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Rice Technical Working Group

Arkansas California Florida Louisiana Mississippi Missouri Texas

PROCEEDINGS. . .

Thirty-Fourth Rice Technical Working Group

Hot Springs, Arkansas • February 27-March 1, 2012

Edited by: Michael E. Salassi, Charles E. Wilson Jr., and Timothy W. Walker

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 National Institute of Food and Agriculture, 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

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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 National Institute of Food and Agriculture, 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 1950, 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 and Website Coordinators also are 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. RTWG 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 and Location and Time of Next Meeting, Members of the Nominations and the Location and Time of Next Meeting Committees are usually selected to represent the different geographical areas.

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 2012 Meeting

The 34th RTWG meeting was hosted by Arkansas and held at the Hot Springs Convention Center in Hot Springs, Arkansas, from February 27 to March 1, 2012. The Executive Committee, which coordinated the plans for the meeting, included Timothy W. Walker, Chair; Charles E. Wilson, Jr., Secretary; and Randall (Cass) Mutters, Immediate Past Chair. Geographic Representatives were Karen Moldenhauer (Arkansas), Chris Greer (California), Ronald Rice (Florida), Xueyan Sha (Louisiana), Nathan Buering (Mississippi), Won Kyo Jung (Missouri), Lee Tarpley (Texas), and Frank Carey (Industry). Administrative Advisors were John Russin (Experiment Station - Louisiana), Joe E. Street (Extension Service - Mississippi), and Anna McClung (USDA-ARS). Publication Coordinator was Michael Salassi (Louisiana). The Industry Representative was Frank Carey (Mississippi). Website coordinator was Chuck Wilson. The Local Arrangements Coordinators for Arkansas were Karen Moldenhauer, Paul Counce, Donna Frizzell, and Debra Ahrent.

Location and Time of the 2014 Meeting

The 2014 RTWG Meeting Location Committee recommended that the 35th RTWG meeting be held by the host state Louisiana. The meeting will be held from February 18 to 21, 2014, at the Sheraton New Orleans Hotel in New Orleans, Louisiana.

2012 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. Anna McClung. The team award was presented to the Nitrogen Use Efficiency Team, whose members included Dr. Richard Norman, Dr. Nathan Slaton, Dr. Trenton Roberts, Dr. Jeremy Ross, Dr. Dustin Harrell, Dr. Brenda Tubana, Dr. Garry McCauley, Dr. Charles E. (Chuck) Wilson, Jr., and Dr. Tim Walker.

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 that it is our toughest award to win. But, since more than one can be given at a RTWG meeting, it is our fairest award granted to all worthy of such distinction. This award was presented to Dr. Garry McCauley, Dr. Elaine Champagne, and Dr. Jim Hill.

Publication of Proceedings

The LSU AgCenter published the proceedings of the 34th RTWG meeting. Dr. Michael Salassi of Louisiana served as the Publication Coordinator for the 2012 proceedings. The 2012 proceedings was edited by Michael E. Salassi, Charles E. Wilson, Jr. (Secretary), and Timothy W. Walker (Chair). They were assisted in the publication of these proceedings by Darlene Regan (LSU AgCenter Rice Research Station) and the panel chairs.

Instructions to be closely followed in preparing abstracts for publication in the 35th RTWG (2014 meeting) proceedings are included in these proceedings.

Committees for 2014

Executive:

Chair:	Chuck Wilson	Arkansas
Secretary:	Eric Webster	Louisiana

Geographical Representatives:

Robert Scott	Arkansas
Zhonli Pan	California
Ronald Rice	Florida
Dustin Harrell	Louisiana
Jason Bond	Mississippi
Donn Beighley	Missouri
Lee Tarpley	Texas

Immediate Past Chair:

Timothy Walker	Mississippi

Administrative Advisors:

John Russin	Experiment Station
Joe E. Street	Extension Service
Anna McClung	USDA-ARS

Publication Coordinator:

Mike Salassi	Louisiana

Web Page Coordinator:

Chuck Wilson	Arkansas

Industry Representative:

Frank Carey	California

2014 Local Arrangements:

Steve Linscombe (Chair)	Louisiana
Eric Webster	Louisiana
Mike Salassi	Louisiana
Karen Bearb	Louisiana
Dustin Harrell	Louisiana

Location and Time of 2016 Meeting:

Lee Tarpley	Texas
Rodante Tabien	Texas

Nominations:

Fugen Dou (Chair)	Texas
Karen Moldenhauer	Arkansas
Larry Godfrey	California
Ronald Rice	Florida
Herry Utomo	Louisiana
Nathan Buering	Mississipppi
Donn Beighley	Missouri
Frank Carey	Industry

Rice Crop Germplasm:

Farman Jodari, Chair	California
Georgia Eizenga	USDA-ARS
James Correll	Arkansas
Karen Moldenhauer	Arkansas
Jim Oard	Louisiana
Xueyan Sha	Louisiana
Dwight Kanter	Mississippi
Rodante Tabien	Texas
M. O. Way	Texas
Qiming Shao	Bayer Crop Science

Ex Officio:

Harold Bockleman	USDA-ARS
Mark Bohning	USDA-ARS
Jack Okamuro	USDA-ARS
Anna McClung	USDA-ARS
Clarissa J. Maroon-Lango	USDA-ARS
Wengui Yan	USDA-ARS

National Germplasm Resources Laboratory:

Mark Bohning	USDA-ARS
Gary Kinard	USDA-ARS

Rice Variety Acreage:

Johnny Saichuk, Chair	Louisiana
Chuck Wilson	Arkansas
Kent McKenzie	California
Nathan Buering	Mississippi
Donn Beighley	Missouri
Ted Wilson	Texas

2014 RTWG Panel Chairs:

Breeding, Genetics, and Cytogenetics:
Jim Oard — Louisiana

Economics and Marketing:
Mike Salassi — Louisiana

Plant Protection:
Michael Stout — Louisiana

Processing and Storage:
Joan King — Louisiana

Rice Culture:
Dustin Harrell — Louisiana

Rice Weed Control and Growth Regulation:
Eric Webster — Louisiana

RESOLUTIONS
34th RTWG – 2012

The 34th meeting of the RTWG, held at Hot Springs, Arkansas, February 27 to March 1, 2012, provided the time and location for the exchange of information among rice research and extension scientists, rice growers, rice industry representatives, and users of rice products. This exchange of knowledge was beneficial to all concerned and has accomplished the aims of the RTWG.

Therefore, the Executive Committee, on behalf of the RTWG, expresses its appreciation to the following individuals and organizations that contributed to the success of the 34th meeting.

1. Timothy W. Walker, RTWG Chair, and all other members of the Executive Committee who organized and conducted this very successful meeting. We recognize Charles E. Wilson, Jr. 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 Hot Springs Convention Center and the Embassy Suites Hot Springs, Hot Springs, Arkansas, for their assistance in arranging lodging, services, and hospitality before and during the RTWG meeting.

3. The Local Arrangements Committee chaired by Karen Moldenhauer for the site selection and overseeing arrangements. To the faculty and staff of the Rice Research and Extension Center, Stuttgart, Arkansas, and the Division of Argriculture, University of Arkansas, for their time and assistance in conducting all aspects of pre- and on-site registration and other conference planning and operational details.

4. To all other University of Arkansas staff who contributed time and effort for numerous vital tasks that made sure this meeting was a success.

5. The Panel Chairs Wengui Yan, Rolfe Bryant, Bradly Watkins, Craig Rothrock, Nathan Slaton, and Robert Scott and moderators for planning, arranging, and supervising the technical sessions. Special recognition is due for the efforts of the chairs and Michael Salassi 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 Certified Crop Advisor Training Session, General Session, and Applied Genomics Workshop speakers for sharing their knowledge and wisdom.

8. Michael Salassi, and the LSU AgCenter staff, for editing and publishing the RTWG proceedings.

9. We gratefully recognize our many sponsors that made the 34th Rice Technical Working Group meeting possible.

RTWG Conference Sponsorship

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Arkansas Farm Bureau Federation

Distinguished Rice Research and/or Education Award

Anna M. McClung

Dr. Anna Myers McClung is the 2012 Distinguished Rice Research and/or Education Award recipient. Dr. McClung's pioneering work in using DNA markers in rice breeding and her dedication to streamline these technologies for the application of rice breeders have been monumental. Her knowledge of industry needs and the ability to relate have helped foster relationships between public breeding and private business that share similar objectives. Her focus in adding value to rice through the development of specialty rice, research activities on grain and milling quality, alternative use of rice by-products, and health benefits will open new markets and enhance full utilization of rice as food to everyone. Her continued activities to discover new donors of important traits and the associated gene discovery will enhance genetic diversity that is critical in sustainable rice production.

Her administrative skills have been honed for years as she holds key positions in university committees, national and international advisory boards, provides direction to advance science and enhance progress beneficial to the rice industry. Her mentoring of students and training of new rice breeders and scientists will create a pool of human resources that will continue rice research and development and be prepared to meet the great challenges of feeding an increasing world population.

Dr. McClung has released 17 rice varieties that have entered commercial production in the U.S., Brazil and Europe. Furthermore, she has identified several germplasms as donors of important traits such as disease resistance and cold tolerance. She released the first U.S. varieties developed using DNA markers and has continued to use this technology in her program.

Dr. McClung published more than 80 peered reviewed papers in various topics, several book chapters and hundreds of abstracts, and generated millions of dollars in research grants. She has been very active in presenting her research outputs not only in scientific meetings but also during field days and farmers meetings. In recognition of her expertise in science and administration, she was invited to several symposia and workshops, and asked to join and be a leader or member of task forces, advisory boards and committees in universities, national and international institutions. Her leadership, wisdom and vision will set the future of rice research and development in the United States and the world.

Distinguished Rice Research and/or Education Team Award

Dustin L. Harrell, Richard J. Norman, Trenton L. Roberts, Jeremy Ross, Nathan A. Slaton, Brenda S. Tubaña, Timothy W. Walker, Garry McCauley, and Charles E. Wilson, Jr.

The Advances in Nitrogen Use Efficiency Team has made tremendous strides in the past 6 years that have greatly improved the efficient use of N fertilizers in commercial rice production to the point that rice has become the most efficient N user of all row crops in the continental United States. Nitrogen use efficiency in rice has been reported to approach 75%, making it one of the most sustainable users of N fertilizers in U.S. row crop production.

One of the most prolific advances by the team was the development of a N soil test for rice. The N soil test for rice, coined N-ST*R for short, began with basic research comparing estimates of seasonal mineralizable N from rice soils using laboratory incubation studies and correlating the results with extractable N from potential N soil tests. A strong relationship between mineralizable N with an alkaline hydrolyzable N extraction that utilizes direct steam distillation provided some promise that a N soil test for rice may be possible. The second phase of the research was a multi-state collaboration focused on correlating and calibrating the soil test using established variety by N trials on research stations and commercial rice fields throughout Arkansas, Louisiana, Mississippi, and Texas. After three years of research, it was determined that a very strong correlation existed for N-ST*R extractable N and rice response to N fertilization when a soil sample from 0 to 18 inches is used. Calibration of N-ST*R ensued and calibration curves for silt loam rice soils were established at the 90, 95, and 100% relative grain yield levels. Phase three of the collaborative research is currently being conducted in all states to validate the N-ST*R calibration curves on commercial rice fields. Commercial validation also serves as an extension outlet to educate rice producers and consultants about the proper use of N-ST*R. Current validation results suggest that, in many cases, N can be used at lower rates on fields testing high in N-ST*R extractable N, resulting in reduced N use, higher N use efficiency and profitability, and improved sustainability. Current calibration of clay soils is on-going.

Another avenue of collaborative multi-state research by the team involves the evaluation of the effectiveness of alternate N fertilizer sources and urea treatments to improve N use efficiency of pre-flood N for drill-seeded, delayed flood rice production. Nitrogen can be lost very quickly by ammonia volatilization when N fertilizers remain on the soil surface for extended periods of time. Volatilization studies in Arkansas and Louisiana on silt loam soils have indicated that as much as 25% of applied urea N can be lost over a 10-day period. A multitude of products are marketed each year by chemical companies claiming to improve N efficiency in rice production; however, collaborative research has shown that only the use of the urease inhibitor products, which contain NBPT, can greatly improve N use efficiency when the fertilizer remains on the soil surface for greater than 3 days. Timely testing and evaluation of fertilizer enhancing products by the collaborative team have saved rice producers immeasurable amounts of money by determining which products work and do not work in drill-seeded, delayed flood rice production.

Lastly, the Advances in Nitrogen Use Efficiency Team is currently working together to improve the precision of midseason N fertilizer recommendations using spectral reflectance technology. This collaborative research began by evaluating passive sensors, aerial imagery, and a hand-held sensor with an active light source for their ability to predict rice grain yield. Research indicated that the sensor with an active light source proved to be the best predictor of rice grain yield. Further collaborative research found that the optimal sensor head orientation was determined to be in the nadir position while optimal sensing timing was determined to be during the window between PI and PD. Research findings coupling the sensor predicted rice yield potential, the response index, and the response of rice to N fertilization were used to create an algorithm that can be used to generate a precise and instantaneous site specific midseason fertilizer recommendation. The predictive algorithm is currently being validated in a multi-state small plot research trial and has shown great potential to improve N use efficiency, economic returns, and improve sustainability.

Distinguished Service Award

Garry N. McCauley

Dr. Garry Nathan McCauley has served the rice industry for 36 years and continues to press forward. In nearly four decades of rice research, Dr. McCauley has generated technologies that benefited not only Texas rice producers but also farmers in other rice growing states and countries. His water saving technologies in the 'Less water/more Rice' concept has made a lot of impacts in increasing grain production by 60% and reducing water use by 40%. The 15 irrigation management tools he developed can reduce irrigation inflow by 15-35% and three of these can reduce water use by 45%. His findings on proper timing of draining the field had tremendous impact in efficiently using irrigation water and increasing grain yield and milling quality. With the current scarcity of water, these technologies are more important than ever. The herbicide evaluations to identify cheaper but effective formulations, the use of low seeding rates and narrower row spacings, and ratooning studies further support his research thrust of decreasing production cost and increasing yield, thereby increasing profitability of rice farming. His works on red rice facilitated red rice control and his research on Newpath herbicide and Clearfield rice varieties enhanced the adoption of this new technology, increasing acreage to 35% in two years. Dr. McCauley obtained more than $3 million in research grants, published more than 170 peer reviewed papers, reviews, book chapters, abstracts and other scholarly articles. He was invited to more than 30 international conferences such as the annual International Rice Congress and the International Rice Conference for Latin America and the Caribbean. He is also an active member of six scientific organizations. Dr. McCauley was a mentor or co-mentor to more than 20 M.S. and Ph.D. students that are now holding key positions in their country of origin or in the United States.

The expertise of Dr. McCauley is recognized worldwide. He has consulted in rice production system designs in India, Jamaica, Haiti, Nigeria, South Africa, Cote d'Ivoire, Uruguay, and Argentina. Dr. McCauley has also served this organization to the fullest extent. He recently went through the ranks of Secretary, Chair, and Past Chair.

Distinguished Service Award

Elaine Champange

Dr. Elaine Champagne is an active participant in the Rice Technical Working Group (RTWG) and has organized and chaired sessions for the Processing, Storage, and Quality section when hosted in Louisiana. She is also an active member of the American Association of Cereal Chemists International (AACCI) and has contributed to this organization by serving as chair of the Rice Milling and Quality Technical committee, established and co-directed the AACCI short course titled Rice Milling and Technology, has served as associate editor for *Cereal Chemistry* since 1995, and served as editor for the third edition of the renowned monograph *Rice: Chemistry and Technology.*

Some of her research accomplishments include relating rice quality measurements to sensory quality. In collaboration with ARS researchers and scientists worldwide, she thoroughly examined the effects of genetic factors, environment, organic fertility management, drying, harvest and storage moisture contents, degree-of-milling, drain and harvest dates, and cooking methods on rice flavor and texture. She related rice flavor and texture to amylose content, protein content, grain dimensions and gelatinization temperature type.

To help the rice industry add value to the rice crop, she established the Rice Utilization Workshop (RUW) and conceived the theme, planned and led seven of these workshops. Because of the influence of these workshops, rice consumption in the United States has increased from 12 to 26 lb/capita since 1990 and the rice industry was successful in extending the whole grain claim to brown rice in 2008. Additionally, through rice sensory workshops, she has helped the rice industry utilize universal flavor and texture descriptors for discussing rice quality.

Distinguished Service Award

James (Jim) E. Hill

Dr. Jim Hill has demonstrated a long-term history of service to the RTWG and the rice industry in the areas of research, education, and international agriculture. He has been a Cooperative Extension Specialist at the University of California since 1975. Since 1980, Jim has focused his efforts on the California rice industry in the areas of weed science and agronomy. His accomplishments have had a direct impact on the California rice industry.

