is a problem for crop producers and continues to be a field of interest among herbicide researchers. As reported with herbicides similar to CB, antagonism by halosulfuron and triclopyr is not due to reduced absorption or hydrolysis. Future research will hopefully bring about remedies to antagonism so that producers can apply a graminicide in combination with other herbicides and maintain adequate weed control with a single herbicide application.

Effects of Simulated Herbicide Drift on Rice

Hensley, J.B., Webster, E.P., Zhang, W., Bottoms, S.L., and Griffin, R.M.

Four studies were conducted at the LSU AgCenter Rice Research Station near Crowley, Louisiana, in 2005 to evaluate the effects of simulated herbicide drift on rice. The experimental design for each study was an augmented two-factor factorial with a nontreated added for comparison. Factor A consisted of herbicide rate. The herbicides were applied at drift rates of 12.5 and 6.3% of the labeled usage rate of 1.07 kg ai/ha glyphosate (133 and 66 g/ha, respectively), 2.63 kg ai/ha glufosinate (61 and 31 g/ha, respectively), 44 g ai/ha imazamox (5.5 and 2.7 g/ha, respectively), and 70 g ai/ha imazethapyr (8.7 and 4.4 g/ha, respectively). Each application was made with the carrier volume varying proportionally to herbicide dosage based on a carrier rate of 233 L/ha. Factor B consisted of application timings at different growth stages: panicle differentiation, boot, and physiological maturity. Each herbicide was evaluated in a separate study. Visual rice injury and rice plant height 21 days after herbicide treatment (DAT) and rough rice yield for the primary and ratoon crop were obtained. Primary and ratoon crop yields were combined and reported as total rice yield. Rice plant height, visual rice injury, and total rice yield data are presented as percent of the nontreated.

In the first study, the nontreated rice had a plant height of 56 cm at 21 DAT and a total rice yield of 7220 kg/ha. Glyphosate applied at 133 and 66 g/ha at panicle differentiation resulted in a rice plant height 70 and 72% and increased crop injury 78 and 54% of the nontreated, respectively, at 21 DAT. When applied at panicle differentiation, glyphosate applied at 133 g/ha resulted in a total rice yield 47% of the nontreated and when applied at 66 g/ha resulted in a total rice yield 61% of the nontreated. Glyphosate applied at panicle differentiation at 133 and 66 g/ha decreased rice plant height at ratoon harvest 5 and 9 cm, respectively. When glyphosate was applied at 133 and 66 g/ha at the boot stage, rice plant height was reduced 88 to 89% and crop injury was increased 10 to 14% of the nontreated at 21 DAT. At the same timing, total rice yield was 52% of the nontreated for both rates. Glyphosate applied at physiological maturity resulted in no effect on rice.

In the second study, the nontreated rice had a plant height of 49 cm at 21 DAT and a total rice yield of 7650 kg/ha. Glufosinate applied at 61 and 31 g/ha at panicle differentiation increased crop injury 23 and 10% of the nontreated, respectively, at 21 DAT. Glufosinate applied at 61 and 31 g/ha at the boot stage increased crop injury 19 and 13% of the nontreated, respectively, at 21 DAT. Glufosinate applied at physiological maturity resulted in no effect on rice.

In the third study, the nontreated rice had a plant height of 70 cm at 21 DAT and a total rice yield of 7370 kg/ha. Imazamox applied at 5.5 g/ha at panicle differentiation increased crop injury 6% of the nontreated at 21 DAT and resulted in a total rice yield 92% of the nontreated. Imazamox applied at the boot stage at rates of 5.5 and 2.7 g/ha reduced rice plant height 90 and 94% and increased crop injury 13 and 9% of the nontreated, respectively, at 21 DAT. Total rice yield was 48 and 54% of the nontreated when imazamox was applied at the boot stage at 5.5 and 2.7 g/ha, respectively. When imazamox was applied at physiological maturity, rice plant height at ratoon harvest was decreased 3 to 5 cm.

In the fourth study, the nontreated rice had a plant height of 54 cm at 21 DAT and a total rice yield of 8440 kg/ha. Imazethapyr applied at rates of 8.7 and 4.4 g/ha at panicle differentiation resulted in a rice plant height 80 and 92% and increased crop injury 23 and 8% of the nontreated, respectively, at 21 DAT. Imazethapyr applied at panicle differentiation at a rate of 8.7 g/ha resulted in a total rice yield 79% of the nontreated and when applied at 4.4 g/ha resulted in a total rice yield 92% of the nontreated. Imazethapyr applied at the boot stage at 8.7 and 4.4 g/ha resulted in a rice plant height 88 and 89% and increased crop injury 15 and 10% of the nontreated, respectively, at 21 DAT. When applied at physiological maturity at a rate of 4.4 g/ha imazethapyr, total rice yield was reduced to 93% of the nontreated. No effect on rice was observed when the 8.7 g/ha rate of imazethapyr was applied at physiological maturity.

A drift rate, of any herbicide evaluated in these studies, at the boot stage of rice generally resulted in the greatest increase in injury and reduction in total rice yield. These data indicate that herbicide drift to rice would be more detrimental at the boot stage than at panicle differentiation or physiological maturity.

Herbicide Developments in the Clearfield Rice Production System

Guice, J.B., Rhodes, A.R., and Rice, C.

The Clearfield Rice Production System has enabled growers to control red rice in a domestic rice crop. The two imidazolinone herbicides used in Clearfield rice are Newpath (imazethapyr) and Beyond (imazamox). In 2005, Clearpath (quinclorac + imazethapyr) also became available for use in Clearfield rice. Clearpath provides broad spectrum, residual weed control when used in a sequential program with Newpath.

In 2005, BASF submitted label changes to the EPA, which would increase the season use rate of Newpath from 0.125 lb ai/A to 0.1875 lb ai/A. The PHI for 0.1875 lb ai/A would be 45 days. The increased rate would only be allowed on enhanced tolerant varieties. Label changes were submitted that would extend the Beyond application timing to Panicle Initiation (PI) + 14 days, for control of red rice.

Field trials were conducted in 2005 to evaluate the optimum application timing of Clearpath. Clearpath was applied either early or late postemergence at 0.378 lb ai/A, in a program with Newpath at 0.0625 lb ai/A. In these field trials, excellent red rice, annual grass, and hemp sesbania control was obtained, regardless of which product was applied first.

Growth Retardation of Red Rice with Newpath in Clearfield Rice

Dunand, R.T.

Preflood applications of imidazolinone herbicides in Clearfield rice are effective in reducing red rice seedling populations. Red rice that escapes needs to be managed to minimize competition with the rice crop and reduce the potential for outcrossing. In situations where red rice infestations are high (>100 plants/m^2), 99% control allows an average survival rate of 1 red rice plant/m^2. Due to the growth habit of red rice, it is very competitive. Red rice is tall (~150 cm) and can produce between 10 and 30 tillers/plant compared with conventional Clearfield varieties that are approximately 100 cm in height and produce 3 to 4 tillers/plant. A study was conducted to determine the effectiveness with which imazethapyr reduces competition of red rice in Clearfield rice as it relates to time of application.

The imazethapyr-tolerant long-grain line, CL161, was drill-seeded on 18-cm row spacings on April 2, 2005. Plot size was 1.8 (15 rows) x 7 m. Seeding rate was 80 kg/ha. Imazethapyr (Newpath, BASF Corp., Research Triangle Park, North Carolina) was applied 2 days prior to establishment of the permanent flood (preflood) and at 2-week intervals after establishment of the permanent flood until 12 weeks postflood. Rate of imazethapyr was 70 g/ha with 0.25% Agri-Dex. Recommended agricultural practices were followed to provide adequate pest control and fertility.

Crop and weed growth and development were evaluated at maturity, and both rice and red rice growth were significantly affected by time of herbicide application. Mature plant height (distance from the soil surface to the tip of the panicle extended vertically) of CL161 ranged between 94 and 101 cm (control = 100 cm). Imazethapyr applied 4 weeks postflood reduced plant height below the control (94 vs. 100 cm). The other postflood treatments and the preflood treatment had plant heights ranging from 97 to 101 cm. With red rice, mature plant height ranged between 129 and 141 cm for the preflood and 2, 4, 6, and 8 weeks postflood treatments (control=152 cm). Treatments at 10 and 12 weeks postflood had no significant effect on red rice plant height (152 and 146 cm, respectively). Due to the moderate to high red rice infestation, lodging was variable, ranging from 0 to 73%. Treatments including imazethapyr applied preflood and postflood at 4, 6, and 8 weeks had minimal lodging (0 to 4%). Treatments applied at 2 and 10 weeks postflood had intermediate lodging (27 and 31%, respectively), and imazethapyr applied at 12 weeks postflood resulted in lodging (75%) equivalent to the control (63%). Red rice panicle density was reduced by all treatments except imazethapyr applied at 12 weeks postflood. Red rice panicle densities were very low (0 to 3 panicles/m^2) with the preflood and 8 and 10 weeks postflood timings, moderate to intermediate (21 to 52 panicles/m^2) with the 2, 4, and 6 weeks postflood timings, and high (75 panicles/m^2) with the 12 weeks postflood timing and control.

Crop maturity and production were evaluated at harvest, and both were significantly affected by time of herbicide application. Grain moisture (an indicator of crop maturity) ranged between 16.9 and 23.7%. The only treatment that matured early compared with the control was the preflood application of imazethapyr (16.8 vs 23.7%). The postflood treatments had grain moistures ranging between 21.8 and 23.7%. Grain yield (adjusted to 12% moisture) was high with the preflood treatment (5687 kg/ha), intermediate (3551 to 4150 kg/ha) with the 2, 4, and 6 weeks postflood treatments, and low (1892 to 2337 kg/ha) with the 8, 10, and 12 weeks postflood treatments. Grain yield in the control was 3192 kg/ha.

Imazethapyr can be effective in reducing competition from red rice in Clearfield rice and can help to limit the movement of traits imparting herbicide resistance to red rice. The effectiveness of imazethapyr is dependent on time of application, with early (pre- and postflood) applications decreasing red rice competition in a typical herbicide/weed control fashion and late-season applications (8 to 10 weeks postflood) decreasing red rice panicle formation in a typical plant growth regulator/growth suppression fashion. Early- and late-season applications combined should provide an adequate reduction in red rice competition while limiting the outcrossing potential in red rice plants that compete with Clearfield rice through maturity.

Influence of Ultraviolet-B Radiation on Rice Tiller Development

Mohammed, A.R., Rounds, E.W., and Tarpley, L.

Low levels of UV-B radiation below the canopy in densely planted rice (*Oryza sativa* L.) fields have a negative impact on tiller initiation and development. Moreover, there is a varietal difference in the response to UV-B radiation in rice. Previous studies indicate an increase or decrease or no effect of UV-B radiation on percentage change in tiller numbers among rice cultivars.

The objective of this study was to examine the effects of UV-B radiation on rice physiology with special emphasis on tiller development of the main crop for three different rice cultivars: Cocodrie, Sierra, and CL161. Rice plants were exposed to UV-B radiation of 0 (control), 8 (ambient), or 16 (twice ambient) kJ m^{-2} d^{-1} in Experiment I and 0, 4 (sub-ambient), or 8 kJ m^{-2} d^{-1} in Experiment II. Exposure was from 20 d after emergence to the early grain-filling stage (76 d after emergence) in a square-wave approach for 8 h from 0800 to 1600 h. The UV-B radiation intensity was checked daily with a UVX digital radiometer. Plant height, tiller number per plant, leaf temperature, chlorophyll content, and leaf sugar content were measured.

Results indicated no significant difference between 8 and 16 kJ m^{-2} d^{-1}. However, there was a significant difference between ambient UV-B level and the control for tiller number in Experiment I for cultivar CL161. Similar results were seen in the second experiment. However, there was no significant difference between sub-ambient UV-B level and the control. When grown under ambient UV-B level, CL161 showed 50% increase in tiller number relative to the lower UV intensity treatments. The increase in tiller number might be due to increase in carbohydrate content or/and increase in the content of photo-oxidation products of Indole Acetic Acid (IAA) under increased UV-B or/and due to the changes in photoreceptor for UV-B. Our results indicated no significant difference in the carbohydrate pool among the cultivars or the UV-B treatments. Hence, increase in tillers might be due to increase in the content of photo-oxidation products of IAA under increased UV-B or/and due to the changes in photoreceptor for UV-B.

Winter Weed Control for Commercial Rice (*Oryza sativa* L.) in Texas

Nanson, W.D., Willingham, S.D., McCauley, G.N., and Chandler, J.M.