In the early 1980s, Jim was instrumental in the rice industry's rapid adoption of semidwarf rice varieties that increased yields by 50 percent, boosting California's rice yield to the highest level in the world. Over the last three decades, Jim's research and education programs have often involved solving issues related to environmental stewardship. As herbicide usage increased, Jim worked with colleagues and the California industry to develop and promote systems and practices to minimize downstream pollution from rice pesticides. As a direct result of these efforts, pesticide residues from rice fields were reduced 98 percent from their early 1980s peak. During the 1990s and early 2000s, Jim worked to help rice farmers adjust to increasing restrictions on the burning of rice straw by initiating and leading an interdisciplinary team to develop effective alternatives to burning, which also preserved habitat for migrating waterfowl and increased biodiversity.

Jim also has made significant contributions to international agriculture throughout his career. From 1999-2002, he joined the International Rice Research Institute (IRRI) in the Philippines where he served as Program Leader for Irrigated Rice and Head of the Division of Crop, Soil and Water Sciences. In this capacity, he worked extensively with national research and extension programs in many countries. Since 2005, he has served as Associate Dean for International Programs in the College of Agricultural and Environmental Sciences. In this capacity, Jim has led, developed or participated in international agricultural development programs with India, Vietnam, Egypt, Afghanistan, Iraq, Philippines, Uruguay and others.

Jim has served as Chair of the USA Rice Technical Working Group and the International Temperate Rice Conference. Jim is a Fellow of the American Society of Agronomy and the Crop Science Society of America. Jim has received numerous awards throughout his career including: 1) The Research and Education Award from the USA Rice Technical Working Group; 2) The California Rice Industry Achievement Award; and 3) the California Rice Commission Circle of Life Award.

Minutes of the 34th RTWG Meeting

Opening Executive Committee Meeting

In attendance: Tim Walker (Chair), Chuck Wilson (Secretary), Cass Mutters (Immediate Past Chair), Anna McClung (USDA-ARS Rep.), Chris Greer (California Rep.), John Russin (Experiment Station Admn. Advisor), Karen Moldenhauer (Arkansas Rep.), Frank Carey (Industry Rep.), Xueyan Sha (Louisiana Rep.), Mike Salassi (Publication Coordinator), and Lee Tarpley (Texas Rep.).

Chair Tim Walker called the meeting to order at 8:34 a.m. on February 27, 2012, at the Hot Springs Convention Center in Hot Springs, Arkansas.

Old Business

Tim Walker presented the financial report from the 2010 meeting. Tim reported that he had 287 pre-registered participants and a total attendance of 342 at the 2010 RTWG. The committee discussed the financial costs and commitments for the permanent web site. Chuck Wilson gave an overview of the agreement with Aristotle that included an up-front charge and a monthly fee. As the host state, Arkansas agreed to cover the monthly expenses through February 2014. Motion was made by Karen Moldenhauer to approve the financial report and was seconded by Cass Mutters. Motion passed unanimously. Mike Salassi discussed the cost of publishing the proceedings.

Chuck Wilson presented the minutes from the 33rd RTWG in 2010. Frank Carey moved that the minutes be approved as printed and dispense with reading. Cass Mutters seconded. Anna McClung made note of one typographical error (Neil Rutger's name had been misspelled). The motion passed.

Tim Walker discussed the permanent website. The Chair will be responsible for the website fees during the 2-year period he is in office. The fee responsibility will pass from one state to the next as the gavel is passed.

New Business

Tim Walker asked for individuals that should be included in the necrology report.

Anna McClung presented Tony Marchetti, Tom Hargrove, and Candido Ricardo Bastos. Mike French was presented by Chuck Wilson. Heather Wilf was presented by Frank Carey.

Award recipients for the 2012 meeting include: Anna McClung, research award; and Garry McCauley and Elaine Champagne, distinguished service awards. The team award was presented to the Advances in Nitrogen Use Efficiency Team. Members of that team included Richard Norman, Nathan Slaton, Trenton Roberts, Dustin Harrell, Brenda Tubana, Garry McCauley, and Tim Walker.

Chris Greer recommended Jim Hill be presented with the Distinguished Service Award. Discussion followed regarding whether documentation should be in place before voting on the Distinguished Service Award. After discussion, it was advised that Chris Greer would get supporting documentation by Tuesday morning. A special meeting of the Executive Meeting was called for Tuesday morning at 8:00 am to consider the nomination of Jim Hill. Recommendations were made to update the MOP to reflect the requirements for supporting documentation for distinguished service award nominations.

Tim Walker proposed forming a publicity committee consisting of three people to manage website transition from one state to the next. The members of that committee would be incoming secretary, chair, and an at-large member from the next host state. After discussion, it was decided that the secretary and chair would work together to transition and may include additional individuals, such as communications staff, at the discretion of the host state.

Karen Moldenhauer moved that the meeting be adjourned and was seconded by Frank Carey. Meeting was adjourned.

Special Executive Committee Meeting

In attendance: Tim Walker (Chair), Chuck Wilson (Secretary), Cass Mutters (Immediate Past Chair), Anna McClung (USDA-ARS Rep.), Chris Greer (California Rep.), John Russin (Experiment Station Admn. Advisor), Joe Street (Extension Service Admn. Advisor), Karen Moldenhauer (Arkansas Rep.), Frank Carey (Industry Rep.), Xueyan Sha (Louisiana Rep.), Mike Salassi (Publication Coordinator), Lee Tarpley (Texas Rep.), Eric Webster, and Steve Linscombe. Chairman Tim Walker called the meeting to order at 8:00 a.m. on February 28, 2012, at the Hot Springs Convention Center in Hot Springs, Arkansas.

Chris Greer moved to accept the nomination of Jim Hill for the Distinguished Service Award. Frank Carey seconded the motion. The motion carried unanimously.

Cass Mutters moved that the following statement be added to the MOP to clarify nominations for the Distinguished Service Award. "The Executive Committee has the right to entertain nomination packets for Distinguished Service Award." The motion was seconded by Karen Moldenhauer and the motion passed.

Karen Moldenhauer moved to adjourn and the meeting was adjourned.

Opening Business Meeting

Chairman Tim Walker called the meeting to order at 8:35 a.m. on February 28, 2012, at the Hot Springs Convention Center in Hot Springs, Arkansas.

The Chair discussed the new RTWG website and how the executive committee had designed to transition the website from one state to the next.

Chairman Tim Walker asked attendees to recognize those colleagues who have passed away since the previous RTWG meeting, including Toni Marchetti, Tom Hargrove, Candido Bastos, Mike French, and Heather Wilf. Kent McKenzie indicated that Howard Carnahan should also be included.

Steve Linscombe, chair of the Nominations Committee, recommended the following individuals for leadership for the 35th RTWG:

Charles Wilson – Chair
Eric Webster – Secretary
Timothy Walker – Immediate Past Chair
Geographical Representatives
Robert Scott – Arkansas
Zhonli Pan – California
Ronald Rice – Florida
Dustin Harrell – Louisiana
Jason Bond – Mississippi
Donn Beighley – Missouri
Lee Tarpley – Texas
Frank Carey – Industry

Nominations Committee
Fugen Dou – Chair
Karen Moldenhauer – Arkansas
Larry Godfrey – California
Ron Rice – Florida
Herry Utomo – Louisiana
Nathan Buering – Mississippi
Donn Beighley – Missouri
Frank Carey – Industry

Terry Seibenmorgen motioned to accept Linscombe's nominations, Xueyan Sha seconded, and motion carried.

Steve Linscombe announced that the 2014 RTWG meetings would be hosted by Louisiana in New Orleans, Louisiana. The dates of the meeting would be February 17 to February 20, 2014.

Minutes of the previous meeting were read by Secretary Chuck Wilson. Natalie Hummel moved to accept the minutes and seconded by Karen Moldenhauer. The motion passed.

Karen Moldenhauer made a motion that the business meeting be adjourned and seconded by Paul Counce.

Meeting was adjourned.

Closing Executive Committee Meeting

In attendance: Tim Walker (Chair), Chuck Wilson (Secretary), Cass Mutters (Immediate Past Chair), Anna McClung (USDA-ARS Rep.), Chris Greer (California Rep.), Joe Street (Extension Service Admn. Advisor), Karen Moldenhauer (Arkansas Rep.), Mike Salassi (Publication Coordinator), Lee Tarpley (Texas Rep.), and Steve Linscombe.

Chairman Tim Walker called the meeting to order at 7:13 a.m. on March 1, 2012, at the Embassy Suites Hotel in Hot Springs, Arkansas.

Old Business

The website transition protocol seems to be resolved. Secretary Chuck Wilson indicated that he would begin the process of digitizing older proceedings so that they could be placed on the website. He also indicated that the links for credit card payments would need to be changed for succeeding host states. Chairman Tim Walker indicated that he would move the web domain licenses to succeeding states to facilitate any changes that become necessary in the future.

Cass Mutters inquired about standardizing units for committee reports and abstracts for proceedings. A member had requested that the acreage committee report in standard units. Cass Mutters made a motion that the yields and acreage in the committee reports as lbs/acre and acres. International units would still be used in presentations and abstracts. The motion was seconded by Karen Moldenhauer. Motion passed.

Secretary Chuck Wilson asked that the executive committee consider clarifying language in the MOP regarding the appointment of administrative advisors. This should reflect that the Southern Association of Agricultural Experiment Station Directors is the organization that appoints the Experiment Station Advisor.

Anna McClung indicated that Ragit Kaiden should be added to the necrology report.

Chairman Tim Walker suggested that the opening executive committee meeting be expanded to one and a half hours and the closing executive meeting be reduced to 1 hour.

Chairman Tim Walker indicated that it had been brought to his attention that two individuals had been inadvertently omitted from the Advances in Nitrogen Use Efficiency Team. Chuck Wilson and Jeremy Ross were vital to the team and should be added.

Cass moved that Chuck Wilson and Jeremy Ross be awarded the Distinguished Rice Research and Education Team Award as part of the team. The motion was seconded by Karen Moldenhauer, and the motion passed.

Anna McClung proposed changing the MOP to reflect how awards should be handled when officers are nominated for awards. Tim Walker agreed to draft a sentence to add to the MOP.

After no further business, the meeting was adjourned at 8:25 a.m.

Closing Business Meeting

Chairman Tim Walker called the meeting to order at 8:30 a.m. on March 1, 2012, at the Embassy Suites Hotel in Hot Springs, Arkansas. He extended his gratitude to Arkansas for hosting the 34th RTWG, to Michael Salassi for his efforts at publishing the proceedings, and to the participants of RTWG for their support of his leadership efforts in recent years.

Chairman Tim Walker reported that Chuck Wilson and Jeremy Ross were inadvertently left off the team that received the Distinguished Rice Research and Education Team Award for Nitrogen Advances and that the Executive Committee had voted to add these two individuals to the award.

Karen Moldenhauer presented the Rice Germplasm Committee report on behalf of Geogia Eizenga. The Rice Germplasm Committee met on February 27, 2012, at the Hot Springs Convention Center. The minutes from the previous meeting were presented and approved. The National Program Staff reported on the federal budget increases in distribution and the change from GRIN to GRIN-Global this coming year. APHIS staff reported they will be testing for Xanthomonas oryzae. New officers were elected for the committee as follows: Farmin Jodari, chair; James Correll, Georgia Eizendga, and Quiming Shao were elected to new terms; Rodante Tabien was elected as a new committee member.

Johnny Saichuk, chair of the Variety by Acreage committee, reported that all states would decrease in rice acreage in 2012. Minutes of previous meeting were presented and approved. Rice acreage for the United States is projected to be down.

Chuck Wilson reported on behalf of Industry Representative, Dr. Frank Carey, that The Rice Technical Working Group Industry Committee again held a successful luncheon at the 34th RTWG meetings in Hot Springs, Arkansas, on Tuesday February 28, 2012. 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 2012 Industry luncheon met all of these goals. The luncheon was attended by approximately 280 guests who heard Mr. Chuck Wilson, Director of Arkansas Field Services and Director of The Rice Foundation located in Stuttgart, AR. Mr. Wilson spoke about the Rice Leadership Development Program and the opportunities provided for future leaders in the rice industry. Discussion focused on both the domestic and international programs. There was a high level of interest as indicated by the attendance and amount of discussion following the presentation.

The Industry Committee would like to thank Dr. Karen Moldenhauer, Chairperson, Local Arrangements Committee, for her invaluable assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 35th RTWG meetings in Louisiana in 2014.

Mike Salassi, publication coordinator, gave a report on the proceedings for 2012 meetings. He indicated he would be in communication with the panel chairs to finalize the abstracts.

One member asked that in the future, the RTWG leadership should make sure mailing lists are inclusive of all authors. Make sure communications occur between panel chairs and secretary to compile master mailing lists.

Chairman Tim Walker again thanked the RTWG for the opportunity to serve as Secretary and Chair. He thanked Chuck Wilson and Karen Moldenhauer for the successful 34th meeting. He then passed the gavel to Chuck Wilson, incoming Chair. He presented a plaque that illustrates the history of the RTWG leadership since 1950 to Chuck Wilson.

Chuck Wilson presented a plaque to Tim Walker in recognition of his service to the RTWG.

Chuck Wilson thanked his faculty and staff that were instrumental for making the 34th RTWG a success. He indicated that the final attendance for the meeting was 345.

There being no further business, the meeting was adjourned.

SPECIAL COMMITTEE REPORTS

Nominations Committee

The Nominations Committee proposed the following individuals for membership on the 2014 RTWG Executive Committee and Nominations Committee:

Executive Committee:

Charles Wilson	Chair
Eric Webster	Secretary
Timothy Walker	Immediate Past Chair

Geographical Representatives:

Arkansas	Robert Scott
California	Zhonli Pan
Florida	Ronald Rice
Louisiana	Dustin Harrell
Mississippi	Jason Bond
Missouri	Donn Beighley
Texas	Lee Tarpley
Industry	Frank Carey

Nominations Committee:

Texas	Fugen Dou, Chair
Arkansas	Karen Moldenhauer
California	Larry Godfrey
Florida	Ronald Rice
Louisiana	Herry Utomo
Mississippi	Nathan Buering
Missouri	Donn Beighley
Industry	Frank Carey

Submitted by
Steve Linscombe

Rice Crop Germplasm Committee

The 32th meeting of the Rice Crop Germplasm Committee was held 27 Feb. 2012 in Hot Springs, AR. Members in attendance were Georgia Eizenga (Chair), Harold Bockelman, Farman Jodari, Dwight Kanter, Jim Oard, Clarissa Maroon-Lango, Anna McClung, Karen Moldenhauer, Xueyan Sha, Qiming Shao, M.O. Way, Wengui Yan. Members participating via conference call were James Correll, Peter Bretting, and Jack Okamuro. Members not present were James Gibbons and Mark Bohning. Gary Kinard, Research Leader of the National Germplasm Resources Unit in Beltsville, MD, was present representing Mark Bohning. Guests in attendance were Debbie Ahrent, Donn Beighley, Virgina Boyett, Rolfe Bryant, Eddie Castaneda, Hanlin Du, Ken Foster, Kirk Johnson, James Silva, Rodante Tabien, and Ted Wilson.

The minutes of the 31st Rice Crop Germplasm Committee held 3 Feb. 2011 in Beaumont, TX, were read and approved by a motion from Karen Moldenhauer, seconded by Dwight Kanter, and supported by the other committee members.

Peter Bretting and Jack Okamuro (USDA/ARS NPS) reported the final USDA/ARS budget included a 3.5% decrease. The FY13 budget proposed a modest increase ($581,000). USDA/ARS NPGS has partnered with the Bioversity and GCDT (Global Crop Diversity Trust) on a 3-year project to transform GRIN to GRIN-Global. Regarding the international treaty (IT), it is hoped that the Senate Foreign Relations Committee will schedule hearings on the FAO Treaty as a prelude to the full Senate vote for consent (or not) to the IT ratification. Also, the Convention on Biodiversity is negotiating the Nagoya Protocol. Both of these treaties will affect U.S. users of germplasm depending on whether the USA is party to these treaties or not.

Gary Kinard highlighted four areas 1) Plant Exploration and Exchange proposals are currently being accepted for FY13; 2) the taxonomy for plants used in GRIN is currently being updated which includes providing a thorough coverage of the wild relatives of all crop species, including the primary, secondary and tertiary gene pools; 3) all the volumes (1898-1997) of the PI (Plant Introduction) documentation have been digitized in conjunction with the National Agricultural Library and these are currently available on the NPGS website; and 4) NPGS personnel in Beltsville have worked with APHIS to facilitated the movement of materials to/from international sources.