Studies were established in the fall of 2004 at the Texas Agricultural Experiment Stations at Eagle Lake and Beaumont, Texas, to evaluate winter weed control for commercial rice (*O. sativa*) in Texas. The herbicides evaluated were clomazone (Command) at 1 lb/A in Eagle Lake and 1.25 lb/A in Beaumont, flumioxazin (Valor) at 2.5 oz/A, glyphosate (Roundup Weathermax) at 1 lb/A, glufosinate (Liberty) at 0.5 lb/A, prosulfuron (Peak) at 0.5 oz/A, and 2,4-D (Weedar 64) at 1 lb/A. Three application times used were fall (October), winter (December), and spring (February). Treatments were applied with a backpack CO_2 sprayer and a four-nozzle spray boom. Weed control was evaluated visually (0-100%) at 2, 4, and 8 weeks after application. Monocot families included in the study were *Poaceae* and *Iridaceae*. Dicot weed families included were *Asteraceae*, *Fabaceae*, *Polygonaceae*, *Brassicaceae*, *Apiaceae, Oragraceae*, *Rubiaceae*, and *Campanulaceae*.

In the fall, clomazone + flumioxazin and clomazone + prosulfuron provided >95% control of all weed species at 8 weeks after application (WAA), but clomazone + prosulfuron didn't provide adequate control of volunteer rice. The winter application of glyphosate + flumioxazin had a >95% control for all winter weed species 8 WAA. In the spring, single applications of glufosinate and glyphosate did not provide adequate control of rescuegrass (*Bromus catharticius* Vahl) in Eagle Lake and winter broadleaves in Beaumont, but all single and sequential applications of glyphosate + flumioxazin provided excellent weed control. Emerging broadleaf signalgrass (*Brachiaria platyphylla* Griseb. Nash) at Eagle Lake and barnyardgrass (*Echinochloa crus-galli* L. Beauv.) in Beaumont were not adequately controlled with any treatment prior to planting. Winter broadleaf control was >90% with all treatments that contained glyphosate + flumioxazin and clomazone + prosulfuron fb glyphosate. Clomazone + prosulfuron, clomazone + flumioxazin, and all treatments with glyphosate applied in February provided >90% control of emerging broadleaf signalgrass (*Brachiaria platyphylla* Griseb. Nash) in Beaumont.

Combinations for Controlling Texasweed in Drill-Seeded Rice

Williams, B.J. and Burns, A.B.

In 2005, two studies were conducted to evaluate programs for controlling Texasweed at the Northeast Research Station near St. Joseph, LA, on a Sharkey Clay soil. Rice was seeded at 100 kg/ha to plots measuring 2 by 4.5 m. 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. At panicle initiation, an additional 42 kg/ha of nitrogen was applied. Herbicide treatments were applied in 140 L/ha of water using a CO_2 pressurized backpack sprayer. The experimental design in both studies was a randomized complete block. A factorial treatment arrangement was used in the first study.

In the first study, penoxsulam at 0.15 L/ha (2.0 oz/A) and 0.17 L/ha (2.3 oz/A) alone and tank mixed with 0.11 L/ha (1.5 oz/A) carfentrazone, 0.58 L/ha (8 oz/A) triclopyr, or 25 kg/ha (0.35 oz/A) halosulfuron was applied at the 1- to 3-inch and 3- to 6-inch weed stages. Texasweed control from penoxsulam alone was best when applied to 1- to 3-inch weeds, but 80% was the best control observed. Early-season control was improved some when penoxsulam was mixed with carfentrazone, but late-season control was not improved compared with 2.3 oz/A penoxsulam. Tank mixing penoxsulam with triclopyr did not improve Texasweed control. Tank mixing 2.0 oz/A penoxsulam with 0.35 oz/A halosulfuron at the 1- to 3-inch timing improved Texasweed control from 70% with penoxsulam alone to 90%. The same treatment at the 3- to 6-inch timing improved control from 50 to 83%.

In the second study, penoxsulam, bispyribac, triclopyr, halosulfuron, and bensulfuron applied alone and in various combinations were evaluated. Triclopyr at 0.80 L/ha (11 oz/A) controlled Texasweed 92% and was the only herbicide that controlled Texasweed when applied alone. As in the first study, combinations of penoxsulam with 8 oz/A triclopyr did not control Texasweed. Penoxsulam at 2.0 oz/A mixed with 35 kg/ha (0.5 oz/A) halosulfuron or 52 kg/ha (0.75 oz/A) bensulfuron controlled Texasweed 67 and 92%, respectively. Penoxsulam at 2.0 oz/A or 0.5 oz/A bispyribac mixed with 0.75 oz/A bensulfuron + 17 kg/ha (0.25 oz/A) halosulfuron controlled Texasweed 93%. Though preliminary, these results suggest that penoxsulam combinations with bensulfuron and/or halosulfuron can be used to control Texasweed. Additional research is needed to confirm these results and to refine rates and timings.

Evaluation of Programs for Alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb) Control in Texas Rice

Willingham, S.D., Nanson, W.D., McCauley, G.N., and Chandler, J.M.

Field studies were conducted in 2005 to evaluate herbicide programs for the control of alligatorweed and its effect on yield in rice production. Studies were located in growers' fields near Eagle Lake, Garwood, and Ganado, TX, where alligatorweed populations were adequate. Penoxsulam (Grasp) at 0.031 kg ai/ha alone and in combination with propanil (Stam) at 3.3 kg/ha or triclopyr (Grandstand) at 0.21 kg/ha and propanil + triclopyr were applied early-postemergence (EPOST) when rice was at the 3-leaf rice stage and alligatorweed was 7.6 to 12.7 cm tall and late postemergence (LPOST) when rice was at the 4- to 5-leaf stage and alligatorweed at 10 to 17.5 cm tall. Additional LPOST treatments included combinations of bispyribac-sodium (Regiment) at 0.028 kg/ha, propanil, triclopyr, bensulfuron (Londax) at 0.027 kg/ha, quinclorac (Facet) at 0.33 kg/ha, and penoxsulam. Treatments were applied with a CO_2 pressurized backpack sprayer and visual alligatorweed control ratings (0-100%) and yield were measured and subjected to analysis of variance. Means were separated using Fisher's protected LSD at the 10% level.

Penoxsulam and penoxsulam + triclopyr at EPOST provided >82 and 86% control at 2 and 4 weeks after treatment (WAT), respectively, and continued until the end of season with penoxsulam + triclopyr. By 7 WAT, control was reduced to <72% with penoxsulam alone. When treatments were applied LPOST, control was >82% except penoxsulam control declined to <73% by 4 WAT. Penoxsulam + propanil and propanil + triclopyr provided <68% season long. When these treatments were applied LPOST, results were similar, <62% with propanil + penoxsulam and <69% with propanil + triclopyr. Bispyribac-sodium provided <76% control alone. The addition of propanil reduced control to <61%; however, the addition of triclopyr increased control to >87% for alligatorweed all season. Bensulfuron and quinclorac + propanil LPOST provided <55% control at 2 WAT and < 66% by 7 WAT. Yield ranged from 9520 to 6791 kg/ha, and penoxsulam + triclopyr treatment yielded only significantly higher than bensulfuron treatment.

Overall, alligatorweed control was achieved with Grasp alone and increased with the addition of triclopyr. Triclopyr increased control in tankmixes; however, propanil reduced control in tankmixes indicating possible antagonism with penoxsulam. Bispyribac-sodium also provided control only when mixed with triclopyr but not alone or when mixed with propanil.

Tolerance of Southern U.S. Rice (*Oryza sativa* L.) to Penoxsulam as Influenced by Application Rate and Timing

Meier, J.R., Smith, K.L., Doherty, R.C., and Kelley, M.B.

A study was established in 2005 at the Southeast Research and Extension Center located in Rowher, AR, to examine rice tolerance to multiple rates of penoxsulam at various application timings. The cultivar Cheniere was drill seeded at 101 kg/ha on a sharkey clay soil and grown under normal rice culture. A complete randomized block design was utilized with four replications. Penoxsulam was applied at 0 kg ai/ha, 0.035 kg ai/ha (1x), 0.053 kg ai/ha (1.5x), and 0.070 kg ai/ha (2x) at the 2-, 4-, and 6-leaf rice growth stages. Applications were made using a CO_2 pressurized backpack sprayer calibrated to deliver 112 L/ha. Observations measured were percent (%) root mass reduction and plant height in centimeters (cm) 2, 4, and 6 weeks after application. Yields were obtained using a small plot combine.

Root mass reduction from 0.035 kg ai/ha of penoxsulam ranged from 12 to 48% across growth stages when observed 15 days after application. Sixteen days after 0.053 kg ai/ha of penoxsulam was applied root mass was reduced from 30 to 61% across growth stages. Root mass was reduced 35 to 70% across growth stages 16 days after 0.070 kg ai/ha of penoxsulam was applied. There was a response between 0.035 kg ai/ha and 0.070 kg ai/ha of penoxsulam at the 4- and 6-leaf application timings. Root mass reduction 15 days after the 2-leaf application ranged from 35 to 38% across rates. Sixteen days after the 4-leaf application root mass was reduced 48 to 70%, and 16 days after the 6-leaf application root mass was reduced 12 to 53% across rates. Plant height from the 2-leaf application ranged from 11 to 19 cm 15 days after application. Sixteen days after the 4-leaf application plant height ranged from 29 to 33 cm and 66 to 67 cm 16 days after the 6-leaf application.

Root mass reduction had diminished to less than 5% in the 2- and 6-leaf application timings by the fourth week after application observation and was not evident 6 weeks after application. However, root mass was still reduced 48 to 60% 4 weeks after the 4-leaf application timing. By 6 weeks after application, root mass reduction was only 8 to 13%. Yield ranged from 9,700 kg/ha to 10,900.

The Need for Herbicide Resistance Management in Rice

Branson, J.W., Smith, K.L., Scott, R.C., and Wilson Jr., C.E.

Resistance to pesticides was first documented in 1908 when San Jose Scales where shown to be resistant to lime sulfur. The idea of herbicide resistance was first published in 1956 and reported in Hawaii as early as 1957. Herbicide resistance has been defined as an altered response to a herbicide by a formerly susceptible species to the extent some individuals are no longer susceptible. It was not until 1968 that herbicide resistance was reported in the continental United States. In 1968, common groundsel was documented to be resistant to triazine. Since that time there are 65 weeds that are resistant to triazines. Listed on the Weed Science Society's web page are 304 resistant biotypes, which consist of 182 different species. These resistant weeds are reported to be in 270,000 fields and combined are resistant to 19 different herbicide families.

Herbicide resistance was first documented in Arkansas rice production in 1990 when *Echinochloa crus-galli* was reported to be resistant to propanil. Since that time, Texas, Missouri, and Louisiana have also reported propanil resistance to this species. In 1998, quinclorac resistance in *Echinochloa crus-galli* was documented in Louisiana. Multiple resistance was reported in 1999 in Arkansas when propanil and quinclorac resistant grass was found. To date, these are the only two documented weed species that are resistant to the herbicides labeled in Arkansas rice production. However, there are 11 weeds in Arkansas that are resistant to different herbicide families.

Clomazone is a carotenoid inhibitor that is widely used in rice production, and its use has increased every year since it was introduced to the rice market. Resistance to carotenoid inhibitors is rare, but there are two documented species. Resistance to herbicides can happen in a very short time when selection pressure is high. This has been clearly shown with the ALS inhibitors where there are 93 resistant species since their introduction. When the same herbicides are continually used year after year, selection pressure for resistant weeds increases, resulting in herbicide resistant weed populations. No herbicides are above resistance, and this was clearly shown with the documentation of glyphosate-resistant weeds.

The need for herbicide resistance management in rice is critical due to the loss of herbicides and no new herbicide families in development. The loss of molinate and proposed restrictions on the use of propanil only increase the need for resistance management. There have been new herbicides introduced to rice production, such as cyhalofop and fenoxaprop for grass weed control. However, resistance to the two herbicides has already been documented in California. Rice varieties tolerant to imazethapyr were introduced as a way to control red rice, and resistance in Arkansas was reported in 2004.

Resistance management strategies are not hard to incorporate, they are just not as convenient as continuing the same practices over and over until the technology no longer works. Herbicide resistance management plans should include: herbicide rotation and herbicide family rotation, crop rotation, monitor suspicious weeds following herbicide applications, and tillage. These practices will help keep the occurrences of resistance at a lower level and provide longer use of current technology.

Rice (*Oryza sativa* L.) Containing the *Bar* Gene is Compositionally Equivalent to the Non-Transgenic Counterpart

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Rice is primarily an energy source in human nutrition, and carbohydrates comprise about 80% by weight of the whole grain. However, in regions of the world where it is considered a staple, rice can be the principal dietary source not only of energy but also of protein, iron, calcium, thiamin, riboflavin, and niacin. A demonstration of compositional equivalence is included in registration dossiers for transgenic crops. In such a demonstration, the transgenic crop and a counterpart are compared in a side-by-side study, grown as is common for commercial production and the key nutritional components are determined by chemical analysis. We will present the statistical comparisons to test for equivalence comparing grain derived from glufosinate-tolerant rice, genetic event LLRICE62, and its non-transgenic counterpart.