Harold Bockelman (USDA/ARS NSGC) reported there were 15 new PI assignments for a total of 18,729 accessions and 253 accessions are not *Oryza sativa*. The NSGC rice core collection includes 1,794 accessions. A total of 20,000 accessions from the Aberdeen Small Grains collection was sent to the Svalbard Seed Vault but Harold was unsure as to how many were rice accessions. More than 500 new accessions are being released from quarantine and this includes most all the accessions from Bangladesh, the Indonesian accessions which produced seed, and the first set of the Brazilian rice core collection accessions. Harold also discussed the need to prioritize the grow-outs of the low inventory seed and about 1,000-1,500 accessions which were more than 10 years old thus just needed to be grown out.

Clarissa Maroon-Lango (APHIS, PPQ) reported seeds from the remaining 121 Bangladeshi rice accessions and 199 rice accessions from the Brazilian rice core collection were released. For 2012, the remaining 82 Brazilian rice accessions were processed and 125 slots were assigned to Targeted Growth Inc. of Seattle, WA. Embryo rescue may be used to grow the Indonesian introductions which previously failed to germinate on media. A laboratory test for *Xanthomonas oryzae* pv. *oryzae* utilizing DNA markers is being tested. If successful, this will be included in the PGQP roster of tests for rice pathogens. The rice panicle mite was reclassified from an actionable to a non-actionable/non-quarantine pest.

WenGui Yan reported on the possible germplasm exchange with China being coordinated through Peter Bretting's office. This is being done between the Institute of Crop Science, Chinese Academy of Agricultural Science, and the USDA/ARS Plant Germplasm System as part of the USDA-China Ministry of Science and Technology-CAAS agreements and will include several different crops, one of which is rice.

Georgia Eizenga reported the Rice Diversity Panel 1 consisting of 413 diverse rice accessions genotyped with 700,000 SNP markers was expanded to a Rice Diversity Panel 2 of approx. 1,440 accessions genotyped with the same SNPs. Efforts are underway to import this panel into the USA from IRRI. Georgia reported the list of U.S. rice varieties is being updated and when complete will be posted on the DBNRRC Sharepoint web site along with the URRN data.

Members whose terms expired in 2012 were James Correll, Georgia Eizenga, James Gibbons, and Qimining Shao. James Correll, Georgia Eizenga, and Qimining Shao were nominated for another six-year term and Rodante Tabien was nominated for the fourth committee position. The motion was made to accept all the proposed nominations by Karen Moldenhauer, seconded by Dwight Kanter, and supported by all members. Farman Jodari was nominated as committee chair. Karen Moldenhauer made a motion to accept the nomination of Farman as chair, Xueyan Sha seconded the motion, and the motion was supported by all members.

The 33rd Rice CGC meeting will be Feb. 5, 2013, in Crowley, Louisiana. Karen Moldenhauer made the motion to adjourn, Xueyan Sha seconded the motion, and the motion was supported by all members.

Rice Crop Germplasm Committee members as of February 27, 2012, with year term ends in parentheses:

Dr. Farman Jodari, Chair (2014)
California fjodari@crrf.org

Dr. James Correll (2018)
Arkansas jcorrell@uark.edu

Dr. Georgia Eizenga (2018)
USDA-ARS georgia.eizenga@ars.usda.gov

Dr. Dwight Kanter (2016)
Mississippi dkkanter@drec.msstate.edu

Dr. Karen Moldenhauer (2016)
Arkansas kmolden@uark.edu

Dr. Jim Oard (2016)
Louisiana joard@agcenter.lsu.edu

Dr. Xueyan Sha (2014)
Arkansas xsha@uark.edu

Dr. Qiming Shao (2018)
Bayer Crop Science qiming.shao@bayer.com

Dr. Rodante Tabien (2018)
Texas retabien@ag.tamu.edu

Dr. M. O. Way (2016)
Texas moway@aesrg.tamu.edu

Dr. Harold Bockelman, Ex-officio
USDA-ARS harold.bockelman@ars.usda.gov

Mr. Mark A. Bohning, Ex-officio
USDA-ARS mark.bohning@ars.usda.gov

Dr. Clarissa J. Maroon-Lango, Ex-officio
USDA-APHIS clarissa.j.maroon-lango@aphis.usda.gov

Dr. Anna M. McClung, Ex-officio
USDA-ARS anna.mcclung@ars.usda.gov

Dr. Jack Okamura, Ex-officio
USDA-ARS jack.okamura@ars.usda.gov

Dr. Wengui Yan, Ex-officio
USDA-ARS wengui.yan@ars.usda.gov

Submitted by
Georgia Eizenga

Publication Coordinator/Panel Chair Committee

Publication Coordinator Michael Salassi communicated by email with the panel chairs before the 2012 RTWG meeting concerning publication of panel attendance, recommendations and abstracts in the RTWG 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 2014 proceedings. Proceedings should be available in both hard copy and CD format within 12 months of the meetings.

Submitted by
Michael Salassi

Rice Variety Acreage Committee

The Rice Acreage Committee convened at 9:45 in the Arlington Room at the Hot Springs Civic and Convention Center in Hot Springs, Arkansas. Committee members present were: Chuck Wilson, Arkansas; Kent McKenzie, California; Johnny Saichuk, Louisiana; Tim Walker (for Nathan Buehring), Mississippi; Donn Beighley, Missouri; and Ted Wilson, Texas. Absent were Ron Rice of Florida and Nathan Buehring of Mississippi. Other guests present were: Chris Greer, University of California; Cass Mutters, University of California; Anna McClung, USDA-ARS; Qiming Shao, Bayer CropScience; Yiming Jiang, Bayer CropScience; Nanyen Chou, Bayer CropScience; Hanlin Du, RiceTec; Ken Foster, Kennan Corporation; Zongbu Yu, University of Arkansas; Kirk Johnson, Bayer CropScience; John Russin, LSU AgCenter; Jack Okamuro, USDA-ARS; Dwight Kanter, Mississippi State University; and Garry McCauley, Texas Agrilife Center.

Minutes of the 2010 Acreage Committee meeting were distributed by Johnny Saichuk. Kent McKenzie moved and Donn Beighley seconded the motion to accept the minutes as presented. The motion carried.

Chuck Wilson provided the Arkansas acreage report. He said the 2010 crop was the largest ever for Arkansas at 1.75 million harvested acres. The major varieties that year were CL151, CLXL745, and Wells. A combination of weather and prices forced the acreage down to 1.15 million harvested acres in 2011. CLXL745 continued to be a major variety while Wells declined to 6% from a high of 50% several years ago. He attributed the decline of acreage to a high percentage of crop failures (low yields) in 2010 followed by flooding that delayed planting in 2011. Even though the crop was planted later, the absence of rice planted on marginal ground resulted in improved yields from 140 bushels per acre in 2010 to 151 bushels per acre in 2011. Considering the competition from other commodity prices, flooding in 2011, and the effects of bacterial panicle blight on the previous two crops, he expects rice acreage to remain flat or decline slightly in 2012.

Kent McKenzie told the group he continues to have difficulty in determining acreage by variety and cautioned the group that these were the best estimates he could provide. He said medium-grain varieties made up nearly 91% of the acreage with almost 40% of the acres planted to M-206. Short-grain acreage declined as a consequence of price. Of the short grains, Koshihikari has become favored over Akitakomachi. Long-grain production represents less than 3% of California's acreage. The unusually dry conditions and lower than normal snowpack suggests the acreage will decline from 530,000 to 500,000 acres. Final water decisions will be determined in April when the snowpack is measured.

Louisiana data were presented by Johnny Saichuk. He said acreage had declined sharply from around 530,000 acres in 2010 to 412,000 in 2011 due mainly to a shift in acreage in northeast Louisiana from rice to corn and soybeans. High prices for these two crops countered by lower than desirable rice prices has some growers switching from rice to soybeans and corn, especially in the northeastern part of the state. Medium-grain varieties made up about 10% of the acreage, a figure he expected to drop in 2012. Hybrid varieties (both Clearfield and traditional) made up 24% of the acres and 65% of the acres were planted to Clearfield types. CL151 was planted on 29% of the acres, followed by CLXL745 at 15% and CL111 at 11%. He said acreage in 2012 would likely be between 400,000 and 420,000.

Tim Walker presented the Mississippi information in place of Nathan Buehring who could not attend because of an illness in the family. Walker said the 2010 crop was the fourth largest ever in Mississippi, but the 2011 was one of the shortest at 153,000 acres with 70% devoted to Clearfield varieties. Clearfield hybrids made up 38% of the acreage with another 7% of non-Clearfield hybrids for a total of 45% of the acres. CL151 and CL111 dominated the remaining acres with 20 and 12%, respectively, planted to them. Walker said he anticipates the 2012 crop to be one of the shortest ever down to the allotment days at 75,000 to 85,000 acres. Problems with heat, sterility and better commodity prices for corn and soybeans are all contributing to the decline.

Missouri's report was presented by Donn Beighley. Beighley said the 2010 crop had been the largest ever at 244,000 acres contrasting sharply with the 115,000 acres in 2011. The dramatic decline was due mostly to environmental conditions; flooding of land resulting from blowing up a protection levee along the Mississippi River to relieve pressure on communities north of them and cool temperatures at planting time. Major varieties grown in 2011 were Wells at 27%, CL111 at 15%, and the hybrids as a group at 28%. For 2012 he expects rice acreage to increase to 175,000 acres with more conventional variety acres being planted than seen in previous years.

The Texas report was provided by Ted Wilson with additional comments made by Garry McCauley. Wilson said in 2010 there were about 187,000 acres of rice planted in Texas producing one of the most disappointing yields at 6,680 pounds per acre combined first and second crop. Only 3% of the acreage was planted to medium-grain varieties. In 2011, acreage dropped slightly to 181,000 while yields improved to 7,677 pounds per acre combined first and second crop. Leading varieties in 2011 were Presidio, CLXL745, and Cheniere at 23, 17, and 11%, respectively. The outlook for 2012 appeared bleak. Depending on a ruling from the Lower Colorado River Authority, water for rice culture in the area southwest of Houston could be severely curtailed. If as expected this happens, acreage in Texas will decrease by 60,000 to 80,000 acres resulting in a crop of 100,000 to 120,000 acres. Garry McCauley commented that in recent years his date of planting study has shown that every week delay in planting beyond March 6 resulted in a decrease of 190 pounds per acre. Heat and drought conditions are the predominant factors affecting the rice crop in Texas.

Submitted by
Johnny Saichuk

Industry Committee

The Rice Technical Working Group Industry Committee again held a successful luncheon at the 34th RTWG meetings in Hot Springs, Arkansas, on Tuesday, February 28, 2012. 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.

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The Industry Committee would like to thank Dr. Karen Moldenhauer, Chairman, Local Arrangements Committee, for her invaluable assistance in coordinating the luncheon. The Industry Committee looks forward to again hosting a luncheon at the 35th RTWG meetings in Louisiana in 2014.

Submitted by
Frank Carey

2010 Arkansas Harvested Rice Acreage Summary

COUNTY/ PARISH	2009 Acreage	2010 Acreage	MEDIUM GRAIN			LONG GRAIN							
			Bengal	Jupiter	Others	Cheniere	CL131	CL151	Francis	RiceTec CLXL729	Rice Tec CLXL745	Wells	Others
Arkansas	113,149	124,854	4,955	7,146	1,525	12,719	10,123	10,253	29,851	3,504	18,170	18,949	7,657
Ashley	14,968	22,004	0	0	0	0	703	7,562	0	2,198	7,826	2,440	1,275
Chicot	36,910	51,044	399	0	0	6,906	1,995	9,566	460	2,609	14,682	4,502	9,924
Clay	77,262	92,421	6,076	533	373	295	590	36,869	1,081	5,309	23,105	6,882	11,307
Craighead	79,299	92,146	7,833	1,280	979	8,309	0	38,431	472	755	13,125	15,486	5,477
Crittenden	37,391	48,374	5,172	170	0	0	0	4,753	0	256	11,499	25,196	1,329
Cross	90,169	100,305	4,698	653	1,958	0	2,463	36,549	5,615	6,600	17,141	17,141	7,487
Desha	34,613	50,778	5,214	345	517	21,076	2,082	6,245	4,319	1,457	2,810	6,661	52
Drew	12,761	16,658	631	0	0	1,092	6,913	750	0	2,707	3,342	0	1,223
Faulkner	1,742	2,755	0	0	0	0	529	0	174	317	951	320	463
Greene	72,790	85,734	5,142	0	0	4,242	509	32,321	2,630	9,671	25,874	3,648	1,697
Independence	8,750	13,340	509	0	0	0	0	5,530	0	2,540	4,760	0	0
Jackson	89,485	108,209	22,304	4,577	1,235	784	653	21,820	131	20,644	16,463	10,583	9,015
Jefferson	69,668	85,137	1,450	0	483	11,997	0	16,917	1,554	6,905	23,563	7,682	14,587
Lafayette	3,089	4,859	0	0	0	0	0	0	0	0	243	63	4,553
Lawrence	105,967	119,377	11,173	1,501	2,501	10,225	5,974	38,947	0	2,528	27,113	9,076	10,340
Lee	25,951	34,503	3,183	95	0	2,437	70	7,589	2,854	1,706	5,535	10,930	104
Lincoln	30,785	35,188	1,442	0	0	3,678	0	443	5,959	0	7,662	12,974	3,031
Lonoke	79,914	93,576	4,383	3,481	516	12,506	5,569	5,764	2,345	12,310	28,529	12,017	6,155
Miller	1,530	3,785	849	0	0	0	0	0	0	0	147	38	2,751
Mississippi	44,462	53,196	390	0	0	2,799	0	10,878	0	2,376	11,036	23,604	2,112
Monroe	57,066	73,638	6,003	1,215	0	13,180	0	6,738	11,995	1,481	15,994	12,958	4,073
Phillips	32,783	46,805	374	101	144	15,154	9,170	6,805	4,006	1,400	7,770	290	1,593
Poinsett	122,004	145,950	30,978	1,025	342	3,173	793	51,091	14,915	4,125	10,948	23,483	5,077
Prairie	62,656	67,715	10,378	3,284	0	9,202	2,931	7,293	2,181	6,748	15,473	4,908	5,317
Pulaski	3,624	5,110	0	0	0	2,095	0	1,047	0	0	0	1,865	102
Randolph	36,170	42,939	4,769	1,160	0	3,084	45	10,795	0	2,222	14,695	680	5,488
St. Francis	42,921	50,992	10,898	0	0	2,961	0	5,369	4,416	0	50	22,581	4,717
White	12,721	17,189	1,902	0	88	1,932	0	1,191	0	1,715	5,596	2,852	1,914
Woodruff	51,908	63,401	2,459	0	48	5,606	0	13,145	10,761	11,406	7,861	5,284	6,830
Others	5,497	7,796	268	0	0	1,261	210	1,116	382	1,157	381	1,433	1,588
Unaccounted	0	25,224											0
2010 Total		1,785,000	153,830	26,566	10,708	156,713	51,323	395,777	106,102	114,647	342,346	264,527	162,461
2010 Percent		100.00%	8.62%	1.49%	0.60%	8.78%	2.88%	22.17%	5.94%	6.42%	19.18%	14.82%	9.10%
2009 Total	1,458,005		182,768	11,657	28,584	78,455	53,704	172,488	140,345	220,733	118,461	240,778	210,030
2009 Percent	100.00%		12.54%	0.80%	1.96%	5.38%	3.68%	11.83%	9.63%	15.14%	8.12%	16.51%	14.41%

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

[2] - Other varieties: AB647, Bowman, Catahoula, CL111, CL142AR, CL161, CL171 AR, CL181AR, Cocodrie, Cypress, Della, Dellrose, Jazzman, JES, Koshihikari, Neptune, Nortai, Pirogue, RiceTec CLXL730, RiceTec CLXL746, RiceTec CLXL751, RiceTec XL723, Spring, Taggart, Templeton, and Trenasse.

[3] - Other counties: Clark, Conway, 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.