A single linear DNA fragment containing one copy of the *bar* gene expression cassette was introduced into the rice variety Bengal. The *bar* gene was isolated from genomic DNA of *Streptomyces hygroscopicus*, a common soil microbe. The *bar* gene encodes the enzyme phosphinothricin acetyltransferase (PAT). Expression of PAT allows the rice plant to be sprayed with the biodegradable, non-selective, herbicide active ingredient phosphinothricin, commonly known as glufosinate ammonium, without crop injuries. The inserted gene is inherited as a simple dominant trait. Stability of the gene insertion has been demonstrated by Southern blot analyses and Mendelian crosses. Furthermore, current molecular techniques were used to make a description of the insertion site on the rice chromosome 6. The 35S promoter and terminator sequences control expression of the bar gene in LLRICE62. The 35S promoter directs high level constitutive expression. The amount of PAT protein in the leaves of LLRICE62 during the vegetative life cycle of the plant has an upper limit of approximately 150 µg/g fresh weight. Roots and grain contain approximately 12 µg/g fresh weight PAT protein. No PAT protein was detected in rice pollen.

The two counterpart rice varieties have the same genetic background, except for the presence of the *bar* gene in the glufosinate-tolerant rice. Field trials were conducted in regions where the variety Bengal is commercially grown using agricultural practices common for those regions. Grain samples were collected from two growing seasons (1998 and 1999), 14 locations, and a 3-fold replication per treatment (non-transgenic rice treated with conventional herbicides, transgenic rice treated with conventional herbicides, and transgenic rice treated with glufosinate-ammonium herbicide). Rough rice samples were ground and analyzed for proximates, fiber compounds, total amino acids, micro-nutrients (minerals, vitamins), and phytic acid.

The statistical approach was a modification of the t-test procedure. Instead of using the t-test table for the means comparisons to determine difference, the equivalence analysis tests whether the treatment differences exceed the range of normal variation of the non-transgenic crop. In the first step of the statistical assessment of the data, the means of the non-transgenic (reference) group were calculated for each nutritional component. Then, equivalence boundaries were set to ± 20% of the means. The next step is the analysis of equivalence for each component. For the overall analysis, an analysis of variance (ANOVA) was calculated with the factors treatment, location, and their interaction term (fixed effects). Based on the ANOVA, 2-sided confidence intervals 100 $(1-2*\alpha)$ % (= 90%), where $\alpha = 0.05$, were calculated pair wise for the treatment differences. Two treatments were considered in these studies as equivalent, if the 90% confidence interval of the difference was within ± 20% of the mean value of the respective reference treatment (non-transgenic crop). In addition, the values for each nutritional component are compared with the ranges reported for commercial rice.

Equivalence assessed by statistical methods was demonstrated for proximates, fiber compounds, all amino acids, most minerals and vitamins, and for the anti-nutrients in rough rice samples. For calcium, iron, vitamin B1, pantothenic acid, and vitamin E equivalence between the datasets could not be proven statistically, but except for vitamin B1, all mean values calculated for these micro-nutrients in the transgenic samples are within the reference range reported in the literature for rice in commerce and were, in fact, not lower than those of the non-transgenic reference. Vitamin B1 levels were higher than those reported in the literature for all treatments including the non-transgenic control, indicating that this is not an effect caused by the genetic modification. The assessment of the composition data and the comparison with reported ranges leads to the conclusion that LLRice62 has the same nutritional value and is compositional equivalent to its non-transgenic counterpart and to other commercial rice varieties.

Risk Assessment of the Transfer of Imazethapyr Herbicide Tolerance from Clearfield Rice to Red Rice

Zhang, W., Linscombe, S.D., Webster, E.P., Tan, S., and Oard, J.H.

Hybridization between Clearfield rice and weedy red rice would have a direct impact on management and long-term strategies of imazethapyr technology for rice weed control. The objective of this research was to determine rates and agronomic consequences for outcrossing between Clearfield rice and red rice. Red rice populations showed extensive variation for plant height, panicle length, tillers/plant, seeds/plant, seed set, and grain weight. Outcrossing was detected from all Clearfield rice cultivars (CL121, CL141, CL161, and CLXL8) to red rice and was confirmed by phenotypic and DNA marker analyses. An overall outcrossing frequency of 0.17% was observed in 2002 red rice samples with a range from 0 to 0.46%. Tolerance of 2002 red rice samples to imazethapyr corresponded to levels of acetohydroxyacid synthase (AHAS) activity. A majority (94%) of the progeny from the 2002 samples segregated 3 resistant:1 susceptible for tolerance to imazethapyr, indicating that a single dominant gene from Clearfield rice was associated with tolerance in the hybrid material. The remaining samples did not segregate for tolerance, suggesting that spontaneous mutations for tolerance were present in this material before or after crossing with Clearfield rice. A four-fold increase in outcrossing frequency of 0.68% was observed in 2003 red rice samples with the highest outcrossing frequency for a single location at 3.2%. Results from this study indicate that outcrossing between Clearfield and red rice will occur rapidly at rates that warrant early-season field scouting and a crop rotation scheme to prolong usefulness of the Clearfield technology.

Fitness of Crosses between Clearfield Rice and Strawhull Red Rice

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When Clearfield (CL) rice (resistant to imidazolinone herbicides) and red rice overlap in the flowering period, low levels of gene transfer occur. Crosses between CL rice CL161 and CL121 with an awnless, strawhull red rice were made to determine the segregation of herbicide resistance and fitness of the first and second generation offsprings. The experiments were conducted mostly at the Rice Research and Extension Center (RREC), Stuttgart, AR, except for the characterization of F_2 plants, which was done at the Cotton Branch Station, Marianna, AR, from 2002 to 2004. Controlled crosses were made in the greenhouse at the RREC in 2002. F_1 plants, V4 to V5, were transplanted in the field, spaced 3 x 4 m apart, on May 29, 2003, for characterization. The majority of F_1 plants did not flower in the field during the summer so all plants were dug up in the first week of October, transplanted into pots, and placed in the greenhouse for seed production. F_2 seeds were planted in the field, by family, for screening of resistant phenotypes and characterization of F_2 plants in 2004. The F_2 plants were sprayed twice with imazethapyr (0.07 kg ai/ha). The first application was done at V2 to V3 and the second application was done 1 week later. The number of plants that emerged was counted. Each plot (family) was visually rated for injury using a scale of 0 to 100%, where 0 = no injury and 100 = complete death. The F_2 plants were then categorized according to the level of injury sustained from the herbicide application: 1) resistant (R, 0 to 20%); 2) moderately resistant (MR, 21 to 80%); and 3) susceptible (S, 81 to 100%). The frequency of plants belonging to each category was determined. Hybrid vigor was apparent wherein crosses between CL rice and red rice resulted in F_1 plants that were 40 to 50% taller than the CL parent, regardless of cultivar used. CL121 and CL161 were 85 and 96 cm tall, respectively. F_1s were also taller than the red rice parent, which was 110 cm tall on average. On average, F_1 plants produced 45% more tillers than CL rice or red rice parent. Fitness traits discussed in this paper include seed production, germination, and onset of flowering of F_1 and F_2 plants. Only filled grains were quantified. Segregation of resistance among F_2 plants is also discussed. CL121 and strawhull red rice initiated flowering within 3 days of each other (95 and 98 DAP, respectively). CL161 flowered 102 DAP. All F_1 plants flowered later than their parents. The majority (85%) of CL121 x RR hybrids flowered in the field 108 DAP (Sept. 13). Sixty-two percent of CL161 x RR hybrids flowered 90 DAP (Aug. 26). None of the hybrids with red rice as the female parent flowered in the field, regardless of CL rice pollen donor. Once transferred to the greenhouse, the vegetative hybrids initiated flowering simultaneously at 140 DAP. Overall, of 62 F_1 hybrids, only 25% flowered in the field and this occurred mostly in mid-September. In general, hybrids of RR x CL121 produced numerically less seed (13/plant) than those of RR x CL161 (90/plant). Hybrids with CL rice as the female parent (either CL121 or CL161) produced more seed (1,596/plant) than hybrids with red rice as the female parent. When planted in the field, F_2 seeds of hybrids with CL161 had a lower percentage of emergence than the CL161 parent. F_2 seeds of hybrids where red rice was the female parent had at least two times the germination percentage of those where Clearfield rice was the female parent, regardless of cultivar. There was a difference in plant response to imazethapyr between CL121 and CL161 plants and among plants of the same cultivar. The majority of CL121 plants (68%) were only moderately resistant while the majority of CL161 plants (83%) were resistant. Nevertheless, the F_2 plants still segregated into a 1:2:1 ratio of R:MR:S, which attributes resistance to a single, partially dominant gene. A fitness penalty was observed among F_1 hybrids in terms of delayed flowering, reduced seed production, and reduced germination of F_2 seed. Seeds of F_2 plants tested showed 95 to 100% germination. The reduced fitness of F_1s is not necessarily due to the herbicide resistance trait. It could be a natural consequence of hybridization between cultivated rice and red rice. Related research could support this hypothesis. The low frequency of outcrosses in producers' fields is also partly due to the reduced fitness of F_1s.

Gene Flow from Herbicide-Resistant and Non-Resistant Rice into Red Rice Populations in U.S. Rice Fields: A Survey of Current Evidence

Gealy, D.R., Estorninos Jr., L.E., Agrama, H.A., and Eizenga, G.C.

Diverse red rice types infest U.S. rice fields. These infestations have remained widespread despite recent successes in controlling red rice in newly-introduced herbicide-resistant rice systems. As a result, the distribution and genetic background of red rice, and the degree to which red rice intercrosses with commercial rice, particularly herbicide-resistant rice, have remained topics of great biological and economic interest. Analyses based on PCR-based simple sequence repeat (SSR) markers are being employed at the USDA-ARS, DB NRRC in Stuttgart, AR, to address these issues from the basic and practical perspectives.

Sixty-two red rice accessions and crosses (or putative crosses) were obtained from the major rice-producing counties in Arkansas and from selected areas of Missouri, Mississippi, Louisiana, and Texas. The genetic background and interrelatedness of these accessions was compared with a wide range of standards, which included 84 common U.S. and foreign commercial (white) rice cultivars/lines, 58 red rice cultivars/lines (non-weedy types), and 37 additional lines of *Oryza* species (other than *O. sativa)* obtained from the USDA-ARS rice germplasm collection. The aforementioned germplasm was genotyped with 32 SSR markers, and the data were analyzed with appropriate software to identify genetic distance, population clusters and population structure. With the exception of the rice-red rice crosses, which clustered between the U.S. rice and red rice entries, the U.S. red rice accessions generally clustered closely together and were genetically distant from all U.S. cultivars. Although these accessions were genetically closer to a number of red rice cultivars and other *Oryza* species, they generally were substantially different from all of the other standards tested. Seven of the 32 SSR markers differentiated between the imidazolinone-resistant cultivars, CL161 and CL121, and two markers (RM224 and RM345) differentiated between these cultivars, as well as a number of common U.S. cultivars and red rice types. Ten SSR markers, in combination with observations of phenotypic traits, were employed to determine rapidly the presence and apparent identity of unknown red rice types and rice-red rice crosses obtained from grower's fields. Further analysis of the data has suggested that as few as five of these markers may reliably differentiate between imidazolinone-resistant cultivars and a sizeable number of other commercial cultivars, red rice types, and crosses. However, such streamlined approaches to identifying unknown plant types may sacrifice some degree of accuracy for speed and affordability.

In a practical example of our efforts, a 'variable' population of 'red rice-looking' plants obtained from a farm field in Mississippi County, AR, in 2005 was shown to contain a number of individuals with green or purple stems; green or pink awns, or no awns; rough or smooth leaves; and red or white seeds. Collectively, these combinations of phenotypic traits are strongly indicative of a segregating population in the F_2 generation or later, that was derived from a cross between rice and an awned blackhull red rice type. This tentative diagnosis was strengthened using the 10 aforementioned SSR markers to confirm a) the presence of numerous homozygous or heterozygous alleles that were also present in one or both of the commercial rice or awned blackhull red rice standards tested and b) that the genetic distances between this group of unknowns and both standards were generally similar. This research shows that key phenotypic traits in combination with SSR analyses can be used effectively to genotype unknown red rice types and determine genetic backgrounds of weedy/red rice types derived from herbicide-resistant or non-resistant rice parents.

Flowering Patterns of Red Rice Biotypes and Clearfield Cultivars are Affected by Planting Dates

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Differences in red rice (RR) biotypes, Clearfield (CL) cultivars, and planting time may impact the rate of herbicide-resistant gene transfer from CL rice to RR. Our objectives in this study were to 1) evaluate the flowering behavior of 12 RR biotypes and two CL rice cultivars with respect to planting dates, 2) to determine yield losses in CL cultivars due to different RR biotypes, and 3) to determine outcrossing rate between CL cultivars and RR biotypes.

The experiments were conducted at the Southeast Research and Extension Center, Rohwer, and at the Rice Research and Extension Center, Stuttgart, AR, in summer of 2005. Results from Stuttgart experiments are presented in this paper. Experimental design was split-split plot with three replications. Planting time, CL cultivar, and RR biotypes were main, sub, and sub-subplot, respectively. Planting dates were April 16 (PD 1), April 27 (PD 2), May 13 (PD 3), and May 26 (PD 4). CL cultivars, CL161 and hybrid CLXL8, were drill-seeded at 90 and 30 lb/A, respectively. Twelve RR accessions from four rice growing zones in Arkansas were used. The accessions represent an assortment of characteristics based on: geographical location (north, south, east, and central Arkansas), hull color (strawhull, brownhull, and blackhull), height, and flowering time. Each red rice accession was planted in the middle of 9-row, 10-ft long plots with four rows of rice on both sides. Data on emergence, flowering, and yield were recorded. After flowering, the RR panicles were bagged to collect seeds for outcrossing rate determination. The middle four rows of rice were harvested and rough rice yield were determined.

In general, strawhull RR emerged faster than brownhull and blackhull. Red rice emergence varied from 10 to 35 days after planting among and between accessions across planting dates. However, RR emergence did not differ by geographical origin. Earlier planted CL rice and RR biotypes took longer to flower than later planted ones. On average, CLXL8 flowered 3 to 5 days earlier than CL161, although flowering was over within a week in both CL cultivars regardless of planting date. Highest synchronization in flowering of RR accessions and CL cultivars was observed in PD 1. The overlap of flowering between RR and CL rice continuously declined with delay in planting time. Thus, PD 4 had the least overlapping in flowering of RR and CL cultivars. Two red rice biotypes did not overlap in flowering time with CL cultivars in any planting dates. Flowering period of RR biotypes ranged from 88 to 128, 87 to 117, 79 to 118, and 71 to 116 DAP in the first, second, third, and fourth planting, respectively. In all plantings, there was synchronization in flowering (50%) between both CL cultivars and at least six RR accessions. Rice yields varied, depending on the RR accessions growing with it. In general, yield losses were higher in CL161 than CLXL8. The yield reduction increased with delay in planting time in both CL cultivars. To determine outcrossing rate, collected red rice seeds will be screened in field using imazethapyr herbicide. Survivors of screening will be confirmed as hybrids using simple sequence repeat (SSR) primers.

Abstracts of Posters on Rice Weed Control and Growth Regulation
Panel Chair: J.M. Chandler

An Early-Stage Weed Identification System in Rice

Zhang, W. and Webster, E.P.

Early-stage weed identification is important for making appropriate weed management decisions in crop production. Misidentification of dominant weeds at an early stage may lead to choosing inappropriate weed control programs, resulting in insufficient weed control and crop yield loss. In addition, the time window for a weed management decision to be made is usually very narrow, thus it is important for such weed identification system to have features such as easy-to-use, directness, and key characteristics. Traditionally, a weed identification system starts with floral characteristics, which may not be applicable in making a timely weed management decision.

A weed identification system was established in 2005, which focuses on using early-stage plant characteristics to differentiate weeds in rice production of southwest Louisiana. In this system, weeds are categorized into three major groups, broadleaves, grasses, and sedges. Under broadleaves, there are two subgroups, annual broadleaves and perennial broadleaves. Under each broadleaf subgroup, key characteristics of cotyledon, leaf, stem, or growth habits are used to further differentiate broadleaf species. Under grasses, there are two subgroups, annual grasses and perennial grasses. Under each grass subgroup, key characteristics of ligule, sheath, leaf, stem, or growth habits are used for further differentiation of grass species. Under sedges, key characteristics of leaf, rhizome, or tuber are used to differentiate the species. The system is designed as a MS PowerPoint presentation using hyperlinks to make selections; therefore, it is easy to use and straight forward in operation. Once a weed is identified, pictures representing different growth stages of the weed are displayed for further confirmation. A hyperlink to control options for a specific weed will also be provided on its final identification page.

Vegetative Response of Creeping River Grass to Flood Depth

Bottoms, S.L., Webster, E.P., Zhang, W., Griffin, R.M., and Hensley, J.B.

Creeping river grass [*Echinochloa polystachya* (Kunth) A.S. Hitch] is an invasive weed in the southern rice producing parishes of Louisiana. Studies evaluating the behavior of creeping river grass in the Amazon flood plains have shown it to have highly competitive characteristics. Creeping river grass forms dense monotypic stands along the rivers and lakes of the Amazon region in South America. These monotypic stands have been shown to exist in areas where there is an 8 m rise in water level annually. Other studies have shown creeping river grass thrives in water 2 m deep. The plant can exist in this region because of water level fluxes associated with the rivers in the Amazon region and the nutrient rich water. When the water recedes, creeping river grass reverts to a dormant state. Creeping river grass uses the terrestrial period when the water levels are low to initiate new growth from nodes of old plant material. The stem section of creeping river grass contains the principal nutrient stock of the plant, which encourages and allows for an aggressive growth habit.

The life cycle of creeping river grass coincides with the cultural practices used in the rice producing region of Louisiana. Rice is grown in a shallow flood, drained for harvest and in many cases re-flooded for a ratoon rice crop or crawfish production. The lengthy flooded period and high nutrient supplementation used in rice production coupled with a terrestrial period at rice harvest encourages the growth and spread of creeping river grass in the ratoon crop or crawfish production, often causing harvest problems for both commodities. Cultural practices associated with rice and crawfish rotation as well as the ability of creeping river grass to thrive in wet conditions and store large quantities of nutrients could cause a reduction in rice yields, impact crawfish harvest and contribute to the spreading of this invasive species.

A two factor-factorial study with four replications was conducted assessing growth of creeping river grass. Factor A consisted of water depths of 0, 5, 10, 15, and 20 cm. Factor B consisted of clear versus turbid water. Stem segments containing one node were obtained from greenhouse stock of creeping river grass, cut to a length of 11 cm and weighed. The segments were planted at a depth of 1.5 cm in a 37.85 L container, 39.7 cm by 43.5 cm. Each 37.85 L container was equipped with a PVC pipe inserted into a fitting in the bottom to control water depth. The containers were filled with 10.4 kg of soil and fertilized with 6 g of 8-24-24. The plant segments were grown for 14 days to allow for plant establishment. At 14 days after planting the aforementioned flood depths were established. Height measurements were taken every 7 days for 21 days after flood establishment. The turbid water treatments were agitated twice daily to maintain a constant turbidity.

Plant height of creeping river grass was different among treatments with the 20 cm depth compared to the 0, 5, or 10 cm; however, no differences in fresh weight, number of nodes, or adventitious roots were observed. Water clarity had no impact on creeping river grass height, fresh weight, number of nodes, or adventitious roots.

Creeping river grass growth is impacted by flood depth when the flood is established soon after germination. These data indicate that a flood depth of 20 cm can reduce the overall length of creeping river grass 71%. A producer, using a pinpoint flood method, may be able to manage the growth of creeping river grass and potentially reduce the spread of this invasive weed.

Promising Weed Suppressive Activity in High-Yielding Indica Rice and Hybrid Rice

Gealy, D.R., Black, H.L., Moldenhauer, K.A., Yan, W., and Rutger, J.N.

Effective weed control in U.S. rice has relied primarily on herbicides since the 1960s. Several indica rice lines tested in the 1980s suppressed aquatic weeds. Since then, they and their crosses with standard U.S. cultivars and other indica lines were found to suppress barnyardgrass (*Echinochloa crus-galli*) better than standard U.S. cultivars. In 2005, several weed-suppressive standards (eg PI 312777) and U.S. cultivars were compared with several high-yielding Asian indica lines (some of which had been mutated to improve plant/grain quality), commercial hybrids, and crosses between weed-suppressive standards and U.S. cultivars.

Field studies were conducted at the University of Arkansas Rice Research and Extension Center near Stuttgart, AR. All rice lines were drill-seeded at a rate of 430 seeds/m^2. Plots were sprayed postemergence with 1.1 kg/ha propanil, one fourth of the standard use rate, to partially suppress weeds. Plant height, days to heading, tiller production, grain yield, and visual control of barnyardgrass were among the characteristics evaluated. Weed suppression activity in 2005 was generally lower than that observed in previous years, probably due to an unusually dry extended period during the planting season that was followed by an unusually rainy/cloudy period early in the growing season. However, previously documented general trends among cultivars were observed. In one study, control ratings for CLXL8 (imidazolinone-resistant hybrid), 4612 (indica line from China), Drew, and several crosses between weed-suppressive standards and U.S. cultivars were as high as those from the weed-suppressive standards PI 312777 and PI 338046 (control >= 54%). Commercial cultivars such as Ahrent, L205, M205, and Lemont provided less control (35-40%). In a second study, CLXL8, STG96L-26-093 (PI 338046/Katy cross), and Drew provided as much control as PI 312777 (weed control >= 54%), whereas Ahrent and Lemont provided 38 and 30% control, respectively. In a third study, Chinese indica lines R312, 4593, and 4612, mutated Chinese indica lines Shufeng 121-1655 and 4484-1665, and commercial hybrids CLXL8 and XP723 provided control comparable with PI 312777 (>= 51%). Ahrent and Kaybonnet were among those entries providing less than 40% control. Several of the mutated indica lines may be promising as parental lines or cultivars with commercially acceptable, high yielding, high quality, weed-suppressive traits.

Alternative Rice Establishment Techniques to Manage Herbicide-Resistant Weeds in California

Moechnig, M., Fischer, A.J., Hill, J., Mutters, R., Eckert, J., and Greer, C.

Integrating cultural and chemical weed control practices may increase cost efficiency of weed management through the reduction of herbicide resistant weed populations, delayed evolution of herbicide resistance, and timely reduction of weed seed banks. Alternative cultural rice establishment techniques, such as drill seeding, stale seedbed, or no-till, may be used to manipulate weed species recruitment and expand herbicide options. In drill-seeded rice, pendimethalin (Prowl) may be used for soil residual control of many grass species. In stale seedbed systems, weeds that emerge prior to rice planting may be controlled with non-selective herbicides, such as glyphosate (Roundup). These herbicides provide alternative mechanisms of action, may be less expensive, and may be more environmentally benign than some of the herbicides used in conventional water-seeded rice systems. Therefore, a large field experiment was established at the Rice Experiment Station to quantify weed species recruitment and the efficacy of herbicides unique to the following rice establishment systems: water-seeded, drill-seeded, water-seeded following stale seedbed using glyphosate, no-till water-seeded following stale seedbed, and no-till drill-seeded following stale seedbed.

Rice establishment systems greatly affected weed species recruitment and weed densities in each year. Drill-seeded rice treatments were dominated by grasses whereas water-seeded treatments were dominated by sedge and broadleaf weed species in each year. Among water-seeded plots in 2005, smallflower umbrella sedge densities decreased by approximately 50% from the conventional to spring-tilled stale seedbed treatment, but decreased by approximately 90% from the spring-tilled stale seedbed to the no-till stale seedbed treatment. Drill-seeded treatments that included the no-till stale seedbed had 85% less *Echinochloa* densities than the conventional treatment, but sprangletop densities were greater in the no-till stale seedbed compared with the conventional drill-seeded treatment. In 2004, one conventional drill-seeded plot contained 160 *Echinochloa* weeds per m^2, which caused 85% rice yield loss in the weedy check area. Across replications, rice yield loss in the weedy checks averaged 14% in the conventional water-seeded plots, 37% in the conventional drill-seeded plots, but less than 5% in each of the stale seedbed plots in 2004. Adequate weed control was achieved with the selected herbicides for each treatment. In the water-seeded conventional and spring tilled stale seedbed treatments, sedge weed species were controlled (> 90%) with a late-season (3-4 rice tiller) application of propanil in 2004 and a tank-mixed application in 2005 of propanil + bensulfuron for added control of greater redstem populations in all water-seeded treatments. No post-emergence herbicide was needed in the water-seeded, no-till, stale seedbed treatment in 2004 as weeds were not present after the preplant glyphosate application. However, greater redstem populations in this treatment in 2005 warranted application of propanil + bensulfuron. In the drill-seeded treatments, a tank-mixed application of pendimethalin + cyhalofop resulted in > 85% control of these grass species. A late-post emergence application of propanil was needed in 2005 for *Echinochloa* escapes in each drill-seeded plot, which appeared to be related to inadequate control from cyhalofop. In the stale seedbed treatments, glyphosate was applied approximately 2 d prior to rice planting in each year. In the water-seeded stale seedbed treatments, preplant glyphosate applications reduced late-season smallflower densities by 50 and 70% in 2004 and 2005, respectively. In the drill-seeded stale seedbed treatment, glyphosate reduced late-season densities of *Echinochloa* by 80 and 40% in 2004 and 2005, respectively, and reduced sprangletop densities by 97% in 2005. Therefore, glyphosate used in the stale seedbed systems greatly reduced weed densities after rice emergence in the water- and drill-seeded systems. Grain yields were not statistically different among treatments in both years.