2011 ARKANSAS HARVESTED RICE ACREAGE SUMMARY

COUNTY/ PARISH	2010 Acreage	2011 Acreage	MEDIUM GRAIN			LONG GRAIN							
			Jupiter	CL261	Others	CL111	CL142 AR	CL151	Rice Tec CL XL729	Rice Tec CL XL745	Rice Tec XL723	Wells	Others
Arkansas	124,854	90,106	7,837	3,780	4,354	4,539	6,893	4,792	4,475	22,296	10,172	4,557	16,412
Ashley	22,004	9,476	0	0	0	290	872	195	1,459	3,972	0	2,654	33
Chicot	51,044	26,981	429	191	0	943	872	175	837	17,450	2,539	2,809	735
Clay	92,421	59,946	8,429	2,862	0	3,231	6,237	12,578	225	18,111	676	2,254	5,341
Craighead	92,146	65,831	13,029	5,980	0	1,050	5,735	16,873	0	13,794	709	1,145	7,518
Crittenden	48,374	22,215	2,618	1,711	0	517	573	1,152	409	10,800	757	3,416	264
Cross	100,305	73,681	5,573	5,573	0	3,038	12,295	15,518	1,626	19,389	1,939	3,315	5,416
Desha	50,778	16,970	2,961	1,042	0	282	116	1,730	2,550	5,403	1,516	71	1,301
Drew	16,658	7,921	384	198	0	558	609	1,003	316	1,894	0	414	2,544
Faulkner	2,755	2,412	194	0	0	165	146	227	0	0	756	0	924
Greene	85,734	57,797	4,018	2,222	0	1,298	5,389	5,701	14,390	23,179	0	0	1,601
Independence	13,340	6,382	1,505	146	0	48	18	2,929	536	904	104	87	104
Jackson	108,209	68,905	21,799	4,870	335	363	4,398	8,694	7,730	13,927	1,599	1,333	3,858
Jefferson	85,137	57,199	2,182	810	0	4,553	1,108	1,824	0	44,394	0	0	2,327
Lafayette	4,859	2,011	138	0	0	0	0	0	0	0	0	722	1,151
Lawrence	119,377	91,045	3,565	7,186	7,487	3,332	7,646	10,132	1,759	24,010	2,375	5,980	17,574
Lee	34,503	11,570	3,012	209	0	669	469	2,661	0	3,195	0	0	1,355
Lincoln	35,188	19,372	1,778	388	0	563	349	296	4,954	2,139	1,588	1,337	5,979
Lonoke	93,576	77,783	6,183	1,072	907	1,318	5,321	10,027	6,828	33,082	1,267	7,743	4,036
Miller	3,785	1,247	0	0	0	0	0	0	0	0	0	275	972
Mississippi	53,196	24,888	787	0	0	649	838	1,153	0	1,289	746	17,271	2,157
Monroe	73,638	42,512	3,779	2,390	904	1,572	2,216	3,584	933	14,291	1,231	4,104	7,505
Phillips	46,805	18,345	210	953	0	317	156	4,439	866	9,623	0	0	1,781
Poinsett	145,950	98,692	29,243	13,517	543	544	9,840	12,217	10,091	11,581	803	4,816	5,497
Prairie	67,715	53,244	12,181	1,200	759	813	766	3,112	8,155	13,311	1,559	1,619	9,770
Pulaski	5,110	4,375	0	304	0	0	411	869	0	0	1,162	0	1,630
Randolph	42,939	30,608	4,945	2,882	0	478	5,510	5,761	0	9,443	0	0	1,590
St. Francis	50,992	32,413	7,999	2,206	357	1,897	3,199	3,236	0	766	2,297	5,993	4,462
White	17,189	9,142	1,945	195	0	0	159	1,318	160	4,524	329	0	512
Woodruff	63,401	44,196	4,827	2,874	0	1,230	2,651	7,522	10,837	9,312	0	1,648	3,296
Others	5,497	5,919	0	599	0	139	313	331	0	879	1,477	245	1,936
Unaccounted	27,524	21,818											21,818
2011 Total		1,155,000	151,551	65,359	15,644	34,394	85,106	140,049	79,137	332,955	35,601	73,809	141,396
2011 Percent		100.00%	13.12%	5.66%	1.35%	2.98%	7.37%	12.13%	6.85%	28.83%	3.08%	6.39%	12.24%
2010 Total	1,785,000		182,768	11,657	28,584	78,455	53,704	172,488	140,345	220,733	118,461	240,778	210,030
2010 Percent	100.00%		12.54%	0.80%	1.96%	5.38%	3.68%	11.83%	9.63%	15.14%	8.12%	16.51%	14.41%

[1] - Harvested acreage. Source: National Agricultural Statistics Service and FSA.
[2] - Other varieties: AB647, Bowman, Catahoula, CL131, CL161, CL171 AR, CL181 AR, Cheniere, Cypress, Della, Dellrose, Drew, Francis, Jackson, Jazzman, JES, Koshihikari, Neptune, Nortai, Priscilla, Rice Tec CL XL746, Taggart, and Templeton.
[3] - Other counties: Clark, Conway, Crawford, Hot Spring, Little River, Franklin, 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.

RICE PRODUCTION OF CCRRF VARIETIES

	2010			2011		
Variety	Seed Seed Acres[1]	Estimated Acres[2]	Percentage	Seed Acres[1]	Estimated Acres[2]	Percentage
M-104	762	18640	3.5%	712	17910	3.4%
M-105	9	9	0.0%	429	430	0.1%
M-202	3658	90460	17.0%	2662	70490	13.3%
M-205	4762	116460	21.9%	4602	105350	19.9%
M-206	8625	210940	39.6%	11086	241500	45.6%
M-208	433	5560	1.0%	314	6500	1.2%
M-401	1453	35540	6.7%	1650	36800	6.9%
M-402	212	5190	1.0%	152	4400	0.8%
Medium Grain	19914	482799	90.6%	21607	483380	91.2%
S-102	392	9590	1.8%	435	8500	1.6%
Calmochi-101	784	19170	3.6%	1,089	18000	3.4%
Calamylow-201	105	101	0.0%	3	60	0.0%
Calhikari-201	16	1600	0.3%	65	1800	0.3%
Koshihikari	NA	11400	2.1%	NA	10400	2.0%
Akitakomachi	NA	3500	0.7%	NA	2000	0.4%
Short Grain	1297	45361	8.5%	1592	40760	7.7%
L-206	118	2000	0.4%	123	3020	0.6%
A-201	198	1200	0.2%	227	1500	0.3%
A-301	234	800	0.2%	93	800	0.2%
Calmati-201	0	40	0.0%	40	40	0.0%
Calmati-202	31	750	0.1%	31	600	0.1%
Long grain	581	4790	2.7%	514	5960	1.1%
Total	21792	532950		23713	530100	

[1] California Crop Improvement acreage of all classes of certified seed for CCRRF varieties.

[2] Acreage estimated based on seed production of these varieties assuming they account for 95% of California-planted acres reported by NASS.

The remaining 5% are proprietary or older CCRRF varieties not in seed production.

2010 LOUISIANA RICE ACREAGE BY VARIETY SUMMARY

Parish	2010	MEDIUM GRAIN		LONG GRAIN									
	Acreage	Jupiter	Neptune	Catahoula	Cheniere	CL111	CL131	CL151	CL161	CLXL729	CLXL745	Cocodrie	Other[1]
Acadia	84,299	6,185	2,535	726	4,360	7,271	1,891	32,708	7,261	2,908	7,269	4,289	6,896
Allen	14,483	100	0	0	0	1,393	0	8,681	0	567	3,130	322	290
Avoyelles	14,283	1,100	0	325	4,640	575	0	4,050	463	0	1,895	1,032	203
Beauregard	1,663	0	0	0	85	130	0	125	0	1,043	280	0	0
Bossier	50	0	0	0	0	0	0	0	0	0	0	0	50
Caddo	105	0	0	0	0	0	0	0	0	0	0	0	105
Calcasieu	14,072	0	0	141	971	507	0	2,899	0	4,081	3,954	338	1,181
Caldwell	1,138	0	0	0	0	0	0	0	0	0	0	0	1,138
Cameron	13,456	0	543	127	877	457	0	2,617	0	3,685	3,570	305	1,275
Catahoula	9,157	0	0	2,700	600	296	1,110	1,000	850	0	1,500	301	800
Concordia	16,580	1,500	0	1,050	1,700	600	4,150	2,000	3,500	0	2,000	0	80
East Carroll	15,655	0	0	11,743	0	521	521	522	0	0	0	1,565	783
Evangeline	47,590	2,800	0	0	2,310	5,600	0	12,430	129	9,155	11,456	3,510	200
Franklin	2,594	0	0	0	0	0	0	2,594	0	0	0	0	0
Iberia	774	0	0	0	317	140	137	0	0	0	0	0	180
Jeff Davis	82,612	4,210	1,725	740	4,452	7,420	1,134	33,390	7,420	2,968	8,588	4,377	6,188
Lafayette	3,240	550	225	0	0	560	0	1,404	0	66	110	200	125
Madison	10,501	0	0	731	5,250		264	630	0	0	0	3,626	0
Morehouse	58,735	2,200	800	0	0	0	9,000	15,235	8,000	8,500	9,500	2,000	3,500
Natchitoches	3,817	0	0	0	0	0	0	0	0	0	0	0	3,817
Ouachita	5,916	1,121	600	364	255	0	0	1,684	0	1,303	0	500	89
Pointe Coupee	4,077	0	0	0	2,037	0	350	1,020	0	0	0	0	670
Rapides	10,996	1,100	0	0	5,539	323	539	2,667	323	0	404	101	0
Red River	401	0	0	0	0	0	0	0	0	0	401	0	0
Richland	9,588	100	0	4,290	0		575	2,924	0	0	144	0	1,555
St. Landry	28,961	863	376	1,072	2,925	1,969	3,330	9,117	4,402	492	1,853	1,716	846
St. Martin	4,537	0	0	0	1,054	615	0	0	439	589	0	428	1,412
Tensas	3,936	0	0	540	530	0	295	1,486	0	0	765	100	220
Vermilion	61,238	1,579	238	168	4,974	5,293	921	27,934	12,208	530	550	1,848	4,995
West Carroll	4,798	0	0	290	0		208	1,000	0	1,600	500	400	800
2010 Total	529,252	23,408	7,042	25,007	42,876	33,670	24,425	168,117	44,995	37,487	57,869	26,958	37,398
2010 Percent	100	4.42	1.33	4.72	8.10	6.36	4.62	31.77	8.50	7.08	10.93	5.09	7.07

[1] Other varieties include CL261, Hidalgo, Jazzman, Trenasse, Wells, and XL723.

2011 LOUISIANA RICE ACREAGE BY VARIETY SUMMARY

Parish	2011	MEDIUM GRAIN		LONG GRAIN							
	Acreage	CL261	Jupiter	Cheniere	CL111	CL151	CL 161	CLXL729	CLXL745	Cocodrie	Other[1]
Acadia	76,421	3,414	5,178	6,150	8,073	30,962	3,940	3,153	2,522	3,784	9,245
Allen	14,935	271	1,084	0	700	5,500	0	2,330	4,200	400	450
Avoyelles	12,746	0	1,100	2,900	607	2,949	311	0	3,223	1,048	608
Beauregard	2,097	0	0	76	0	140	160	406	1,290	25	0
Bossier	50	0	0	50	0	0	0	0	0	0	0
Caddo	0	0	0	0	0	0	0	0	0	0	0
Calcasieu	8,542	891	200	211	281	1,967	0	1,054	2,670	492	776
Caldwell	550	0	0	0	0	550	0	0	0	0	0
Cameron	15,382	388	775	662	1,322	4,627	0	0	925	3,305	3,378
Catahoula	2,208	0	0	375	623	730	0	0	0	350	130
Concordia	11,142	0	90	470	3,395	300	0	0	3,600	300	2,987
East Carroll	2,530	0	0	0	0	0	0	120	860	0	1,550
Evangeline	40,849	300	3,519	500	3,000	7,300	200	11,891	9,639	225	4,275
Franklin	121	0	0	0	0	121	0	0	0	0	0
Iberia	754	0	0	0	0	40	138	0	0	0	576
Jeff Davis	79,510	3,383	5,220	6,100	8,133	29,557	4,066	4,744	6,777	6,000	5,530
Lafayette	4,050	220	328	300	400	1,586	0	250	400	250	316
Madison	6,412	0	1,212	1,200	1,000	0	0	0	0	1,500	1,500
Morehouse	30,520	1,049	2,449	0	6,000	0	0	522	17,000	500	3,000
Natchitoches	2,460	136	1,060	0	101	0	0	0	506	0	657
Ouachita	4,950	0	700	500	0	1,150	0	0	300	600	1,700
Pointe Coupee	0	0	0	0	0	0	0	0	0	0	0
Rapides	8,872	220	30	5,557	500	250	300	0	0	0	2,015
Red River	430	0	0	0	34	0	0	0	172	0	224
Richland	5,694	0	0	0	940	1,408	0	0	219	0	3,127
St. Landry	21,810	354	1,185	4,034	1,520	6,608	3,588	487	2,595	649	790
St. Martin	4,547	0	0	1,640	275	305	430	142	570	340	845
Tensas	1,140	0	0	0	505	0	0	0	120	0	515
Vermilion	51,441	3,361	1,117	4,526	6,192	24,040	2,860	2,254	1,352	1,298	4,441
West Carroll	2,964	0	0	0	80	0	0	1,327	1,557	0	0
2011 Total	413,127	13,987	25,247	35,251	43,681	120,090	15,993	28,680	60,497	21,066	48,635
2011 Percent	100	3.39	6.11	8.53	10.57	29.07	3.87	6.94	14.64	5.10	11.77

[1]Other varieties include Caffey, Catahoula, CL131, CL142, CL181, Cypress, Hidalgo, Jazzman, Jazzman 2, Neptune, Sabine, XL723, XP753, XP754, XP756.

2010 Mississippi Rice Acreage Survey

County	Clearfield 111	Clearfield 131	Clearfield 151	Clearfield XL 729	Clearfield XL 745	Cocodrie	Cheniere	Wells	XL 723	Other[1]	2010 Acreage	2009 Acreage
Bolivar	3,770	8,203	26,801	6,419	7,021	18,575	2,730	0	3,603	1,178	78,300	72,000
Coahoma	2,333	3,600	3,401	2,979	1,737	7,100	844	1,142	1,067	622	24,825	18,630
Grenada	0	0	100	0	0	100	0	0	0	0	200	200
Humphreys	306	1,253	2,752	656	753	2,670	200	0	97	213	8,900	4,060
Issaquena	100	0	1,373	0	850	833	0	0	0	0	3,156	1,713
Leflore	680	2,400	8,295	80	945	7,430	2,430	0	0	500	22,760	17,525
Panola	0	0	584	0	0	6,000	0	0	0	0	6,584	4,800
Quitman	433	2,213	8,823	506	540	9,521	0	0	143	821	23,000	20,415
Sharkey	0	0	821	0	0	2,219	225	0	0	150	3,415	1,800
Sunflower	1,512	3,687	9,632	5,705	6,042	19,514	2,550		2,673	685	52,000	38,268
Tallahatchie	1,931	1,931	1,738	1,931	195	11,588	0	0	0	0	19,314	14,080
Tunica	505	1,205	3,893	6,643	7,560	3,635	0	0	5,123	326	28,890	25,667
Washington	1,072	4,288	11,793	715	715	11,793	2,859	715	357	1,429	35,736	29,630
2010 Total Acres	12,642	28,780	80,006	25,634	26,358	100,978	11,838	1,857	13,063	5,924	307,080	
2010 Percent	4.1	9.4	26.1	8.3	8.6	32.9	3.9	0.6	4.3	1.9	100	
2009 Total Acres	0[2]	48,729	65,879	10,442	7,256	94,097	7,162	1,335	3,692	9,565		248,788
2009 Percent	0.0	19.5	26.4	4.2	2.9	37.7	2.9	0.5	1.5	1.4		100

[1] Other includes varieties not listed on the column headings.

[2] Does not mean this variety was not grown in 2009. It was placed in the Other category due to a limited amount of acres planted.

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

2011 Mississippi Rice Acreage Survey

County	Clearfield 111	Clearfield 151	Clearfield XL 729	Clearfield XL 745	Cocodrie	Cheniere	XL 723	Other[1]	2011 Acreage	2010 Acreage
Bolivar	7,264	12,003	6,012	9,322	10,913	1,084	2,938	1,186	50,722	78,300
Coahoma	2,073	2,897	878	1,159	2,588	348	749	678	11,370	24,825
Desoto	0	193	0	0	142	0	0	0	335	1,156
Grenada	0	167	0	0	161	0	0	0	328	200
Holmes	0	109	0	0	83	0	0	42	234	1,461
Humphreys	382	412	126	687	323	0	0	66	1,996	8,900
Issaquena	0	227	0	0	542	0	0	111	880	3,156
Leflore	754	1,156	1,067	2,177	952	76	302	270	6,754	22,760
Panola	850	1,698	142	452	2,154	0	87	0	5,383	6,584
Quitman	1,331	2,661	248	412	1,232	325	151	0	6,360	23,000
Sharkey	0	232	0	0	461	0	0	162	855	3,415
Sunflower	1,152	1,679	5,016	6,744	1,891	825	1,468	576	19,351	52,000
Tallahatchie	978	2,246	292	540	1,849	249	103	0	6,257	19,314
Tate	0	348	0	0	521	0	0	0	869	934
Tunica	563	891	5,881	9,035	1,224	213	4,533	836	23,176	28,890
Washington	2,883	4,894	2,178	3,789	3,768	0	589	753	18,854	35,736
Yazoo	490	947	0	0	836	0	0	0	2,273	1,907
2011 Total Acres	18,720	32,760	21,840	34,317	29,640	3,120	10,920	4,680	155,997	
2011 Percent	12.0	21.0	14.0	22.0	19.0	2.0	7.0	3.0	100	
2010 Total Acres	12,814	81,572	25,941	26,878	102,825	12,189	13,439	5,938		312,538
2010 Percent	4.1	26.1	8.3	8.6	32.9	3.9	4.3	1.9		100

[1] Other includes CL 142AR, CL 152, XL 753, Sabine, Rex, and other varieties not listed on the column headings.

[2] Does not mean this variety was not grown in 2010. It was placed in the Other category due to a limited amount of acres planted.

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

Missouri Rice Acreage

The 2010 Missouri rice acreage was certified at 244,000 A, a 14% increase over 2005 when we set the previous acreage record and 24,000 over predicted acres. In 2010, the variety distribution was (50 – 70%) Clearfield (CL151, CL131, CL111, CL171, CL hybrids); (33 – 50%) hybrids (RTCLXL 745, RTCLXL 729, RTXL 723); (24%) Wells, Cheniere, Trenasse, Jupiter, Templeton, Francis. The state average was 140 bu/A (6300 lb/A) with a very wide range (75 to 217 bu/A), conventional varieties (125 to 180 bu/A), hybrids (165 to 217 bu/A), and Clearfield varieties (75 to 180 bu/A).

Missouri acreage in 2011 was approximately 115,000 acres with yields ranging from 140 to 210 bu/A, with a state average of 150 bu/A (6750 lb/A). The major varieties are Wells (27%), Templeton (2%), Taggart (5%), CL111 (15%), CL142-AR (5%), CL151 (9%), CL261 (2%), Jupiter (7%), and hybrids (28%). The acreage was a decrease of 54% from 2010 acres.

For 2012, we expect rice acreage to increase to 175,000 acres with more conventional variety acres being planted than seen in previous years.

2010 Texas Rice Acreage by Variety (Acreage)

Variety Acres By County

County	2009	2010	Acreage	% MC	Long Grain															Medium		Other
	Acreage	Acreage	Change	Ratooned	Presidio	CL111	CL151	Cheniere	Cocodrie	CLXL745	XL723	Catahoula	XL729	Milagro	Texmati	Sierra	Jasmine 85	XP729	Wells	Neptune	CL261	
East Zone																						
Brazoria	16452	17366	5.60%				4342															13024
Chambers	1262	11191	786.80%	11		3357		3357				4476										
Galveston	1527	463	-69.70%	0																		
Hardin	460	504	9.60%																			
Jefferson	13749	17264	25.60%	65		5076				3349			3332							4765	725	
Liberty	7227	7812	8.10%	72		1555				6257												
Orange																						
East Total	40677	54600	34.20%	49		10171	4422	3419		9783		4558	3393							4852	738	13263
Northwest Zone																						
Austin	1036	1111	7.20%	28				198	913													
Colorado	31587	32116	1.70%	83	1381	3982	5749	8382	289	867	7676	964		1381		385				289		771
Fort Bend	5589	4857	-13.10%	26	277	1141			962	665												1812
Harris																						
Lavaca	1057	1401	32.50%	54			357		745			298										
Robertson																						
Waller	6379	6288	-1.40%	92	553	497	786		799	1327	2327											
Wharton	43064	45024	4.60%	53	10356	4863	8374	3782	4007	2206	3512	5178		1171		135		946		225		270
Lamar	215																					
NorthWest Total	88927	90797	2.10%	64	12567	10483	15267	12362	7715	5066	13514	6440		2552		520		946		514		2853
Southwest Zone																						
Calhoun	2154	2177	1.10%	82					1141		1036											
Jackson	11350	11042	-2.70%	70	3776			1458	5013			806										
Matagorda	24594	25103	2.10%	16	3765				2510			1255			2510	1255	1255					12552
Victoria	1771	1922	8.50%	100	1922																	
Cameron																						
SouthWest Total	39869	40244	0.90%	39	9461			1458	8662		1036	2060			2509	1255	1255					12549
Northeast Zone																						
Bowie	517	881	70.40%	0				440											440			
Hopkins																						
Red River																						
NorthEast Total	517	881	70.40%	0				441											441			
State Total	169990	186522	9.70%	54	22146	20578	19711	17709	16465	14749	14626	13045	3349	2565	2523	1785	1262	951	442	5307	729	28578

2011 Texas Rice Acreage by Variety

Variety Acres By County (Values for counties are surveyed acreages)

County	2010 Acreage	2011 Acreage	Acreage Change	% MC Ratooned	Long Grain																Medium		Other*
					PRES	CLXL	CL151	CHEN	XL723	CATA	COCO	SIER	CLXL	TEXM	CL111	RISO	JASM	JAZZ	CLXP	XP753	NEPT	CL261	
East Zone																							
Brazoria	17366	17604	1.4%																				
Chambers	11191	11555	3.3%		728			4668		4668								1109				370	
Galveston	463	951	105.4%					951															
Hardin	504	313	-37.9%																				
Jefferson	17264	16949	-1.8%			7390							1830				1729		847		5169		
Liberty	7812	7030	-10.0%	85		5315	1561												148				
Orange																							
East	**54600**	**54402**	**-0.4%**	**85**	**1086**	**18944**	**2328**	**8379**		**6961**			**2729**				**2578**	**1654**	**1484**		**7708**	**552**	
Northwest Zone																							
Austin	1111	1166	5.0%	100	1166																		
Colorado	32116	34281	6.7%	80	5142	4936	5725	3120	7268			583	686						34		2023		4799
Fort Bend	4857	4869	0.2%	78	1208	623		969	565		565												940
Harris																							
Lavaca	1401	1280	-8.6%	0																	1280		
Robertson																							
Waller	6288	6051	-3.8%	100		726	157		4012		448				551					121			30
Wharton	45024	41656	-7.5%	100	7790	7082	11330	3957	1791	2916	1583				1250						3624		333
Lamar		204																					
NorthWest	**90797**	**89507**	**-1.4%**	**90**	**15335**	**13393**	**17247**	**8062**	**13662**	**2922**	**2601**	**584**	**687**		**1804**				**34**	**121**	**6941**		**6114**
Southwest Zone																							
Calhoun	2177	2249	3.3%	42	578					232													1439
Jackson	11042	11739	6.3%	43	2900	1010		2500			1749												3569
Matagorda	25103	21479	-14.4%	39	12393	430	838					2663		2320	430	2040					387		
Victoria	1922	1851	-3.7%	2	1851																		
Cameron																							
SouthWest	**40244**	**37318**	**-7.3%**	**39**	**17717**	**1439**	**838**	**2499**		**232**	**1749**	**2662**		**2319**	**430**	**2039**					**387**		**5007**
Northeast Zone																							
Bowie	881	429	-51.3%	0				429															
Hopkins		105																					
Red River																							
NorthEast	**881**	**534**	**-39.4%**	**0**				**534**															
State	**186522**	**181761**	**-2.6%**	**77**	**37509**	**30570**	**21792**	**18439**	**15151**	**8685**	**4828**	**3607**	**2796**	**2578**	**2478**	**2267**	**1921**	**1232**	**1143**	**134**	**13871**	**411**	**12347**

Acreage Source: USDA/CFSA Certified Acreage.

RECOMMENDATIONS OF THE PANELS

BREEDING, GENETICS, AND CYTOGENETICS

W.G. YAN, Chair; J. OARD, Chair - Elect (2014); D. BEIGHLEY; Z. CHEN; N. CHOU; H. DU; G. EIZENGA; T. GUO; K. GORDON; C. HARPER; S. HUNG; Y. JIANG; K. JOHNSON; D. KANTER; Y. LI; YL LIU; A. MCCLUNG; K. MOLDENHAUER; J. OKAMURO; X. PAN; S. PINSON; R. RASMUSSEN; P. SANCHEZ; B. SCHEFFLER; X. SHA; Q. SHAO; R. TABIEN; H. WANG; J. WANG; L. WILSON; W. XIAO; P. XU; Z. YAN; and Z. ZHANG; 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 economics of hybrid rice seed production is needed. Genetic control of efficiency of solar energy conversion, including photosynthetic efficiency, respiration losses, translocation rates, source-sink relationships, plant morphology, chlorophyll characteristics, etc., must be explored to determine if such factors can benefit the development of superior yielding cultivars. Understanding the genetic, epigenetic, physiological, morphological, and environmental factors that influence ratoon crop yield is important for cultivar improvement. Genetic stocks and new rice accessions that have current or as-yet-unanticipated value should be preserved by entering them into the newly established Genetic Stocks - Oryza (GSOR) collection or the USDA Germplasm Resources Information Network (GRIN). Materials in the GSOR will be accessible through GRIN and will be freely available to all interested researchers.

Molecular Genetics and Genetic Engineering
Molecular genetic studies have accelerated rapidly in rice due to the favorable qualities of this species, including its small genome size, ease of transformation, and availability of genome sequence information. 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 relevant to U.S. breeding efforts. Genetic engineering is considered an emerging tool that will complement traditional methods for germplasm and cultivar development. Genes for herbicide, insect, and disease resistance and nutritional quality 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, grain quality, disease resistance, and stress tolerance should be transferred into elite lines or directly into commercial cultivars.

Response to Environment and Changing Climate
Superior-yielding, widely adapted cultivars need to be developed that have increased tolerance to low soil nutrients, water availability, and temperatures during seedling emergence and stand establishment; greater tolerance to extremes in temperatures during flowering and grain filling stages that reduce grain and milling yields; greater tolerance to saline or alkaline conditions; plant types with the capability of maximizing light energy use, express higher metabolic efficiencies; and possess increased water and nitrogen use efficiency. However, because of the geographical and climatic diversity among rice-producing areas in the United States, a need still exists to develop cultivars for specific areas. New cultivars and advanced experimental lines should be tested for reaction or response to registered/experimental pesticides which may be widely used in weed, disease, or insect control in order to determine whether they are tolerant or susceptible.

Hybrid Rice Research
Hybrid rice has proved its advantages on yield, disease resistances, and adaptation in the U.S. and received wide interests from growers, processers, and researchers. Research should be conducted for creating male sterile germplasm and elucidating genetic control of male sterility/fertility, outcrossing characteristics, general combining ability (GCA), and special combining ability (SCA) using the most updated genomic technology. The USDA rice germplasm world collection contains about 20,000 accessions introduced from 116 countries, which provides the wide range of genetic diversity for distant crosses that is essential for yield heterosis. The achievements from genomic research should improve breeding efficiency for hybrid rice cultivars using molecular markers to assist selections of male sterile and restoring lines, elite outcrossing characteristics for effective production of male sterile lines and hybrid seeds, and GCA as well as SCA for maximum heterosis. Similarly with conventional cultivars, development of new hybrids that have high yield potential, improved resistance to diseases and insect pests, and have grain milling and cooking properties necessary to meet the needs of domestic and export markets is critical.

Resistance to Diseases and Insects
Intensive studies are required to develop cultivars resistant to economically important diseases and insects. Breeding for increased resistance to all known fungus races responsible for rice diseases blast (*Magnaporthe oryzae*), sheath blight (*Rhizoctonia solani*), aggregate sheath spot (*Rhizoctonia oryzae sativae*), and stem rot (*Sclerotium oryzae*) should be emphasized with the objective of obtaining highly resistant cultivars within all maturity groups and grain types. Efforts should be made to develop cultivars with greater field 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 (*Burkholderia glumae*), bakanae (*Gibberella fujikuroi*), leaf scald, leaf smut, "pecky rice", and the physiological disease straighthead should be continued. A continuing emphasis on germplasm resources for resistance to these diseases in various cultural systems is needed. Breeding for insect resistance to rice water weevil (*Lissorhoptrus oryzophilus* (Kuschel)), rice stink bug (*Oebalus pugnax* (Fabricius)), grape colaspis, sugarcane borer (*Didatrea saccharalis* (F.), Mexican rice borer (*Eoreima loftini* (Dyar), and stored grain insects is also encouraged.

***Oryza* Species**
Other species of *Oryza* may contain the needed resistance to important diseases, insects, and environmental stresses as well as yield and grain cereal/chemical qualities that have been lost during domestication of *O. sativa*. Evaluation of these species and the transfer of desirable factors into commercial cultivars should be pursued. As germplasm lines are recovered from interspecific crosses, their cooperative evaluation for disease resistance, insect resistance, and other traits important in commercial production would be essential for their application to the U.S. rice industry. 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 made to develop cultivars with enhanced fertilizer use efficiency.

Milling, 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, nutritional value, and health benefits. 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, mineral composition, cooking properties, and resistant starch. An industry wide effort should be made to obtain feedback on our breeding effectiveness of grain quality improvements from export markets. There is increased interest in developing rice cultivars to target specialty markets, such as soft cooking rice, aromatics, waxy types, Jasmine and Basmati types, and Japanese premium quality rice. Research efforts need to be directed toward determining quality traits associated with various specialty rice varieties, analytical methods for evaluation, genetic variability, influence of environmental variables on character expression, and factors associated with consumer acceptance.

Development and Distribution of 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 for sustainable food production by increasing genetic diversity and decreasing production vulnerability. All breeders and geneticists must make continuing efforts to preserve and broaden the world collection of rice germplasm. 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 data. Increased efforts are also needed to evaluate and maintain all entries in the active, working collection and to enter all descriptive data into GRIN, the USDA Rice World Collection public database.

Germplasm Evaluation and Enhancement

Efforts should be made to develop relatively adapted, broad-based gene pools having a diversity of phenotypic and genotypic traits based on genetic understanding of the World Collection. Characteristics include components required for increasing yields of cultivars and/or hybrids, such as straw strength, seed size, panicle size, seed set, and panicle number per plant. Other useful characteristics such as bioenergy production from rice by-products may be incorporated into existing or new gene pools as appropriate when such germplasm is identified during evaluation efforts. Genetic male sterility and/or gametocides that are essential for hybrid rice may facilitate these efforts. Development of indica germplasm with high yield and grain quality standards similar to U.S. cultivars should be pursued. The core strategy is an effective way to evaluate large germplasm collections phenotypically and genotypically. A core subset of about 10% of the USDA World Rice Collection has been established which provides a workable size for genetic structure analysis and a rich gene pool for valuable gene exploration. A mini-core subset representing 1% of the USDA World Rice Collection has been established and its modest size will facilitate extensive phenotyping and deep sequence genotyping. Comprehensive evaluations of the core and mini-core subsets for genome-wide association studies should be pursued by cooperative federal, state, and industry efforts.

Training of New Rice Breeders

There is concern about the decreasing number of students interested in pursuing degrees in plant breeding. Who will replace the current and retiring U.S. rice researchers in the future? New efforts to develop and train our next generation of scientists at all levels needs 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. Interaction with K-12 students, teachers, science curriculum coordinators, and advisors is strongly urged as a means to encourage students to select plant breeding-related fields of study for their college degrees. Interaction with undergraduate students will be required to encourage them to continue their studies with higher degrees to become knowledgeable breeders and geneticists. In addition, 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 to adequately prepare the next generation of plant breeders and geneticists. Effort should be made to create opportunity for rice breeders to interact with breeders of other crops for information exchange.

ECONOMICS AND MARKETING

B. WATKINS, Chair; M. SALASSI, Chair – Elect (2014); F. BLOECHL; D. BROWN; E. CHAVEZ; N. CHILDS; B. COATS; B. CROSS; K. GLOVER; N. GUTIERREZ; T. HRISTOVKA; J. JIN; V. KAROV; T. OBORN; D. ROBERTS; and E. WAILES; Participants.

Supply/Production Research

Investigate water use practices in various rice production 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.

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

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

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

Evaluate the economic benefits of land forming (straight levees, zero grade) to rice production.

Policy, Demand, and Marketing Research
Evaluate potential impacts of the current round of 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.

Evaluate the performance of the rough rice futures market.

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

Evaluate the impacts of SPS (sanitary and phytosanitary) measures on U.S. rice trade.

PLANT PROTECTION

C. ROTHROCK, Chair; N. HUMMEL, Chair-Elect (2014); J. BEUZILIN, B. BLACKMAN, D. GROTH, C. HOLLIER, Y. JIA, S. KLANKA, A. MÉSZÀROS, Y. WAMISHE, and T. WILSON; 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, weed science, and molecular biology 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 oryzae* Cavara = *P. grisea* Sacc. (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 and *B. gladioli* Saddler. 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 causes 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 on the genetic makeup of blast including the composition of blast avirulence genes in blast nurseries in each state should be conducted to support existing and future research and extension programs, including breeding for improved resistance using major resistance genes.