These results suggested that integration of cultural and chemical weed control practices provided additional options for weed management in continuous rice. Drill-seeding rice followed by an early post-emergence application of pendimethalin may effectively reduce seed banks of grass species biotypes that are resistant of conventional water-seeded rice herbicides. Adding a stale seedbed component to this system will reduce post-emergence weed pressure in highly infested fields. In water-seeded/stale seedbed systems, eliminating spring tillage greatly reduced populations of sedge weed species. Modeling approaches are being evaluated to identify optimal rotations of these establishment systems for managing problematic weed species and herbicide resistant biotypes.

Fall Applications of Glyphosate Control Alligatorweed in Drill-Seeded Rice

Burns, A.B. and Williams, B.J.

Studies were established in 2003 on Woodsland Plantation, near Monroe, LA, to evaluate fall applications of herbicides for alligatorweed control. The field were the studies were established was planted to rice in 2002, fallowed in 2003, planted to rice in 2004 and fallowed in 2005. During the fallow period the field was disked twice, cultivated, and leveled. The field was flooded each year during the winter for duck hunting. The alligator weed population at this site was well established, very dense, and covered the ground 90 to 100%. Four experiments were established. Fall applications of penoxsulam were evaluated in the first experiment. Glyphosate and several phenoxy herbicides applied alone and in combination with each other were evaluated in a second experiment. Two salt (Na and K) formulations of glyphosate were compared in the third experiment. In the fourth trial, the effect of application timing on glyphosate, glyphosate plus 2,4-D and glyphosate plus triclopyr was evaluated. Herbicide applications in the first three studies were made September 15, 2003. Herbicide applications in the fourth study were made September 15, October 1, and October 15, 2003. Herbicide treatments were applied in 140 L/ha of water, using a CO_2 pressurized backpack sprayer, to plots measuring 4 x 5 m. The experimental designs were randomized complete blocks, and a factorial treatment arrangement was used in the fourth study.

Penoxsulam, regardless of rate (1.7 to 3 oz/A), controlled alligatorweed 90 to 100% in the fall but had little effect the following spring. 2,4-D, triclopyr, dicamba, and picloram controlled alligatorweed in the fall 90 to 100%. However, only picloram controlled alligatorweed better than 70% the following spring. In May 2004, picloram at 1.2 L/ha (1 pt/A) and 2.4 L/ha (2 pt/A) controlled alligatorweed 60 and 90%, respectively. Glyphosate at 1.12 kg/ha also controlled alligatorweed 90% in May 2004. Glyphosate formulation did not affect alligatorweed control. The best alligatorweed control (90 to 87%) in May of 2004 was observed when 1.12 kg/ha glyphosate was applied on September 15 or October 1. Alligatorweed control with glyphosate dropped to just 47% when applications were delayed until October 15. Also, tank mixing glyphosate with either 2,4-D or triclopyr reduced alligatorweed control. Glyphosate at 1.12 kg/ha applied on September 15, 2003 and October 1, 2003 also resulted in at least 87% alligatorweed control in the spring and fall of 2005.

These results indicate that incorporating fall applications of glyphosate (applied alone) into rice production systems may be the best method for controlling established alligatorweed. The timing study is currently being repeated. Additional research is needed to determine if similar results can be expected with new alligatorweed infestations.

Evaluation of Barnyardgrass Control Measures for Creeping River Grass in Imidazolinone-Tolerant Rice

Griffin, R.M., Webster, E.P., Zhang, W., Leon, C.T., Bottoms, S.L., and Hensley, J.B.

Two field studies were conducted near Crowley, Louisiana, from 2004 to 2005 to determine the most effective barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] herbicide program for control of creeping river grass [*Echinochloa polystachya* (Kunth) A.S. Hitchc.]. Soil was a Crowley silt loam (fine montmorillonitic, thermic Typic Albaqualf) with 1.4% organic matter and pH 5.5. Plots consisted of eight 19-cm spaced rows, 5 m long. Imidazolinone-resistant (IR) CL161 rice (*Oryza sativa* L.) was drill-seeded at 112 kg/ha on May 16 and April 9 in 2004 and 2005, respectively. Creeping river grass control was visually estimated 7 days after final herbicide treatment (DAT) and continued weekly until 49 DAT on a scale of 0 to 100%, where 0 = no injury and 100 = plant death. The experimental design for both studies was a randomized complete block with four replications.

The first study included postemergence (POST) herbicide programs: 208 g ai/ha cyhalfop early POST (EPOST) fb 315 g/ha cyhalofop late POST (LPOST), 22 g ai/ha bispyribac EPOST fb 22 g/ha bispyribac LPOST, 66 g ai/ha fenoxaprop EPOST fb 86 g/ha fenoxaprop LPOST, 70 g ai/ha imazethapyr EPOST fb 70 g/ha imazethapyr LPOST, and 50 g ai/ha penoxsulam mid-POST (MPOST). Each herbicide application was assessed with and without 448 g ai/ha clomazone preemergence (PRE). Herbicide applications were applied using a CO_2-pressurized backpack sprayer delivering a volume of 140 L/ha and 186 Kpa. The herbicide program that included clomazone PRE fb sequential POST cyhalofop applications controlled creeping river grass 85%. Herbicide programs that had similar control included two POST cyhalofop applications, as well as programs containing two applications of imazethapyr. Control was at least 65% for programs containing bispyribac, fenoxaprop, or penoxsulam; however, programs that included bispyribac and fenoxaprop contained two applications of each herbicide, respectively, while penoxsulam was only applied in a single MPOST application. Averaged across herbicide programs, creeping river grass control was 81 to 84% at 7 to 21 DAT. This control was probably due to increased activity of the herbicides applied to small actively growing plants. At 28 DAT, control of creeping river grass decreased to 77 and 63% at 49 DAT. This indicates that regrowth occurred, causing reduced control as the season progressed. Early ratings reflected bleaching from clomazone and initial leaf chlorosis or desiccation from POST herbicide applications.

The second study included PRE herbicide programs: 448 g/ha clomazone PRE, 448 g/ha clomazone plus 420 g ai/ha quinclorac PRE, 448 g ai/ha pendimethalin plus 420 g/ha quinclorac delayed PRE (DPRE), 70 g/ha imazethapyr PRE, and 175 g ai/ha mesotrione PRE. Each herbicide application was followed by a MPOST application of 314 g/ha cyhalofop. The herbicide programs of clomazone PRE, pendimethalin plus quinclorac DPRE, and imazethapyr PRE controlled creeping river grass 78 to 81%. Control was 72% for programs containing clomazone plus quinclorac PRE or mesotrione PRE. The combination of clomazone and quinclorac PRE fb cyhalofop MPOST controlled creeping river grass 72% while clomazone PRE fb cyahlofop MPOST contolled the weed 80%. Averaged across herbicide programs, creeping river grass control was 78 to 82% at 7 to 35 DAT. At 42 DAT, control of creeping river grass decreased to 71% and at 49 DAT control decreased to 67%. Creeping river grass regrowth occurred later in the season, causing reduced control.

Producers have the choice of using conventional or IR rice production systems to control creeping river grass. Creeping river grass was controlled with herbicide programs containing POST applications of cyhalofop or imazethapyr, as well as programs containing clomazone PRE, pendimethalin plus quinclorac DPRE, and imazethapyr PRE. Total POST herbicide programs can be used to control creeping river grass; however, POST herbicides must be applied to small, actively growing creeping river grass to obtain adequate control. Creeping river grass control was higher during the earlier ratings in both studies. This indicates the plant stolons may have recovered from the initial herbicide application. The addition of herbicides with residual activity may provide control of other weeds and as a result increase rice yield. Ratoon rice, as well as rotation into crawfish production, may impact late-season regrowth or infestations after rice is harvested. Populations of this weed that are allowed to survive and propagate could impact future rice production.

Annual Grass Control in Clearfield Rice

Williams, B.J. and Burns, A.B.

Programs for controlling Amazon sprangletop and red rice were evaluated in several studies in 2004 and 2005. The trials were conducted at the Northeast Research Station near St. Joseph, LA, on a Sharkey Clay soil and at the Macon Ridge Research near Winnsboro, LA, on a Gigger silt loam soil. Rice was drill-seeded at 100 kg/ha to plots measuring 2 by 4.5 m. 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. At panicle initiation, an additional 42 kg/ha of nitrogen was applied. Herbicide treatments were applied in 140 L/ha of water using a CO_2 pressurized backpack sprayer. The experimental designs were randomized complete blocks, and factorial treatment arrangements were used when appropriate.

In 2005, either 0.88 L/ha (13.5 oz/A) cyhalofop or 0.15 L/ha (2 oz/A) imazamox was mixed with 0.3 L/ha (4 oz/A) imazethapyr in the first or second imazethapyr application. Cyhalofop at 1.1 L/ha (15 oz/A) or 0.37 L/ha (5 oz/A) was also applied postflood following two applications of imazethapyr. Tank mixing one of the imazethapyr applications with either cyhalofop or imazamox improved sprangletop control compared with imazethapyr alone. Tank mixing the second imazethapyr application with cyhalofop or imazamox resulted in the best control (90 to 93%). Imazethapyr alone resulted in 78% sprangletop control. Applying, cyhalofop or imazamox postflood also resulted in excellent (90 to 92%) sprangletop control. In similar studies (4) conducted in 2004 and 2005, the most consistent sprangletop control (87 to 95%) was observed from postflood cyhalofop and imazamox applications. Treatments were also applied at the 3- to 4-leaf weed stage, but control was very erratic (53 to 90%). Sprangletop control from fenoxaprop was also erratic, ranging from 53 to 88%.

In 2004 and 2005, red rice control as affected by imazamox timing and rate was evaluated in three trials. Imazamox was applied at 0.3 L/ha (4 oz/A), 0.37 L/ha (5oz/A), or 0.44 L/ha (6 oz/ha) at the 2-4 tiller, PI, PI+10, or P+17 stages. Few differences in rate were observed, but timing was critical. If applied too early, coverage was an issue, and red rice was often too large at the PI+17 timing. In general, the best control was observed after red rice emerged from the canopy just before or at the boot stage of red rice. Beyond also controlled Amazon sprangletop and barnyardgrass when applications were made before early boot stages. In 2005, two 4 oz/A imazethapyr applications controlled red rice (87%), as well as two 0.44 L/ha (6 oz/A) imazethapyr applications. The best red rice control (99%) was observed when two 4 oz/A imazethapyr applications were followed by 5 oz/A imazamox at the boot stage. Imazamox alone controlled red rice 57, 70, 80, and 90% when applied at the 1-2 lf, 4-5 lf, 1 WAF, and Boot timings.

A study was conducted in 2004 and 2005 to evaluate the effect of tank mixing 4 oz/A imazethapyr with 1.5 L/ha (1.3 qt/A), 3 L/ha (2.6 qt/A), and 6 L/ha (5.2 qt/A) pendimethalin applied to 1- to 2-leaf rice on sprangletop and red rice control. Sprangletop and red rice control improved when the pendimethalin rate was increased from 1.2 to 2.6 qt/A but not when increased from 2.6 to 5.2 qt/A. Single applications of pendimethalin plus imazethapyr resulted at least 10%, and as much as 30%, more sprangletop and red rice control than single applications of imazethapyr. Imazethapyr plus 2.6 qt/A pendimethalin resulted in superior sprangletop control and red rice control similar to two imazethapyr applications. Imazethapyr plus 2.6 qt/A pendimethalin followed by imazethapyr resulted in sprangletop and red rice control equal or superior to two imazethapyr applications followed by 5 oz/A imazamox.