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. Chemical and cultural management options for bacterial panicle blight need more research and intensive screening for higher levels of resistance is required.

6. Research on the molecular genetics of host/parasite interactions, including molecular characterization of the pathogen isolates, and their interaction mechanisms with 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. Research using Rep-PCR for *M. oryzae* and PCR based on rDNA for other pathogens, and pathogen critical pathogenicity factors and their interacting genes should be explored.

7. 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.

8. 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.

9. Molecular characterization of virulent blast races IE1k and IC1 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. An international blast differential system or monogenic lines or near isogenic lines with major blast resistance genes should be established to provide effective screening for useful blast resistance genes.

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

11. 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), *Colaspis louisianae*; 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); an exotic stink bug, *Oebalus ypsilongriseus* (DeGeer), found in Florida; sugarcane beetles, *Eutheola rugiceps* (LeConte); and billbugs, *Sphenopherous* spp.; 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 non-target organisms, c) compatibility with other agricultural chemicals, d) relationship between dosages and mortality, and e) proper timing, application, and formulation.

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

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

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

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

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

9. Monitor rice for possible introduction of exotic pests.

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

11. Strive to deliver research results and pest management recommendations to producers in a timely manner using methods that will lead to the adoption of recommended practices.

POSTHARVEST QUALITY, UTILIZATION, AND NUTRITION

R. BRYANT, Chair; S. LINSCOMBE, Chair-Elect (2014); A. BILLIRIS; J. TEAGUE, B. GRIGG; Y.J. WANG; P. COUNCE; J. STEWART; V. ANDAYA; K. GLOVER; V. MCNEELY; L. POPE; H. HUANG; S. PINSON; D. MCCASKILL; Q. SHAO; Z. PAN; E. CHAMPAGNE; K. BETT-GARBER; D. KANTER; T. SIEBENMORGAN; and A. MCCLUNG; 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.
Determine mechanisms for head rice loss when rice is transferred.

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 prospective new varieties for processing quality.

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

Determine the 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 rice components (i.e. starch, protein) in native and modified forms.

Study the genetic mechanisms controlling amounts and compositions of components that 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.

Evaluate genetic, growth environment and grain processes on the nutritional value of rice grain.

RICE CULTURE

N. SLATON, Chair; D. HARRELL, Chair-Elect (2014); P. BOLLICH; J. CORBIN; P. FITTS; D. FRIZZELL; E. GASORE; J. HILL; R. NORMAN; S. PHILLIPS; T. ROBERTS; L. TARPLEY; T. WALKER; and C. 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, uptake and translocation of plant essential and non-essential nutrients, 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.

Develop a better understanding of the micro- and macro-environment of the rice canopy and its influence on growth of the rice crop.

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.

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.

RICE WEED CONTROL AND GROWTH REGULATION

B. SCOTT, Chair; E. WEBSTER, Chair-Elect (2014); D. JOHNSON, B. DAVIS, M. KURTZ, A. MOHAMMED, D. GEALY, P. DEVKOTA, D. MANNELLO, S. RANA, J. BOND, and L. LEE; 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.

Understand interactions between plant growth regulators and environmental factors.

Identification of Candidate Genes in Rice for Resistance to Sheath Blight Disease by Whole Genome Sequencing

Silva, J., Scheffler, B., Sanabria, Y., De Guzman, C., Galam, D., Farmer, A., Woodward, W., May, G., and Oard, J.

Recent advances in whole genome sequencing have allowed identification of genes for disease susceptibility in humans. The objective of our research was to exploit whole genome sequences of 13 rice (*Oryza sativa* L.) inbred lines to identify non-synonymous SNPs (nsSNPs) and candidate genes for resistance to sheath blight, a disease of worldwide significance. Whole genome sequencing by the Illumina GA IIx platform produced an average 5X coverage with ~ 700 K variants detected per line when compared with the Nipponbare reference genome. Two filtering strategies were developed to identify nsSNPs between two groups of known resistant and susceptible lines. A total of 333 nsSNPs detected in the resistant lines were absent in the susceptible group. Selected variants associated with resistance were found in 11 of 12 chromosomes. More than 200 genes with selected nsSNPs were assigned to 42 categories based on gene family/gene ontology. Several candidate genes belonged to families reported in previous studies, and three new regions with novel candidates were also identified. A subset of 24 nsSNPs detected in 23 genes was selected for further study. Individual alleles of the 24 nsSNPs were evaluated by PCR whose presence or absence corresponded to known resistant or susceptible phenotypes of nine additional lines. Sanger sequencing confirmed presence of 12 selected nsSNPs in two lines. "Resistant" nsSNP alleles were detected in two accessions of *O. nivara* that suggests sources for resistance occur in additional *Oryza* sp. Results from this study provide a foundation for future basic research and marker-assisted breeding of rice for sheath blight resistance.

Reevaluating Rice Fungicide Rates, Timings, and Tank Mixes

Groth, D.E., Dischler, C., and Monte, L.

The lack of sheath blight-resistant cultivars requires rice farmers to often use fungicides to control the disease and avoid significant reductions in grain and milling yields. Numerous different rates, timings, and tank mixes have been suggested to farmers. Different rates, timings, and tank mixes were tested for their efficacy to control sheath blight and increase yields and milling.

Artificially inoculated field tests were conducted at the Rice Research Station, Crowley, LA. Various commercially available fungicides, including Quadris, Gem, Quilt, Stratego, and Tilt, at various rates and combinations were applied to the foliage at mid-boot, heading, and 5, 10, and 15 days after heading using a CO_2 pressurized sprayer. Plots were evaluated for sheath blight severity and infestation at maturity. Yield and milling were determined. Experiments were arranged in a randomized complete block design with four replications. Trials were conducted over two years (2010-2011).

Sheath blight significantly reduced rice grain and milling yields. There were no significant differences in sheath blight severity and incidence between different rates and tank mixes. However, late timings, after heading, were very detrimental to disease control. Most tank mixes increased yields but were not significantly different from each other. Again, late fungicide applications after heading were detrimental to rice yield improvement. Although disease control was somewhat different for different rates and tank mixes, sheath blight development was delayed long enough to improve rice yields. The key factor was to apply the fungicide at the correct timing.

Resistance to Rice Herbicides in the Southern U.S.: A Need for New Modes of Action

Norsworthy, J.K., Johnson, D.B., Scott, R.C., Smith, K.L., and Bond, J.

In Arkansas, propanil was first used in 1959, with resistance to the herbicide by barnyardgrass confirmed in 1990. Prior to 1990, there was no program in place to screen or evaluate plants for resistance. In the early 1990s, a screening program was developed at the University of Arkansas to test for propanil resistance. Shortly thereafter, it was recognized that propanil resistance by barnyardgrass in Arkansas rice was widespread. In 1992, through a Section 18 label, quinclorac became the solution for managing propanil-resistant barnyardgrass, but in 1999, a biotype resistant to both propanil and quinclorac was confirmed. Clomazone was then registered in Arkansas rice in 2000 and has been used on 70 to 80% of the rice acreage annually. In 2007, a barnyardgrass biotype with resistance to clomazone was documented. The following year, a barnyardgrass biotype was confirmed resistant to several acetolactate synthase (ALS)-inhibiting herbicides. The ALS-inhibiting herbicides imazethapyr, imazamox, penoxsulam, and bispyribac have been labeled in rice for 8 to 9 years. Imazethapyr and imazamox use is restricted to Clearfield® rice, but more and more growers plant Clearfield rice and rely on the ALS-inhibiting herbicides for barnyardgrass control. Barnyardgrass samples submitted from 131 rice fields from 2006 through 2010, mainly Arkansas, have been evaluated for resistance to propanil, quinclorac, clomazone, cyhalofop, penoxsulam, imazethapyr, and glyphosate. Of these samples, 62 were resistant to propanil (47%), 41 resistant to quinclorac (31%), 7 resistant to ALS-inhibiting herbicides (5%), and 2 resistant to clomazone (<2%). Evaluation of an additional 26 samples from the 2011 season is on-going. Additionally, Amazon sprangletop, rice flatsedge, and smallflower umbrellasedge populations have been screened for resistance. Resistance of these weeds to the ACCase- and ALS-inhibiting herbicides will be discussed.

Propanil- and quinclorac-resistant barnyardgrass quickly became a widespread problem following the first documented cases of resistance to these herbicides, and if a similar pattern occurs for biotypes resistant to clomazone and the ALS-inhibiting herbicides, rice producers in Arkansas and Mississippi will soon be left with few options for barnyardgrass control. To date, there are no known populations of barnyardgrass having resistance to fenoxaprop or cyhalofop, two acetyl-CoA carboxylase-inhibiting, postemergence herbicides. These two herbicides are often applied to barnyardgrass as a "salvage" treatment when other herbicides have failed, placing unprecedented selection on these herbicides. Additionally, thiobencarb and pendimethalin are labeled in rice for residual control of barnyardgrass, but control with these herbicides is highly dependent on soil moisture and is often erratic. In past years, new chemistry became available to rice producers as barnyardgrass evolved herbicide resistance to older chemistry. Unless new chemistry is brought into rice soon, barnyardgrass control in rice in the near future looks bleak. The University of Arkansas and Mississippi State University continues to recommend the use of multiple modes of action for weed control and encourages growers to submit samples for herbicide resistance evaluation from fields where resistance is suspected.

Field-Scale Validation of N-ST*R for Silt Loam Soils in Arkansas

Roberts, T.L., Norman, R.J., Slaton, N.A., Wilson, Jr., C.E., and Williamson, S.M.

Producer profitability is closely tied to commodity prices and production costs, which are in a constant state of flux. In recent years, market volatility, technology costs, and input costs have pressured producers to make critical decisions concerning where to "cut" unneeded expenditures. Increasing nitrogen (N) fertilizer prices threaten the long-term sustainability of U.S. rice production, and the implementation of a soil-based N test will result in better management of N fertilizer and more profitable rice production, while lowering the potential environmental impact. Soil fertility specialists have searched for a soil-based testing method to manage N fertilization in crop production for decades. Current practices rely on soil type, residual inorganic-N (NO_3^- and NH_4^+), yield goal, and/or previous crop to determine N fertilizer recommendations. Many crops, such as corn and rice, require large amounts of N fertilizer when utilizing either a yield-based or soil-texture based fertilizer recommendation. These methods do not take into account the soil N that may become mineralized during the growing season and have no predictive value. Conventional rice production has relied on yield goal estimates for determining N fertilizer needs, which can often lead to over-fertilization of crops and potentially higher impacts on the surrounding environment. Understanding the amount of N that can be supplied by the soil may significantly reduce the amount of N fertilizer required in many fields to obtain maximum rice yields. Implementation of a soil-based N test for rice production will allow N fertilizer recommendations on a field specific basis and ensure more profitable rice yields while lowering environmental impact due to excess N.

Researchers at the University of Arkansas have been working diligently over the past eight years to develop N-ST*R: a soil-based N test for rice that will provide the first field-specific N rates for rice produced in the Midsouth USA. The basis of this research was to develop an analytical procedure that quantifies the amount of N the soil could provide to the rice crop during the growing season. A direct steam distillation procedure was developed to index the availability of soil N and was correlated and calibrated to rice response parameters on silt loam soils. A unique aspect of N-ST*R is that it measures a pool of potentially available soil N that is not prone to loss mechanisms such as NO_3^-. The best relationships between N-ST*R values and N calibration rates were found when the soil was sampled 45 cm deep, which may be considered the effective rice rooting depth on silt loam soils.

Research with N-ST*R has shown that in most situations the standard N recommendation results in over-fertilization and some producers planting rice after continuous soybean, catfish, or fallow may be able to eliminate or drastically reduce the N fertilizer rate while maximizing yields. Work on the N-ST*R recommendations has led to the development of three calibration curves; Economic Optimum (90% Relative Grain Yield), Optimum (95% Relative Grain Yield) and Above Optimum (100% Relative Grain Yield). Utilization of the three N-ST*R calibration curves will allow producers to make management decisions based on their production philosophy and production costs. Implementation of a soil-based N test will allow site-specific N fertilizer recommendations, thereby avoiding excess N applications and lowering potential environmental impacts, while decreasing the incidence of lodging and disease. Small-plot validation of N-ST*R has been completed with N-ST*R Optimum and Above Optimum predicted N rates producing similar or higher yields in almost all of the 14 study sites. This research has been promising but has not been fully tested and must be implemented on a large scale to determine the robustness of the calibration curves and the ability of N-ST*R to capture field N availability and variability.

Field-scale strip trials were conducted in 2011 to validate the N-ST*R calibration and soil sampling protocol and educate producers, consultants and county agents on the new technology. Prior to planting, 10 soil samples were taken to a depth of 45 cm from each field and analyzed by N-ST*R to determine the N rate and degree of variability in soil N availability. All of the sites sampled and included in the study resulted in N rate recommendations that were significantly lower than the producer's practice and the standard recommendation of 165 kg N ha^{-1} for rice produced on silt loam soils. Nitrogen rates in the strip trials for the N-ST*R treatments ranged from 40 - 151 kg N ha^{-1}, and at all sites, the N-ST*R predicted N rate was less than both the producer practice as well as the standard recommendation. Results obtained from these trials indicate that N rates can be significantly reduced with little to no impact on rice yields. Incorporation of this research will not only increase producer profitability while maintaining current production levels but decrease potential for environmental impacts due to over fertilization.

Analysis for the Next Farm Bill: Implications for the U.S. Rice Sector

Wailes, E.J.

U.S. government farm program payments have traditionally been an important component of income for rice farm businesses. In 2012 farm commodity program funding is being targeted for reduction to help decrease the federal budget deficit. Under the current commodity program of the 2008 farm bill, rice producers were supported by several price and income supports, including loan deficiency payments, counter-cyclical payments, direct payment, and participation in a shallow revenue loss program known as ACRE. Loan deficiency payment and counter-cyclical payments are made if market prices are low relative to the loan rate and target price, respectively. Over the past 5 years, market prices have been relatively high and therefore payments under these programs have not been made. Direct payments are based on having historically produced rice, but there is no requirement that rice must be produced for a farmer to receive this payment. Relative to other crops, rice direct payments have accounted for about 10 percent of the total and on a per acre basis are more than twice as high as for other crops. The ACRE program was not used by the rice sector for a variety of reasons, perhaps most importantly because moving average prices were increasing over the recent 5-year period. The bottom line is that direct payments, even though not tied to rice production, were viewed by rice producers as the economically and politically important commodity program needed to financially stabilize U.S. rice farm enterprises.

Farm commodity programs are being targeted for significant reduction because the farm sector as a whole, in recent years, has experienced record net farm revenues. While direct payments are the most efficient and transparent farm income support program, they have become unpopular in large part because they are so transparent and in the face of record farm incomes, viewed as being unnecessary by a broad segment of the agricultural policy establishment. In the face of commodity program budget cuts on the order of $23 to $33 billion over the next 10-year federal budget baseline, this broad segment of the agricultural sector has sought to maintain crop insurance federal subsidies to help manage yield and revenue risks, to seek a reformulation of the shallow revenue loss program, and to eliminate the direct payment and counter-cyclical payment programs.

Rice producers are among the least likely of all agricultural producers to have participated in crop insurance. This is reasonable since yield variability for irrigated rice tends to be less important; therefore, rough rice yields tend to be much more stable compared with other non-irrigated grains and oilseeds. Revenue products are tied to the a guarantee linked to the CME rough rice futures contract which has experienced serious convergence problems to the detriment of farmers as hedgers but also as purchasers of revenue-based crop insurance. So the way forward for U.S. rice producers with respect to commodity program support will be challenging. Crop insurance products need to be developed for rice that address both the price and cost (particularly energy-based costs) as well as factors that affect milling yield rather than rough rice yields such as mid-season temperatures, insect damage, and weather events. Current insurance products are inadequate.

Moving from the current certain direct payment to only an unlikely indemnity insurance payment or shallow loss payment will pose significant difficulties for U.S. rice producers. The rice sector is vulnerable to this abrupt and likely change in U.S. commodity policy. Without significant gains from research to improve both land and water resource productivity and financial returns, we may expect a significant contraction in U.S. rice production.

High-temperature Exposure Impacts on Rice Functional Properties

Siebenmorgen, T.J. and Ambardekar, A.A.

Rapid drying using high-temperature air has gained interest in the rice industry, but the effects of elevated-temperature exposure on physicochemical properties are of concern. This study investigated the effects of exposing rough rice to elevated temperatures for various durations without removing moisture. Physicochemical property response was evaluated in terms of head rice yield (HRY), germination percentage, milled-rice yellowing, pasting properties, and gelatinization temperatures. Two long-grain cultivars, pureline Wells and hybrid CL XL729, at initial moisture contents (IMCs) of 17.9 and 18.6%, respectively, and dried moisture content (DMC) of 12.5%, were hermetically sealed and exposed to 40°, 60°, and 80°C for various durations.