These trials demonstrate that cyhalofop can be incorporated into Clearfield rice systems to improve sprangletop control, with postflood applications being most effective. Also, both pendimethalin and imazamox can improve sprangletop and red rice control. Imazamox is most effective postflood after weeds emerge from the canopy but before the boot stage. Pendimethalin at 2.6 qt/A applied with imazethapyr at the 1- to 2-leaf stage is very promising, but additional research on rice response to high pendimethalin application rates is needed.

Penoxsulam - a New Herbicide for Weed Management in Rice

Williams, B.J. and Burns, A.B.

Programs for controlling weeds in drill- and water-seeded rice with penoxsulam were evaluated in several studies in 2004 and 2005. The trials were conducted at the Northeast Research Station near St. Joseph, LA, on a Sharkey Clay soil and at the Macon Ridge Research near Winnsboro, LA, on a Gigger silt loam soil. Rice was seeded at 100 kg/ha in drill-seeded experiments or 170 kg/ha in water-seeded experiments. Permanent floods were established 4 to 5 weeks after planting in drill-seeded rice and the pinpoint flooding method was used for water-seeded rice. Nitrogen, in the form of prilled Urea, was applied at 126 kg/ha just before permanent flood. At panicle initiation an additional 42 kg/ha of nitrogen was applied. Herbicide treatments were applied in 140 L/ha of water using a CO_2 pressurized backpack sprayer to plots measuring 2 by 4.5 m. The experimental designs were randomized complete blocks and factorial treatment arrangements were used when appropriate.

Penoxsulam demonstrated excellent activity on barnyardgrass, hemp sesbania, rice flatsedge, ducksalad, dayflower and purple ammannia in both drill- and water-seeded rice. In drill-seeded rice, 0.15 L/ha (2.0 oz/A) penoxsulam controlled small weeds when applied to 2- to 3-leaf rice, but at least 0.168 L/ha (2.3 oz/A) was needed at the 4- to 5-leaf stage for consistent control of larger weeds. Penoxsulam at 0.190 L/ha (2.6 oz/A) controlled both barnyardgrass and hemp sesbania postflood. In water-seeded rice, penoxsulam controlled barnyardgrass best when applied from pegging through 2- to 3-leaf rice. Hemp sesbania control was best when penoxsulam (2.3 oz/A) was applied at the 2- to 3-leaf stage. The best control of purple ammannia and ducksalad from penoxsulam was observed from pegging treatments.

Penoxsulam at 0.15 L/ha (2 oz/A) plus 1.5 L/ha (1.3 pt/A) clomazone applied to 1- to 3-leaf rice resulted in excellent control of barnyardgrass, Amazon sprangletop, hemp sesbania, and rice flatsedge. In some studies, additional applications were needed to control hemp sesbania coming up after the application. Cyhalofop plus penoxsulam combinations controlled barnyardgrass, sprangletop, flatsedge, and hemp sesbania at the 2- 3-leaf stage. Tank mixing cyhalofop with penoxsulam reduced postflood sprangletop control compared with cyhalofop alone.

Imazethapyr plus penoxsulam combinations in Clearfield rice were also promising. Texasweed control was improved, and hemp sesbania was controlled when imazethapyr was tank mixed with penoxsulam. In 2004, but not 2005, a reduction in red rice control was observed when penoxsulam was tank mixed with imazethapyr.

Overall, these trials indicate that penoxsulam can be used to control weeds in rice production systems common to Louisiana. However, additional research is needed with postflood applications of penoxsulam and penoxsulam combinations with imazethapyr or cyhalofop.

Postflood Weed Control with Penoxsulam in Southern U.S. Rice

Richburg, J.S., Lassiter, R.B., Haygood, R.A., Mann, R.K., and Walton, L.C.

Rice growers continue to face weed control challenges in rice. Penoxsulam, Grasp SC, developed by Dow AgroSciences LLC, is a new postemergence broad-spectrum triazolopyrimidine sulfonamide herbicide for use in rice. Grasp SC was launched commercially in rice in 2005 in the United States. Primary use methods of Grasp SC in the Mid-South United States include postemergence, preflood application in drill-seeded rice, and early postemergence application in water-seeded rice. Even with intensive management, rice growers often still face significant weed problems after the permanent flood has been applied to the rice. Preliminary research prior to 2005 had indicated that Grasp SC applied postflood in rice would provide control of barnyardgrass and key broadleaf weeds. Therefore, the objectives of this research were to evaluate the rice tolerance and weed control efficacy of Grasp SC applied postflood at various application timings alone and in tank-mixtures to broaden the spectrum of control.

Experiments were conducted in AR, LA, MO, MS, and TX during the 2005 growing season. Research methods utilized were typical of small plot research.

Grasp SC provided control of *Echinochloa* species, as well as many annual rice weeds including hemp sesbania (*Sesbania exaltata)*, ducksalad (*Heteranthera limosa*), alligatorweed *(Alternanthera philoxeroides)*, smartweed (*Polygonum* spp), eclipta (*Eclipta alba*) and annual sedge (*Cyperus* spp). In general, the best weed control with Grasp SC was achieved when applied 7 to 10 days after the permanent flood was established. Rice injury from postflood applications of Grasp was minimal. Tank mixtures of Grasp SC with Basagran and Aim did result in antagonism on numerous weeds. The use rate of Grasp SC postflood is 40 to 50 g ai/ha (2.3 to 2.8 oz product/A). Grasp SC can be applied from rice emergence up to 60 days prior to harvest in drill-seeded rice and from rice pegging with 1 leaf up to 60 days prior to harvest in water-seeded rice.

Performance of Foliar Applied Penoxsulam in California Water-Seeded Rice

Haack, A.E., Mann, R.K., and Shatley, D.G.

Penoxsulam is a triazolopyrimidine sulfonamide herbicide developed globally by Dow AgroSciences LLC for control of major rice weeds. Granite SC is a new liquid formulation (240 grams penoxsulam/liter SC) product being developed for postemergence weed control in California rice. When applied postemergence in rice research trials, penoxsulam provided excellent control of watergrass (*Echinochloa oryzoides*), annual arrowhead (*Sagittaria* spp), ducksalad (*Heteranthera limosa*), and ricefield bulrush (*Scirpus mucronatus*). Rice has demonstrated excellent tolerance to liquid postemergence applications of penoxsulam in research trials in California. Penoxsulam can be applied in tank mix with cyhalofop and propanil to increase the weed control spectrum. In large commercial type trials, penoxsulam as Granite SC was applied to rice at 10 different locations in the Sacramento Valley, CA. Trial sites ranged from 5 to 20 acres in size and were managed by grower/cooperators, which provided a true assessment of product performance under commercial conditions. Control of susceptible weed species, including but not limited to watergrass (*E. oryzoides),* ricefield bulrush *(S. mucronatus),* ducksalad *(Heteranthera spp)*, and annual arrowhead *(Sagittaria* spp*)* met or exceeded grower expectations. No adverse effects to the rice were observed.

Index of Abstract Authors

INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2008 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 32nd 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 32nd RTWG meeting in 2008, or earlier as stated in the Call for Papers issued by the 32nd RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2008 RTWG meeting and their email and mailing addresses are presented on page 203. In case of other questions or in the absence of being able to access the Call for Papers, contact:

   Dr. Don Groth
   LSU AgCenter, Rice Research Station
   1373 Caffey Road
   Rayne, LA 70578
   Phone: 337/788-7531
   FAX: 337/788-7553
   Email: dgroth@agcenter.lsu.edu

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 32nd RTWG meetings. The appropriate due date will be identified in the Call for Papers for the 32nd 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 32nd 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.

ADDRESSES FOR 2008 PANEL CHAIRS

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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 Lafayette, LA	M.D. Morse L.C. Hill	E.A. Sonnier D.L. Calderwood	California Rice Varietal Improvement Team	
			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 Houston, TX	D.S. Mikkelsen	J.B. Baker	Texas Rice Breeding and Production Team	
			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	B. Wells	S.D. Linscombe	
	S.-T. Tseng			
			Advances in Rice Nutrition Team	
2000 Biloxi, MS	D.M. Brandon	R.K. Webster	P.K. Bollich	C.E. Wilson
	J.W. Stansel		R.J. Norman	
			Bacterial Panicle Blight Discovery Team	
2002 Little Rock, AR	F.L. Baldwin	M.A. Marchetti	M.C. Rush	D.E. Groth
	R.H. Dilday	J.F. Robinson		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	J.A. Musick	F.N. Lee	M.A. Marchetti
	A.D. Klosterboer	J.E. Street	A.K. Moldenhauer	
	F.N. Lee	J.F. Williams	Individual	
	W.H. Brown	S.L. Wright	R.D. Cartwright	

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
			LSU Rice Variety Development Team	
			S. Linscombe	X. Sha
2006	T.P. Croughan	J.N. Rutger	P. Bollich	R. Dunand
The Woodlands, TX	R. Talbert	F. Turner	L. White	D. Groth
			Individual	
			R. Norman	

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
31st	2006	The Woodlands, Texas	D.E. Groth	G. McCauley	D.E. Groth M.E. Salassi

- 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.

RICE TECHNICAL WORKING GROUP

MANUAL OF OPERATING PROCEDURES

2006

I. Purpose and Organization

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 (ARS), the Economic Research Service, the Cooperative State Research, Education, and Extension Service and other agencies of the United States Department of Agriculture (USDA). 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.

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 other members. The current disciplines or Panels represented are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Processing and Storage; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Each Panel has a Chair who, along with the Secretary/Program Chair, solicits and receives titles, interpretive summaries, and abstracts of papers to be presented at the biennial meeting. The papers are presented orally in concurrent technical sessions or via poster. Each Panel over the course of the meeting develops proposals for future work, which are suggested to the participating members for implementation.

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 the Extension Service of the rice growing states designate an Extension Service Administrative Advisor.

Other members of the Executive Committee are elected biennially by the membership of the RTWG; they include the Chair who has served the previous term as Secretary/Program Chair, a Geographical 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 from one of following areas: i) chemical, ii) seed, iii) milling, iv) brewing industries, v) producers, or vi) consultants. The Publication Coordinator also is on the Executive Committee. The Coordinator of the RTWG website is an ex-officio member of the Executive Committee.

Standing committees include: i) Nominations, ii) Resolutions, iii) Rice Crop Germplasm, iv) Rice Variety Acreage, v) Awards, and vi) Location and Time.

II. Revised Memorandum of Agreement

The previous Memorandum of Agreement is published in the 30th RTWG Proceedings in 2004. The following is a revised Memorandum of Agreement accepted by the 31st RTWG membership in 2006.

REVISED MEMORANDUM OF AGREEMENT
FEBRUARY 2006

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 seven 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 seven 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 the 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 findings 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 meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled 'Rice Tech Working Group Contingency Fund,' established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical 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 seven interested states and agencies.

III. Description of Committees, Positions, Duties, and Operating Procedures

A. Executive Committee

The Executive Committee conducts the business of the RTWG, appoints standing committees, organizes and conducts the biennial meetings, and presents the awards. 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. A quorum (i.e., eight members are present, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. A simple majority vote is needed to pass any motion and the Chair only votes in the case of a tie. The Executive Committee is composed of the following 15 members: i) three officers—Chair, Secretary/Program Chair, and Immediate Past Chair; ii) seven Geographical Representatives from each major rice producing state; iii) three administrative advisors from the major agencies of Agriculture Experiment Stations, State Agricultural Extension Services, and the USDA; iv) a Publication Coordinator; and v) a Rice Industry Representative. The Officers, Geographical Representatives, and the Publication Coordinator shall be elected to the Executive Committee at the Opening Business meeting of each biennial meeting to serve through the close of the next regular biennial meeting. Industry personnel participating in the biennial meeting elect the Industry Representative.

1. **Chair**
   The Chair provides leadership to the RTWG by organizing the agenda and presiding over the Business and Executive Committee meetings, presiding over the Awards process, appointing temporary or ad hoc committees to explore and address RTWG interests, and act as the official spokesperson for the RTWG during his/her period of office. If the nomination process for selecting geographical representatives and members of the Nominations committee fails to produce a candidate, then it the responsibility of the Chair to work with the state delegation in selecting a candidate from that state. The Secretary/Program Chair is usually nominated by the Nomination Committee to be Chair at the next biennial meeting. If the Chair nominated cannot serve or complete the full term of office, it is the responsibility of the Executive Committee to appoint a new Chair.

2. **Secretary/Program Chair**
   The Secretary/Program Chair serves a two-year term and is responsible for organizing, conducting, and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair appoints a Local Arrangements Committee and Chair from their home state to help with organizing and conducting the biennial meeting. The Secretary/Program Chair is responsible for the minutes of all Business and Executive Committee meetings, the publishing of the minutes of these and other committees (i.e., Rice Crop Germplasm, Rice Variety Acreage, Nominations, and Resolutions) at the RTWG in the Proceedings and ensuring the Panel Chairs correctly publish their minutes and abstracts in the Proceedings. The Secretary/Program Chair is responsible for setting up the RTWG website. The Secretary/Program Chair is a member of the Executive Committee and usually resides in the state the biennial meeting is conducted. The Secretary is usually chosen by active rice workers from the meeting host state and the candidate identified to the Nominations Committee for election. If the Secretary/Program Chair nominated cannot serve or complete the full term of office, it is the responsibility of the member on the Nominations Committee of the hosting state to appoint a new Secretary/Program Chair.

3. **Immediate Past Chair**
   Provides guidance to the incoming Chair to facilitate a smooth transition and lend continuity between biennial meetings. The Chair is nominated by the Nominations Committee to be the Immediate Past Chair at the next biennial meeting.

4. **Geographical Representatives**
   There are currently seven geographical representatives representing each of the major rice producing states, Arkansas, California, Florida, Louisiana, Mississippi, Missouri, and Texas, on the Executive Committee. Each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to serve a two-year term on the Executive Committee. If the Geographical Representative nominated cannot serve or complete the full term of office, it is the responsibility of the delegate on the Nominations Committee from that state to appoint a new Geographical Representative.

5. **Administrative Advisors**
   The Administrative Advisors provide advice and lend continuity to the Executive Committee. A minimum of three Administrative Advisors will be appointed to the RTWG to represent the major agencies involved. They shall consist of: i) a Director of an Agriculture Experiment Station from a rice-growing state elected by the Station Directors of the rice-growing states; ii) a Director of a State Cooperative Extension Service from a rice-growing state elected by the Extension Directors of the rice-growing states; and a USDA Administrative Advisor from the ARS named by the Administrator of the Agricultural Research Service. No term limit is established.

6. **Publication Coordinator(s)**
   The Publication Coordinator is responsible for assembling, editing and publishing of the RTWG Proceedings from the biennial meeting. They serve on the Executive Committee to handle all matters related to the publication of the RTWG Proceedings. Currently, two co-publication coordinators serve this position. Only one of these coordinators has a vote on the Executive Committee. This is a voluntary position requiring the approval of the RTWG Executive Committee to serve. No term limit is established.

7. **Industry Representative**
The Industry Representative represents all aspects of the U.S. rice industry to the Executive Committee and serves as liaison with other rice industry personnel. Responsibilities include keeping all interested rice industry personnel informed of the activities of the RTWG. Industry personnel participating in the biennial meeting elect the Industry Representative. If the Industry Representative nominated cannot serve or complete the full term of office it is the responsibility of the Industry members of the RTWG to appoint a replacement.

B. Standing Committees

The Executive Committee has appointed the following Standing Committees.

1. **Nominations Committee**
The purpose of the Nominations Committee is to nominate the Secretary/Program Chair, Chair, Immediate Past Chair, Geographical Representatives to the Executive Committee, and the members or delegates to the Nominations Committee. The Nominations Committee is composed of eight members. Seven of the members represent each of the seven major rice-producing states and one delegate is from the U.S. Rice Industry. As with the Executive Committee, each state nominates via the Nominations Committee one active rice worker from either a state or federal agency to be their delegate on the Nominations Committee and the Rice Industry is responsible for designating who their delegate is on the committee. The Chair of the Nominations Committee is from the next state to hold the RTWG biennial meeting. If a delegate on the Nominations committee cannot serve or complete the term of office, it is the responsibility of the Geographical Representative from that state to appoint a replacement. Each delegate is responsible for polling the active rice workers in their state or industry to determine who their Geographical Representative is on the Executive Committee and who their delegate is on the Nominations Committee. The Chair of the Nominations Committee is responsible for obtaining the results from each delegate on the Nominations Committee, compiling the results, and reporting the results to the RTWG at the Opening Business meeting for a vote. When a state is next in line to host a biennial meeting, it is the responsibility of the delegate from that state to nominate the Secretary/Program Chair. Since the Secretary/Program Chair moves up to RTWG Chair and the RTWG Chair to Past Chair, it is the responsibility of the Chair of the Nominations Committee to nominate them to the RTWG members.

2. **Resolutions Committee**
The Resolutions Committee is responsible for the resolutions pertaining to the biennial meeting and for the Necrology Report when appropriate. The purpose of the Resolutions Committee is to author with the Secretary, the Resolutions section of the RTWG Proceedings that expresses appreciation to individuals and organizations that contributed to making the biennial RTWG meeting a success. The Committee is usually comprised of at least two active members that have had long-term involvement with the RTWG and are very familiar with the RTWG participants and the workings of the RTWG. The incoming Chair appoints the Resolutions Committee members.

3. **Rice Crop Germplasm Committee**
The Rice Crop Germplasm Committee functions not only as an RTWG committee but also as the Rice Crop Germplasm Committee for the National Plant Germplasm System. In this capacity, it is part of a specific national working group of specialists providing analysis, data, and recommendations on genetic resources for rice and often-related crops of present or future economic importance. This committee represents the user community and membership consists of representation from federal, state, and private sectors; representation from various scientific disciplines; and geographical representation for rice. There are also ex-officio members on the committee from the National Plant Germplasm System. The Rice Crop Germplasm Committee, along with the other Crop Germplasm Committees, is concerned with critical issues facing the NPGS including: i) identifying gaps in U.S. collections and developing proposals to fill these gaps through exchange and collaborative collecting trips; ii) assisting the crop curators in identifying duplications in the collections, and in evaluating the potential benefits and problems associated with the development and use of core subsets; iii) prioritizing traits for evaluation and developing proposals to implement these evaluations; iv) assisting crop curators and GRIN personnel in correcting passport data and ensuring that standardized, accurate, and useful information is entered into the GRIN database; v)

assisting in germplasm regeneration and in identifying closed out programs and other germplasm collections in danger of being lost and developing plans to rescue the important material in these programs; vi) working with quarantine officials to identify and ensure new techniques for pathogen identification that will assist in the expeditious release of plant germplasm; and vii) maintaining reports on the status of rice for Congress, ARS National Program Staff and Administrators, State administrators, and other key individuals involved with the NPGS. The Committee members serve six-year terms. They rotate off of the Committee in two-year intervals. The Rice Crop Germplasm Committee Chair appoints a committee who nominate a slate of members, which will maintain the diversity of the membership, nominations also are requested from the floor, and elections takes place among the voting members to fill the six-year terms of office. A Chair is then elected from the voting membership for a two-year term. The Chair can only be elected to two consecutive terms of office unless completing the term of a previous Chair.

4. **Rice Variety Acreage Committee**
The purpose of the Rice Variety Acreage Committee is to collect and summarize data on varieties by acreage for each state and publish the summary in the RTWG Proceedings. The Committee consists of the rice specialists from each of the seven major rice-producing states and one other representative, usually a breeder or a director of an experiment station. No more than two members can represent any one state. The Chair of the Rice Variety Acreage Committee solicits information from each of the states then compiles it for the Committee report published in the RTWG Proceedings. Members of the Rice Variety Acreage Committee solicit their own members, first based on state and then on knowledge and interest expressed by active members of the RTWG to be part of the Rice Variety Acreage Committee. The Chair of the Rice Variety Acreage Committee is elected by the members of the Committee and may serve more than one term. No term limits have been established for members of the Rice Variety Acreage Committee.

5. **Awards Committee**
The Awards Committee is composed of the Executive Committee. See section IV. C., 'Guidelines for RTWG Awards' for details regarding responsibilities and duties of the Awards Committee.

6. **Location and Time Committee**
The Location and Time Committee is made up of three individuals, two from the state next to hold the biennial meeting and one from the state following the next host state. This Committee explores when and where the next biennial RTWG meeting will be held. The incoming Chair appoints the Location and Time Committee members.

C. Website Coordinator

D. Revisions to the Manual of Operating Procedures

The Executive Committee with a majority vote has approved this 'Manual of Operating Procedures' for use by the Rice Technical Working Group. This 'Manual of Operating Procedures' is a working document that should be amended or modified to meet the needs of the Rice Technical Working Group. Amendments or modification to this 'Manual of Operating Procedures' can only be made by a quorum of the Executive Committee with the approval of the majority of the Executive Committee. The RTWG Chair can only vote in the case of a tie.

IV. Biennial Meeting Protocols

A. Biennial Meetings

The biennial meetings are hosted by the participating states in the following rotation: Arkansas, Louisiana, Texas, California, Missouri, and Mississippi. A state is allowed to host a biennial meeting if the state is deemed by the Executive Committee to have a sufficient number of rice scientists to properly conduct a biennial meeting. The Secretary/Program Chair is responsible for organizing, conducting, and financing the program of the biennial meetings in concert with the Chair, Panel Chairs, and Chair of Local Arrangements. The Secretary/Program Chair is responsible for setting up the RTWG website. The Chair organizes the agenda and presides over the Business and Executive Committee meetings and the Awards process. Panel Chairs coordinate the oral and poster presentations in their discipline with the Secretary/Program Chair, editing of abstracts with the Publication Coordinator, updating of panel recommendations, and choosing their successor. Detailed information on the business meetings; detailed responsibilities of the Publication Coordinator, Panel Chairs, and the Local Arrangements Committee; timeline of preparation for the biennial meeting; instructions for preparation of abstracts; and guidelines for the RTWG awards are listed in this section.

1. **Executive Committee Meetings**
   The agenda for the Executive Committee meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Executive Committee meetings. Following is a typical agenda.

   a. Opening Executive Committee Meeting (held on day prior to start of meeting)

      <u>Old Business</u>
      i) The Chair opens the meeting
      ii) The Chair gives the Financial Report of the previous RTWG meeting. The Chair then entertains a motion to accept the Financial Report.
      iii) The Secretary reads the minutes of the previous RTWG Executive Committee Meetings and entertains a motion to accept the minutes.
      iv) The Chair leads a discussion of any old business from the previous RTWG Closing Executive Committee Meeting.

      <u>New Business</u>
      i) The Necrology Report read by Chair.
      ii) The Chair announces RTWG award recipients and asks the Executive Committee to keep this information secret until after the Awards Banquet.
      iii) The Chair leads a discussion of any New Business that has developed since the last RTWG meeting. Several months prior to the RTWG meeting the Chair should solicit any New Business items from the Executive Committee.

   b. Closing Executive Committee Meeting (held on last day of meeting)

      <u>Old Business</u>
      i) The Chair opens meeting
      ii) The Chair leads a discussion of any topics that were not adequately addressed at the Opening Executive Committee Meeting.
      iii) Executive Committee members discuss and address any business items that have become a topic of interest during the RTWG meeting.

2. **Opening General Session and Business Meetings**
   The agenda for the Opening General Session and Business meetings varies, but there is a standard protocol and a few items that are always discussed. Robert's Rules of Order govern all Business meetings. Following is a typical agenda.

   a. Opening General Session and Opening Business Meeting (begins the RTWG meeting)
      i) The Chair opens the meeting and thanks the host state delegation for preparing the program. The Secretary welcomes the RTWG membership to their state.
      ii) The Chair opens the Business Meeting by asking the Secretary to read the minutes of the Closing Business meeting from the previous RTWG meeting and the Chair then entertains a motion for acceptance of the minutes.
      iii) The Chair opens the Business Meeting and informs the RTWG membership of business discussed at the Opening Executive Committee Meeting.
      iv) The Chair reads the Necrology Report and asks for a few moments of silence.
      v) The Nominations Committee Chair reads the nominations for the Executive Committee and Nominations Committee to the RTWG membership. The RTWG Chair then entertains a motion to accept the nominations.

vi) The Chair calls on the Chair of the Location and Time Committee of the next biennial meeting to report when and where the next RTWG meeting will be held.
vii) The Secretary informs the membership of last minute alterations in the program and any additional information on the meeting, hotel, etc.
viii) The Chair asks for a motion to adjourn the Opening Business Meeting.
ix) The General Session usually ends with invited speaker(s).

b. Closing Business Meeting (ends the RTWG meeting)
   i) The Chair opens the meeting and calls for Committee reports from Resolutions, Rice Crop Germplasm, Rice Variety Acreage, Rice Industry, and the Publication Coordinator.
   ii) The Chair thanks the Publication Coordinator(s) for their efforts in coordinating, editing, and publishing the RTWG Proceedings.
   iii) The Chair thanks the host state delegation for hosting the RTWG Meeting.
   iv) The Chair then passes the Chair position to the Secretary/Program Chair. The incoming Chair thanks the Past Chair for service to the RTWG and presents the Past Chair with a plaque acknowledging their dedicated and valuable service to the RTWG as the Chair.
   v) The incoming Secretary/Program Chair informs the membership of the time and place for the next RTWG meeting.
   vi) The incoming Chair invites every one to attend the next RTWG meeting and asks for a motion to adjourn the RTWG meeting.