Exposure to 40° and 60°C did not affect HRY for either cultivar or MC level, regardless of exposure duration. Exposing samples of Wells and CL XL729 at IMC to 80°C for 4 h resulted in significantly reduced HRYs of 2.3 and 2.5 percentage points, respectively. A slight trend for reduced HRY of both cultivars at DMC was observed at the 80°C/4-h exposure, but was statistically insignificant. Exposure of rice to 40°C, regardless of cultivar, MC, or duration, did not affect germination percentage. While a 2-h, or longer, exposure of both cultivars at IMC to 60°C completely inhibited germination, shorter exposure of either cultivar at IMC or DMC had little impact on germination percentage. In contrast, exposure of the cultivars to 80°C, at both IMC and DMC, completely inhibited germination.

Exposure to 80°C for even very short durations and to 60°C for durations greater than 4 h produced significant yellowing in both cultivars at IMC. Significant yellowing in both cultivars at DMC was also observed during a 28-day storage following 80°C exposure. In general, peak viscosities of both cultivars, at both moisture contents, increased only after extended exposure to 40°C, but peak viscosities increased sharply and immediately upon exposure to 60° and 80°C. No significant differences were observed in gelatinization temperatures of either cultivar, at either moisture content, from elevated-temperature exposure.

Results from this study suggest that extreme-temperature exposure of rough rice affects HRY, germination percentages, yellowing, and pasting properties. The extent of impact is dependent on duration of exposure and rough rice moisture content.

Abstracts of Papers on Breeding, Genetics, and Cytogenetics
Panel Chair: Wengui Yan

Diversity of Elite Inbred Lines of Rice as Revealed by Whole-Genome Sequencing

Silva, J., Scheffler, B., Sanabria, Y., De Guzman, C., Galam, D., Farmer A., and Oard, J.

Recent studies in certain crop species have identified extensive genomic variation when evaluating diverse germplasm with different gene array and sequencing technologies. The objective of our research was to assess genomic variation of 13 elite rice (*Oryza sativa* L.) inbred varieties by whole genome sequencing (WGS). A total of 1.3 M non-redundant variants were detected with SNP frequencies being nearly equal for *O. sativa* spp. *indica vs. O. sativa* spp. *japonica* varieties. The largest proportion of SNPs was found in intergenic regions while frequency of insertion/deletions (indel) variants was rare. Measures of overall subpopulation differentiation and SNP diversity were relatively high, punctuated by specific chromosomal regions that featured either extremely low or high levels of variation. Only a small percentage of SNPs fixed in the *indica* varieties were absent in the *japonica* varieties. Both phylogenetic and biplot analyses based on sharing or standardized frequency of alleles revealed that the 13 varieties could be assigned to three distinct groups. Genome-wide linkage disequilibrium (LD) in general extended up to 1 Mb, but substantial variation in LD was observed within each chromosome. Results from this study indicate that considerable genomic variation occurs even among elite inbred rice varieties that can be exploited in future crop improvement efforts. Whole genome sequencing of elite material increases our understanding of rice diversity at a high sequence resolution that complements previous research of diverse germplasm and different sequencing strategies.

Genetic and Epigenetic Regulation of Seed Development and Grain Filling in Rice (*Oryza sativa*)

Nallamilli, B.R.R., Zhang, J., Mujahid, H., and Peng, Z.

Cereal endosperm provides half of all human food calories and serves as main feedstock for livestock. The regulatory mechanism of cereal endosperm development is largely unknown. Polycomb complex has been shown to play a key role in the regulation of endosperm development in *Arabidopsis*, but its role in cereal endosperm development remains obscure. In addition, the enzyme activities of the polycomb complexes have not been demonstrated *in vitro* from any plants. Here, we purified the rice *OsFIE2*-polycomb complex using tandem affinity purification and demonstrated its specific H3 methyltransferase activity. We found that the *OsFIE2* gene product was responsible for H3K27me3 production specifically *in vivo* and that the gene expression was not regulated by imprinting. Genetic studies showed that a severe reduction of *OsFIE2* expression led to completely endosperm-free seeds and a moderate reduction resulted in smaller seeds and loss of seed dormancy. Genome-wide ChIP-seq analyses found that a large number of endosperm specific regulatory genes and storage nutrient metabolic pathway genes were directly regulated by H3K27me3 modification in the rice endosperm. Our results suggest that *OsFIE2*-polycomb complex positively regulates rice endosperm development and grain filling via a mechanism highly different from that in *Arabidopsis*.

Genome-Wide Identification of Protein Acetylation in Rice (*Oryza sativa*)

Nallamilli, B.R.R., Edelmann, M., and Peng, Z.

Protein acetylation is a reversible dynamic modification regulated by acetyltransferases and deacetylases. Recent advances in mass spectrometry based high-throughput proteomics and antibody-assisted modification studies have substantially contributed to the detection of histone acetylation and the understanding on the regulation of the acetylation modification. However, the extent of lysine acetylation in non-histone proteins still remains poorly understood, particularly in cereal crops. Here, we report a large scale study of lysine acetylation in rice non histone proteins. We identified 105 lysine acetylated sites on 75 proteins of diverse biological functions. Western blot studies further confirmed the lysine acetylation status of the non-histone proteins in different tissues of rice. Analysis of identified lysine acetylated proteins clearly demonstrates that lysine acetylation is not limited to histones but also occurs in diverse cytoplasmic proteins, chloroplast proteins and mitochondrial proteins in rice. Our results demonstrate that lysine acetylation occurs on diverse non histone proteins and suggest that protein acetylation is an important control mechanism for the regulation of non-histone proteins in rice.

Light Captured by Rice Leaves, Stems, and Panicles: The Continuing Search for Superior Performing Rice Cultivars

Wilson, L.T., Samonte, S.O.P.B., Medley, J.C., and Yang, Y.

A goal of the Texas A&M rice-breeding program is to better define the combination of primary phenotypic traits that increase yield for a targeted environment. Primary phenotypic traits are defined as plant characteristics that are near invariant across a wide range of conditions of environmental stress and are suspected of being controlled, in most cases, by one or a few genes. Unlike secondary phenotypic traits, that vary over time within a field, and across fields and seasons, the near invariance and strong influence of primary phenotypic traits on crop growth and development allows their use in predicting potential yield performance.

To date, we have identified over 30 primary phenotypic traits (from both published literature and from our experiments) and have conducted detailed simulation analyses on the effect of four of these traits (maximal rate of phytomer production, node of panicle differentiation, maximum mass of individual grain, maximum leaf mass = function of nodal position) on yield. These analyses have been followed by field experiments to provide independent verification data. We have measured a number of primary phenotypic traits for both inbred and hybrid selections and, in some cases, for sets of inbred parents and their F_1 progeny. Herein, I present an aspect of our results involving light interception. Specifically, we describe variation in the contribution of leaves, stems, and panicles to light interception, as measured by a genotype leaf, stem, and panicle light extinction coefficients, respectively. Leaf light extinction coefficients estimated for male pollen donors and female recipients suggest a measureable paternal effect. Our results also further document the extreme plasticity of rice, in this case, in terms of canopy light interception. A secondary goal of this research is to refine our rice model's ability to accurately capture a genotype's diurnal and seasonal light interception.

Using Genomic Analysis to Trace the Introduction of *Oryza sativa* to Africa

Gilbert, E., Jackson, A., Fjellstrom, R., and McClung, A.

Oryza sativa is widely cultivated in various countries throughout Africa with the largest acreage being in West, West Central, and East Africa. It has largely supplanted the locally domesticated African rice (*O. glaberrima*). *Oryza glaberrima* cultivation never spread beyond West Africa, so in the other regions of the continent, *O. sativa,* or Asian rice, is the only rice under cultivation. Asian rice is only one of several introduced crops that have become critical to African agriculture; however, the origins, timing, and historical processes behind the introduction of *O. sativa* are poorly understood compared with other introduced crops such as maize, taro, and bananas. Rather than focusing on the introduction of Asian rice to Africa, scholars have been more interested in the role of enslaved African rice cultivators in the spread of rice farming to the Americas. There is archeological evidence for the presence of *O. sativa* on the East African coast by 800. Because other crops that were introduced to Africa in the middle of the first millennium, like bananas and taro, came from Southeast Asia, it is generally assumed that the same was true for rice. Bananas and taro diffused rapidly across the continent and are now found in virtually all of high rainfall areas of the continent. Historical evidence suggests that rice did not appear in the interior of East Africa or Central Africa until the 19th century. Thus, the process by which Asian rice spread through Africa was more tentative and gradual than other food crops. Because historical observers could not distinguish between *O. glaberrima* and *O. sativa*, it is impossible to tell whether travelers' reports of rice cultivation in West Africa as early as the 14th century refer to Asian or African rice. Thus, the timing and origins of the Asian rice grown in West Africa are unknown.

Our project attempted to use genomic analysis to determine the origins of Asian rice in Africa and to trace its diffusion within the continent. We selected for analysis 162 *sativa* lines and five *glaberrima* lines from the USDA National Small Grains collection. We chose landraces whenever possible or lines designated as "cultivated material" in the belief that these varieties would be descendants of populations that were originally introduced to the continent. Our sample included lines from multiple regions of Africa along with those from potential points of introduction in Asia, the Americas, and southern Europe. The samples were analyzed with 50 genome-wide microsatellite markers. Population structure was assigned by the program Structure v2.3.3 and further analyzed with Principal Components Analysis (PCA) and cluster analysis based on genetic distance.

The samples were grouped into six subpopulations: temperate japonicas, aromatics, aus, indicas, and two discrete subpopulations of tropical japonicas (TRJ1 and TRJ2). In the Mediterranean region, temperate japonicas predominated. East Africa had some indicas, but the TRJ2 group was prominent. West Africa had a cluster of indicas and aus in the Senegambia region but TRJ1 was widespread in the Gulf of Guinea and in Central Africa. TRJ1 was also the predominant group in South America, the Caribbean, and North America.

Assuming the germplasm that we have access to today is a reflection of rice that was historically cultivated, we tentatively conclude that Asian rice was introduced to Africa in several independent processes. The temperate japonicas of the Mediterranean region represent one of these and may be part of the introduction of Asian crops to this region associated with the expansion of Islam in the 8th century. The TRJ2 group, which appears in mainland East Africa, Madagascar, South Asia and above all in insular Southeast Asia may be associated with the Austronesian expansion that brought Southeast Asian settlers to Madagascar and bananas and taro to Africa also. The TRJ1 group that is found on both sides of the Atlantic is intriguing. The lines in this group were very closely related despite their wide geographic distribution suggesting a fairly recent introduction. Interestingly, TRJ1 varieties are found in places associated with the slave trade in Africa and the use of slave labor on plantations in the Americas. The TRJ1 population may be a consequence of the post-Columbian opening of sea contacts across the Atlantic and between the Atlantic and Indian Oceans. The close relationships between the members of the TRJ1 group and their geographical distribution offer partial support for the "Black Rice" thesis, which contends that enslaved Africans played a central role in the spread of rice cultivation to the Americas. The cluster of indicas and aus in the Senegambia region may represent a fourth introduction of *O. sativa* to Africa.

High-Yielding Limited-Water Plant Type of Texas

Samonte, S.O.P.B., Wilson, L.T., Tabien, R.E., Medley, J.C., and Harper, C.L.

High grain yield is one of the goals in any rice breeding program. A high-yielding limited-water (HY LW) rice plant type was designed for Texas in the 1990s and bred for in the 2000s. The HY LW plant type is intended to be planted when insufficient water, such as during a drought, prevents the growing of the ratoon crop. HY LW rice lines were selected for high levels of four primary phenotypic traits – maximum node production rate, main culm panicle node number, potential leaf mass, and potential grain mass. This study was conducted to evaluate the grain yield and yield-related trait performance of HY LW plant type selections developed for Texas.

Twenty-six HY LW lines and check cultivar Cocodrie were evaluated in replicated yield trials in 2008 and 2009 at the Texas A&M AgriLife Research and Extension Center at Beaumont, TX. These genotypes were evaluated for grain yield, the four primary phenotypic traits, and for yield-related traits.

Results showed that 22 HY LW lines had higher grain yields (averaged across years) than Cocodrie, including five that were significantly higher. The mean of the top five yielding genotypes were higher than that of Cocodrie in grain yield by 23.3%, maximum node production rate by 4.2%, main culm panicle node number by 9.6%, leaf mass at heading by 87.0%, panicle mass at harvest by 14.7%, tiller density by 10.2%, leaf area at heading by 72.4%, stem mass at heading by 87.8%, number of spikelets per main culm panicle by 0.6%, plant height by 15.7%, maturity by 5.0%, and harvest index by 1.7%, whereas number of filled grain per main culm panicle was lower by 10.6%. The design and breeding for the HY LW plant type were successful, and the lines developed are potential cultivars or useful as parents in rice breeding programs. Furthermore, rice breeders may also consider evaluating the plant type design in their rice growing region.

Two Very Early Elite Rice Breeding Lines with High Grain Yield and Milling Quality Potentials in Texas

Tabien, R.E., Harper, C.L., Samonte, S.O.P.B., Wilson, L.T., and Frank, P.M.

Rice is an important crop in Texas, where it has been grown in large-scale production since 1892. A 2010 report indicated that the rice industry contributed a total of $1,014 million in total goods and services to the economy of Texas, and that more than 5,000 people in Texas depend on rice as a source of income. For nearly 100 years, rice breeding in Texas has been conducted by scientists of the U.S. Department of Agriculture. However, in the early 2000s, this activity was transferred to the state, thus the Texas State Rice Breeding Program was established. Initially, bi-parental crosses were created using U.S.-released cultivars to develop new high yielding cultivars with high milling potentials, blast resistance and other important traits such as fast tillering and leaf production. These crosses were advanced and plant selections were included in the pedigree nursery (PN). Further selections in PN provided entries for the unreplicated observational nursery (ON). The first replicated preliminary yield trial (PYT) conducted in Beaumont included the best entries advanced from the ON. Resistance to rice blast disease and grain quality traits were evaluated using DNA markers before their inclusion in the replicated yield trials. After a series of yield trials in Beaumont, the best entries were tested in two locations and then in three locations in Texas. The elite lines from these trials were nominated to the Uniform Regional Rice Nursery (URRN), which is a multi-state trial involving five states.

After a series of trials spanning 4 to 6 years, two elite lines, RU0703144 and RU0704190, were identified as having high main crop grain yield and milling potentials in Texas and were comparable with or better than the highly popular cultivar Cocodrie. The line RU0703144 was selected from a cross of two popular cultivars in Texas, those being Cypress and Cocodrie. It had a mean main crop yield of 9,022 kg/ha in 13 trials. This was 9% more than Cocodrie, which was released by Louisiana in 1998, and 5% more than Presidio, a Texas cultivar released in 2005. Mean yield across five states (Arkansas, Louisiana, Missouri, Mississippi and Texas) was 9,033 kg/ha. The total milled rice percentage of RU0703144 was comparable with Cocodrie at 71% but generally rated higher in whole milled rice percentage (62% vs 60%). On average in Texas, this line heads in 80 days and matures in 118 days, it is 97 cm tall and is a non-lodger. It has an intermediate apparent amylose content, low alkali spreading value, intermediate gel type, and conventional long-grain cooking type, which is typical for U.S. conventional long-grain rice. The disease package of this line is very much like Cocodrie, having resistance to rice blast and susceptibility to sheath blight.

Line RU703190 was derived from a cross of Cocodrie and L202 from California. In four years at the URRN in Beaumont, it had a high mean main crop grain yield of 9,920 kg/ha, a 7% yield advantage over Cocodrie and 8% over Presidio. It has a high whole grain milling yield of 62% and a total milling yield of 74%. This line heads in 81 days and matures in 116 days. It is 93 cm tall and is a non-lodger like RU0703144. Similarly, it is a typical U.S. long grain with an intermediate amylose content, low alkali spreading value, intermediate gelatinization temperature, and cooking quality that is very similar to that of Cocodrie. It has a disease package similar to Cocodrie and RU0703144. RU0703190 is the first elite rice line developed using model- and marker-assisted selection. It possesses the combination of desirable traits identified by physiological-based rice plant simulation modeling, and derived through DNA marker-assisted selection for blast diseases and grain quality. These two elite lines are currently the best candidates for cultivar release in Texas.

Improvement of Blast Resistance and Grain Amylose Using Marker-Assisted Breeding in Hybrid Rice

Xiao, W.M., Sun, D.Y., Chen, Z.Q., Wang, H., Guo, T., Liu, Y.Z., and Zhang, J.G.