3. Publication Coordinator(s)

The Publication Coordinator(s) are responsible for providing instructions for manuscript preparation, collecting abstracts from the Panel Chairs, assembling all pertinent information for inclusion in the Proceedings, final review, and publication of the Proceedings upon the conclusion of each RTWG meeting. The Publication Coordinator(s) solicit input from the Executive Committee, Panel Chairs, and the general membership for changes and/or adjustments to the RTWG Proceedings content, style, format, and timetable. It is, however, the Publication Coordinator(s) responsibility to make the final decision on changes appropriate to insure the Proceedings are a quality product and reflective of the goals and objectives of the organization. This flexibility is needed to insure that publication of this information through their respective institution is done in accordance with university or other agency requirements. The Publication Coordinator(s) are responsible for updating the guidelines for submitting abstracts as needed and including this information in the published Proceedings and also on the RTWG host website once the call for abstracts is made. The Publication Coordinator(s) are responsible for mailing proceedings in CD and hardcopy format to the general membership and also placing the Proceedings on the internet.

4. Panel Chairs

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 six disciplines or Panels. The current Panels are: i) Breeding, Genetics, and Cytogenetics; ii) Economics and Marketing; iii) Plant Protection; iv) Processing and Storage; v) Rice Culture; and vi) Rice Weed Control and Growth Regulation. Such elections 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. Program development involves scheduling of oral and poster presentations, securing moderators to preside at each panel session, editing of abstracts, seeing that the Panel Recommendations are updated at each biennial meeting and approved by the participants in the respective Panel sessions, and election of a successor. Since the Secretary is from the RTWG host state, the Panel Chairs elected should also be from the host state if possible to facilitate close cooperation with the Secretary and other Panel Chairs. If an elected Panel Chair cannot serve or fulfill the duties, then it is the Secretary's responsibility to replace the Panel Chair with someone preferably from the same discipline.

Each Panel Chair is responsible for collecting all of the Panel abstracts prior to the RTWG biennial meetings. The appropriate due date will be identified in the Call for Papers for the RTWG meeting. Each Panel Chair is responsible for assembling the 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 RTWG meeting and submitted to the Publications Coordinator(s) to accommodate preliminary preparation of the Proceedings prior to the meeting. The Panel Chairs are strongly encouraged to edit the abstracts for content clarity and RTWG format to expedite publication of the Proceedings. These materials will be merged in the final Proceedings in the format submitted. Final editing will be performed 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.

Panel Chairs are to organize the oral presentations in the concurrent Technical Sessions and the posters for the Poster Sessions with the Secretary/Program Chair.

5. Local Arrangements

The Local Arrangements Committee and the Chair of this Committee are typically appointed by the Secretary/Program Chair to help with meeting site selection and organizing and conducting the biennial meetings. Thus, they usually reside in the state the biennial meeting is conducted due to logistics. Typical responsibilities include: a survey of possible meeting sites and establishments; working with the hotels for rooms, meeting space, and food functions; securing visual aids; helping with spouse activities; solicitation of donations; and providing speakers and entertainment.

6. Financing the Biennial Meeting, Start-up Money, and the Contingency Fund

a. The biennial RTWG meetings are financed through registration fees and donations from industry and interested parties. The Executive Committee established a base amount of $6,000 that is to be transferred from one host state to the next as start-up money to begin preparations for the RTWG meeting prior to when donations or registration fees can be collected.

b. 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 meeting will be transferred by the Secretary/Program Chair to the RTWG Contingency Fund, entitled ‘Rice Tech Working Group Contingency Fund,’ established at the University of Arkansas in the Agriculture Development Council Foundation. In instances where USDA or industry personnel are elected to serve as RTWG Secretary, either the Local Arrangements Chair or the Geographical 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.

c. The Contingency Fund was established as a safety net for states hosting the biennial meetings. It is to be used by the host state when the startup money transferred from the previous state to host the biennial meetings is insufficient or when a state goes into debt hosting the biennial meetings. If the funds are used as start up money by the host state then it must be repaid by the host state when a sufficient amount of money has been secured to repay the loan. If the funds are used by the host state due to debt incurred in hosting the biennial meeting then no repayment is required. Use of the Contingency Fund by a host state is subject to approval by the Executive Committee.

7. Complementary Rooms, Travel Reimbursements, Registration Fee Waivers

Complementary rooms (Suite) are provided during the meeting for the Chairman and Secretary. Typically, the hotel will provide rooms free of charge in association with a certain number of booked nights. Invited speakers may be provided travel funds, free room, or registration, depending on meeting finances. The Local Arrangement Committee usually does not provide any travel assistance for attendees. Registration can be waived or refunds given on the discretion of the Local Arrangement Committee based on their financial situation. Possibly, a certain amount should be specified non-refundable before registration is begun. Distinguished Service Award recipients usually have their registration fee waived for the day of the award banquet if they are not already registered.

8. Biennial Meeting Preparation Timeline

May 1, 00	Secure Hotel
May 1, 01	Pre RTWG planning meeting
June 15, 01	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 01	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 01	First call for papers and a call for awards nominations
Sept. 15, 01	Second call for papers (Reminder; e-mail only)
Oct. 15, 01	Titles and interpretive summaries due
Dec. 1, 01	Abstracts due
Dec. 1, 01	Award nominations due to Chair
Dec. 1, 01	Registration and housing packet sent
Jan. 3, 02	Reminder for registration and hotel (e-mail only)
Jan. 29, 02	Last day for hotel reservations
Jan. 30, 02	Abstracts due to Publication Coordinators from Panel Chairs
Jan. 30, 02	Registration due without late fee
Feb. 28, 02	RTWG Meeting

9. Program Itinerary

The biennial meetings begin on Sunday afternoon with committee meetings followed by a social mixer in the evening. The meetings end on Wednesday morning with the Closing Business meeting. The Awards presentations are made at dinner Monday or Tuesday evening or at a luncheon on Tuesday. See programs from previous RTWG meetings for more details.

<u>Sunday:</u> Registration usually begins Sunday afternoon and standing committees and ad hoc committees meet Sunday afternoon. A Sunday evening social mixer is hosted by the RTWG.

<u>Monday</u>: Registration continues Monday morning and posters are usually setup prior to the Opening General Session. The Opening General Session starts the biennial meeting with opening remarks from the Chair, a welcome from the Secretary Program Chair, the opening business meeting, and ends with invited speakers. The concurrent technical sessions (i.e., oral presentations) of the six Panels begins after the Opening General Session on Monday. Posters are on display throughout the meeting or removed Monday evening and new ones placed on display Tuesday morning and removed Tuesday evening, depending on the number of posters and poster sessions.

<u>Tuesday:</u> The concurrent technical sessions continue on Tuesday and extend through Tuesday afternoon, depending on the number of papers. Each concurrent technical session ends with the review of the panel

recommendations. If there are a sufficient number of posters then a second poster session is held on Tuesday.

Wednesday: The biennial meeting usually ends on Wednesday with the Closing Executive meeting and then the Closing Business meeting.

10. Symposia
Symposia are welcomed in conjunction with the RTWG biennial meetings. Symposia must not interfere with the RTWG biennial meetings and are to be held prior to the committee meetings on the first day (i.e., Sunday) of registration and after the Closing Business meeting.

11. Functions by Industry and Other Groups
Functions held in conjunction with the RTWG biennial meetings are welcomed as long as they do not interfere with the RTWG biennial meetings. Thus, these functions must be held prior to the committee meetings on the first day (i.e., Sunday) of registration and after the Closing Business meeting. Exceptions are informal, brief functions held at the meal breaks of breakfast, lunch, or dinner.

B. Instructions for Preparation of Abstracts for Biennial Meetings
Beginning with the Proceedings for the 24th Rice Technical Working Group meetings, Desktop Publishing software was chosen for expediting the post-meeting publication process using Microsoft Word (Windows). 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: i) title of materials, ii) corresponding RTWG Panel, iii) corresponding author's name, daytime telephone number, and e-mail address, and iv) computer format (i.e., MS Word and version number). These criteria apply uniformly to i) presented paper abstracts, ii) poster abstracts, iii) symposia abstracts, iv) panel recommendations, and v) 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.

1. Presented Paper, Poster, and Symposia Abstracts
To be published in the printed Proceedings, presented paper, poster, and symposia abstracts for the RTWG meetings must be prepared as follows. Please follow these instructions -- doing so will expedite the publishing of the Proceedings.

a. 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 RTWG meeting, or earlier as stated in the Call for Papers issued by the RTWG meeting Chair and/or Panel Chairs. Please e-mail the abstract to the Panel Chair by the deadline and mail the hard copy thereafter. If e-mail is not available, mail the electronic file to the panel chair on a IBM compatible CD or floppy disk.

The respective Panel Chairs for the next RTWG meeting and their e-mail and mailing addresses are presented in this proceedings. In case of other questions or if unable to access the Call for Papers, contact:

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b. Margins: Set 1-inch 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.

c. Type: Do not use any word processing format codes to indicate boldface, etc. Use 10 point Times New Roman font.

d. Heading:
   i) Title: Center and type in caps and lower case.
   ii) 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.).
   iii) Affiliation and location: DO NOT GIVE AFFILIATION OR LOCATION. Attendance list will provide each author's affiliation and address.

e. Body: Single space, using a ragged right margin. Do not indent paragraphs. Leave a single blank line between paragraphs.

f. Content is limited to one page.
   i) Include a statement of rationale for the study.
   ii) Briefly outline methods used.
   iii) Summarize results.

g. Tables and figures are not allowed

h. Literature citations are not allowed.

i. Use the metric system of units. English units may be shown in parentheses.

j. When scientific names are used, italicize them -- do not underline.

C. Guidelines for RTWG Awards

1. The RTWG Chair shall solicit nominations, and when appropriate, award on a biennial basis the following types of awards, namely:

a. <u>The Distinguished Rice Research and/or Education Award</u>

   i) <u>Individual category</u> – An award may be made to one individual at each RTWG meeting in recognition of recent achievement and distinction in one and/or more of the following: (1) significant and original basic and/or applied research and (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.

   ii) <u>Team category</u> – Same as the individual category, one team may be recognized at each RTWG meeting. All members of the team will be listed on each certificate.

b. <u>The Distinguished Service Award</u> - 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, or 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. The Awards Committee shall consist of the Executive Committee.

3. Responsibilities and duties of the Awards Committee are as follows:

a. 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. If a member of the Awards Committee is nominated for an award in a given category, it is common courtesy to abstain from voting in that category.

b. To review all nominations and select worthy recipients for the appropriate awards. Selection on awardees will be determined by a simple majority vote once a quorum is mustered. A quorum for the Awards Committee is when at least eight members vote, excluding the Chair. The Awards Committee Chair (RTWG Chair) can only vote in the case of a tie. The names of recipients shall be kept confidential, but recipients shall be invited to be present to receive the award.

c. The Awards Committee shall arrange for a suitable presentation at the biennial RTWG Meeting. The Chair of the RTWG shall present the awards by speaking briefly about the accomplishments of the award recipient(s) and after presenting the award allow the recipient(s) an opportunity to express their appreciation.

d. The Awards Committee shall select appropriate certificates for presentation to the recipients of the awards.

4. **Those making nominations for the awards shall be responsible for supplying evidence to support the nomination, including three recommendation letters, pertinent biographies of each nominee, and a concise but complete explanation of the accomplishments. Fifteen 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 granted.**

    a. 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.

    b. A member of an organization, described in 4.a, may nominate or co-nominate two persons.

    c. Nominations are to be sent to the Awards Committee for appropriate consideration.

    d. The deadline for receipt of nominations shall be three months preceding the biennial meeting.

    e. Awards need not be made if in the opinion of the Awards Committee no outstanding candidates have been nominated.

D. Off-Year Executive Committee Business Meeting

The Executive Committee of the 2004 RTWG Meeting voted to have an Off-Year Executive Committee Business Meeting to add continuity, indoctrinate new Executive Committee members, and discuss pertinent topics more timely. The time and place of the Off-Year meeting is flexible and the possibility of conducting the meeting through distance education is a viable alternative to meeting at designated location. The best time for the meeting is from February to August in the off-year and it can be held in conjunction with such meetings as the Breeders' Conference or the organizational meeting for the next RTWG. The meeting can also be held independently at a central location or at the next RTWG meeting site to allow the Executive Committee to become familiar with the hotel and available facilities. A quorum (i.e., eight members are present, excluding the Chair) of the Executive Committee must be present for the Executive Committee to do business. It is the responsibility of the RTWG Chair and the Secretary/Program Chair to call this meeting and set the agenda in concert with the other members of the Executive Committee.

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