Rice (*Oryza sativa* L.) is one of the most important food crops for half the world's population, and hybrid rice with yield advantages over conventional rice has been commercialized since 1976. Blast (*Magnaporthe Oryzae*) is the most damaging disease in rice, and grain amylose is essential for cooking quality. Many elite hybrids failed to be successfully commercialized because either blast or amylose or both are not satisfactory. Hence, our objective in this study was to improve both blast resistance and grain amylose in hybrid rice using marker-assisted breeding.

H4 is a mutant identified from cultivar Zhong-Er-Ruan-Zhan that had travelled in a space shuttle. Resistant spectrum to blast increased to 36 biotypes in H4, 14 more than its wild type. Amylose remains the same with its wild type, 14.0%. Gene mapping identified *Pi46(t)* responsible for the wide-spectrum resistance marked by RM224 and *wax* for intermediate amylose marked by RM190 in H4 mutant. Elite restoring line R173 that was severely susceptible to panicle blast with high amylose content (24.2%) was crossed with H4 and backcrossed as a recurrent parent. About 400 individuals in the BC2F2 population were screened with RM224 for *Pi46(t)* and RM190 for *wax.* The selected individuals with both genes were comparatively evaluated with the recurrent parent R173 both phenotypically and genotypically. In the field, 10 individuals looked similarly with R173, thus selected. After genotyping with 101 SSR marker loci covering the whole genome, the one with the highest monomorphism of 96% with R173 was selected from the 10 resulted from field selection.

After selfing for five generations, the selected line was named R1173. Following evaluation demonstrated that R1173 was resistant to all 36 biotypes as H4 mutant at seedling stage, 15 more than its recurrent parent R173, which was resistant to 21. The resistance-spectrum of R1173 increased 41.7% over R173. Furthermore, R1173 showed a high resistance to panicle blast in a natural blast nursery for two consecutive cropping seasons, while R173 was highly susceptible. The amylose content of R1173 was 15.0%, 1.0% higher than H4 mutant but 9.2% lower than its recurrent parent R173.

For evaluation of its combining ability, R1173 was crossed with three male sterile lines, Tianfeng A, Huanong A and Peiai 64S, to produce three hybrids. All the hybrids yielded similarly with those hybrids derived from its recurrent parent R173. All the hybrids derived from R1173 had a broad-spectrum resistance to dozens of *M. Oryzae* biotypes inoculated with a mixture to a field nursery at seedling stage and at adult stage, while the hybrids derived from R173 were highly susceptible. The three male sterile lines are high in grain amylose, each over 24.0%. The hybrids derived from R1173 had intermediate amylose contents, ranging from 19.0 to 22.0%, while the hybrids derived from R173 had high contents ranging from 24.0 to 25.0%.

Our study demonstrates the advantages of marker-assisted selection in hybrid rice breeding. Screening 400 offspring plants with two molecular markers for blast and grain amylose is much quicker, and the selection is more accurate than blast evaluation for 36 biotypes and lab analyses for amylose. In addition to saving money and time, the breeding process pyramids two genes and improve disease resistance and cooking quality simultaneously not only in restoring line, but also in its derived hybrids.

A Major Gene Resistant to Straighthead was Identified Using Two RIL Populations

Pan, X.H., Yan, W.G., Jia, M., Jackson, A., Jia, L.M., Zhang, Q.J., Xu, P.Z., Huang, B.H., Correa, F., and Li, S.G.

Straighthead, a physiological disorder of rice (*Oryza sativa*) characterized by sterility of florets and an accompanying reduction in yield, occurs in numerous countries including the United States. Cultivar resistance is the most effective and economical strategy for straighthead control. Understanding the genetic basis for straighthead resistance in rice sets a solid foundation for cultivar improvement. In this study, we developed two recombinant inbred line (RIL) F_9 populations, Zhe733 (resistant)/R312 (susceptible) and Cocodrie (susceptible)/Jing185 (resistant). Straighthead was evaluated in single row plots in a randomized complete block design with three replications at Dale Bumpers National Rice Research Center in 2008 and the evaluation was repeated in 2009. Monosodium methyl arsenate (MSMA) at 6.7 kg ha^{-1} as a solution was applied to the soil surface and incorporated before planting in order to induce straighthead. The parents of each population were repeatedly tested in each tier as controls. Straighthead was rated using a scale of 1 to 9 at maturity based on floret fertility or sterility and panicle emergence from the flag leaf sheath, where 9 was the most susceptible and 1 was the most resistant. Means from six replications for each line gathered over a 2-year time period were used for gene mapping.

In total, 170 Zhe733/R312 F_9 RILs and 91 Cocodrie/Jing185 F_9 RILs were screened with 136 (selected from 521) and 159 (selected from 473) polymorphic markers, respectively. JoinMap 4.0 was used to calculate marker distance and build linkage maps for each population. Qgene 4.3.8 was used to estimate QTL parameters (locations, effects and test statistics) with composite interval mapping (CIM). QTL with logarithm of odds (LOD) scores > 3.0 were reported as QTL for straighthead resistance.

Four loci were identified from the Zhe733/R312 population, one on Chromosome (Chr) 8 (LOD=23.0), Chr7 (LOD=5.0), Chr6 (LOD= 4.8) and Chr11 (LOD=3.0). From the Cocodrie/Jing185 population, two loci were identified, one on Chr8 (LOD= 27.0) and another on Chr3 (LOD=3.8). The QTL region on Chr8 was the largest QTL identified in both populations. The Chr8 QTL explained 42% of total variation with a gene effect of -1.93 in Zhe733/R312 and 67% of total variation with a gene effect of -2.05 in Cocodrie/Jing185. The negative effect of the gene indicates a decrease of straighthead rating and an increase of straighthead resistance.

The QTL on Chr8 was located between RM6838 and RM72 within a genetic distance of 1.0 cM and a physical distance of 0.91 Mb in Zhe733/R312. The QTL region of Zhe733/R312 on Chr8 overlapped with the region identified from the Cocodrie/Jing185 population. The QTL region in Cocodrie/Jing185 was between RM22559 and RM72 with a genetic distance of 1.9 cM and a physical distance of 1.02 Mb. RM6838 in Zhe733/R312 and RM22559 in Cocodrie/Jing185 were physically located very close to each other at 5.85 Mb and 5.70 Mb, respectively. RM72 at 6.76 Mb was the most distal marker of the QTL identified in both populations. The overlapping intervals on Chr8 identified in both populations verify the presence of a major QTL at this location.

Application of molecular markers to plant breeding is regarded as an efficient and economical way to evaluate or identify the trait of interest through genotype instead of phenotype, especially for straighthead, which evaluation requires MSMA. Successful application of marker-assistant selection (MAS) depends on three factors: 1) marker(s) should co-segregate or be closely linked (genetic distant 1cM or less is sufficient for MAS) with the desired trait, 2) marker(s) should be tightly linked to no more than three QTLs, and 3) all QTLs selected for MAS should be stable across environments. In the present study, straighthead evaluation was conducted over two years, which accounted for environmental effects. We are making further efforts to fine map this gene. Molecular marker(s) identified from fine mapping will be verified using straighthead information in the USDA rice core collection. Once verified, the markers associated with this QTL will be ready for breeders to use for cultivar improvement.

Understanding of Evolutionary Genomics of Invasive Species of Rice

Jia, Y., Gealy, D., Burgos, N., Olsen, K., and Caceido, A.

Red rice is an aggressive, weedy form of cultivated rice (*Oryza sativa*) that infests crop fields and is a primary factor limiting rice productivity in the U.S. and worldwide. As the weedy relative of a genomic model species, red rice is a model for understanding the genetic and evolutionary mechanisms by which weediness evolves. Previous work has revealed that red rice in the U.S. has two independent evolutionary origins and is likely descended from Asian domesticated rice. We aim to investigate evolutionary questions on the genetic basis of evolution of weedy rice by addressing the following two questions: What does QTL mapping reveal about genomic regions underlying traits that distinguish weedy rice strains from their putative cultivated progenitors? Do these regions differ for the two independently evolved U.S. weed strains? Thus far, we have analyzed the population genomic structure of U.S. red rice, and this information provides a foundation for directly examining the genetic basis by which weediness evolves. Toward this end, we have advanced two mapping populations of the cross of SH (straw hull red rice) and indica (1135-010 X Dee Geo Woo Gen) consisting of 216 individuals and the cross of BHA (black hull red rice) and indica (1996-09 X Dee Geo Woo Gen) consisting of 328 individuals to F_5 plants. F_6 seedlings of both populations are being advanced in a greenhouse for phenotyping in the summer of 2012. Overall goals and progress of population development and characterization will be presented.

Understanding Rice Heterosis Using Deep Sequencing

Venu, R.C., Jia, Y., Liu, G., Jia, M.H., Nobuta, K., Sreerekha, M.V., Moldenhauer, K.,
Pellegrini, M., Jacobsen, S., McClung, A., Meyers, B., and Wang, G.-L.

Heterosis is a complex biological phenomenon where the offspring show better performance compared with the inbred parents. Although rice breeders have used heterosis in hybrid rice production for nearly 40 years, the genetic and molecular mechanism underlying the heterosis in rice is still poorly understood. Large scale transcriptome profiling has been used for heterosis studies in many crop plants and identified numerous candidate genes that are associated with the trait. In this study, we used Illumina's massively parallel signature sequencing (MPSS) technique to deeply analyze the transcriptome of rice F_1 hybrid derived from a cross between the sequenced *japonica* rice Nipponbare and *indica* rice 93-11. MPSS libraries were constructed using RNA isolated from leaves, roots and meristem tissues harvested from parents and their F_1 hybrid. About 1 to 3 million signatures were obtained from each library. The gene expression level of unique signatures in the F_1 hybrids was compared with their parents. The identified genes in the F_1 hybrid were classified into five major categories based on their expression level: above the high parent level, high parent level, mid parent level, low parent level and below the low parent level. Using cluster analysis, the commonly and specifically expressed genes in Nipponbare, 93-11 and F_1 hybrid were identified in all three tissues. Functional classification of these genes was carried out using Kyoto Encyclopedia of Genes and Genomes (KEGG), Gramene and MSU Rice Genome Annotation Project databases. Identification of these genes in the *japonica/indica* hybrid has provided new insights into the molecular basis of heterosis in rice.

Comparative Mutational Site of High Lysine Rice Lines and Other Crops

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

The amino acid industry is a multi-billion dollar market. Amino acids are used for a variety of purposes, including human food and animal feed supplement (lysine, methionine, and threonine), flavor enhancers (monosodium glutamic, serine, and aspartic acid), and specialty nutrients in the medical field, such as intravenous nutrient solutions for pre- and post-operative care. Industrial production of lysine and glutamic acid is done by fermentation (microbe based), while methionine is made by chemical synthesis. The animal feed industry represents the second largest consumer of amino acids after monoglutamimate (MSG)'s consumer. Lysine, methionine, tryptophan, and others improve the nutritional quality of animal feed by supplying essential amino acids that is in low abundance in grain.

Lysine is an essential amino acid in both human and monogastric livestock nutrition. Lysine is the most limiting amino acid in rice grain and cereal seeds that represent the major source of food and animal feed worldwide. This amino acid is synthesized from aspartate through one of the two branches in the aspartate family biosynthetic pathway. Another branch of the pathway gives rise to two other important essential amino acids, methionine and threonine. Lysine synthesis is controlled by two key enzymes, aspartate kinase and dihydrodipicolinate synthase (DHDPS; EC 4.2.1.52). DHDPS catalyzes the first reaction that is unique to lysine biosynthesis. It condenses 3-aspartic semialdehyde with pyruvate to form 2, 3-dihydrodipicolinate. DHDPS is feedback inhibited by lysine and it represents the rate-limiting step in the pathway to the lysine synthesis. Within the lysine synthesis pathway in the plant, DHDPS is the most sensitive enzyme among the major regulatory enzymes in lysine synthesis in plants, including aspartate kinase that is also feedback inhibited by lysine. DHDPS has *I0.5* of 10–50 μM. In contrast, aspartate kinase has *I0.5* of 100–700 μM. When compared with bacteria, plant's DHDPS is about 100-fold more sensitive to lysine inhibition than *Escherichia coli*'s DHDPS (*I0.5* of 1,000 μM).

Three high protein rice lines, WLS09128, CCD091301, and CCD091380, that have an average lysine increase of respectively 54.2, 45.8, and 20.8% were used to evaluate molecular property of the DHDPS gene. Based on their cDNA sequence, the DHDPS gene in line CCD091301and CCD091380 showed nucleotide/base alteration. High lysine line WLS09128 has a deletion mutation. Mutational differences among these lines will be discussed in more detail in the presentation. Two additional high lysine rice lines that do not exhibit any changes in their DHDPS gene will also be discussed to improve understanding of various factors that could contribute to higher lysine content and to establish a strategy for further improvement.

Field Performance and Grain Characteristics of High Protein Rice Lines

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

High protein rice is an important aspect of improving nutritional value of rice. Increasing protein content in rice grain has both economical and humanitarian interest. In the United States, the interest of developing high protein rice can be connected directly to the emerging market demand associated with a healthier lifestyle. Improved protein content in rice provides the basis for developing high nutritive value varieties that could potentially be used to support functional food. The future market that is driven by a better knowledge of nutrigenomics will demand that each food product is to carry unique nutritional value to support a healthier life style. Rice is a rich source of natural dietary energy and a good source of thiamine, riboflavin, and niacin. Un-milled (brown) rice contains a significant amount of dietary fiber. Rice bran is a natural source of dietary fiber, vitamins, minerals, specific oils (γ-oryzanol), and some disease-fighting phytochemicals. In developing countries, where plants directly account for the majority of the food, the high protein rice developed can be used to fulfill both humanitarian and economical purposes. In addition to strengthening the competitiveness of U.S. rice, high protein rice can be used to alleviate some malnutrition problems in many parts of the world.

Among advanced high protein lines that were evaluated in the preliminary yield trial at the Rice Research Station, five high protein lines have comparable yield potential similar with the cultivars they were derived from. Their grain appearance looks normal with milling quality comparable with their original parents. There were slight variations in their phenotypic performance (plant height, leaf type, vigor, and heading date) when compared with their original parental lines. These differences, however, is minor. The objective of this study was to conduct field evaluations and determine genetic stability of elite high protein lines for their protein content, potential yield, and grain characteristics. The test was conducted for three years at the Rice Research Station main field near Crowley, LA, in a randomized complete block design with three replications using a plot size of 1.2 x 4.8 m^2. The field was fertilized using 123 kg/ha urea in a split application. The plots were maintained flooded but occasionally drained for weed control purposes. Conventional rice herbicides were used to control weeds. During the growing season, data of important agronomic characteristics, including vigor, plant height, heading date, maturity, lodging, and potential yield, were collected. At maturity, seed from each plot was harvested, threshed, dried to 12% moisture content, and stored in a -20^{o}C freezer. In addition to grain potential, data of important agronomic characteristics, including vigor, plant height, heading date, maturity, lodging, and milling quality, were collected. A random sample of bulked brown rice from each plot was used to determine their protein contents. Data collected were used to analyze the field performance and genetic stability of high protein lines.

Significant differences for all the characters studied were found among high protein genotypes evaluated. For some characters, including vigor, heading date, and yield, the linear component of G x E interaction was significant. Based on high mean, unit regression and non-significant non-linear components, the experimental line 06PCY122425 was the best in the 3-year evaluations. The analyses and results of each trait studied, including specific grain characteristics and percent of chalkiness, will be further discussed.

Genetic Dissection of Two Key Domestication Traits, Seed Dormancy and Seed Shattering in U.S. Red Rice

Subudhi, P.K., Parco, A., Singh, P.K., Deleon, T., Karan, R., Birder, H., and Cohn, M.A.

Red rice, a major weed in rice growing areas of the southern United States, is used as a model to elucidate the genetic basis of weediness with special emphasis on seed dormancy (SD) and seed shattering (SH), which are two key traits for survival and persistence of the majority of weed species. Two recombinant inbred line (RIL) populations were developed from crosses Bengal x PSRR-1 (BR-RIL) and Cypress x PSRR-1 (CR-RIL) and evaluated for SD and SH. Bengal is a non-dormant and shattering-resistant rice cultivar and Cypress exhibits moderate intensity of shattering and seed dormancy whereas PSRR-1 is a red rice accession with high intensity of shattering and seed dormancy.

In BR-RIL population, 10 QTLs each for SH and SD were localized on seven of the 12 rice chromosomes accounting for 59 and 52% of the phenotypic variation, respectively. The largest QTL for SH on chr 4 explained 25% and the largest SD QTL on chr 7 accounted for 17% of the phenotypic variation. Red rice alleles were responsible for increased SH in six QTLs, whereas seven QTLs for increased SD were derived from red rice. In CR-RIL population, five SH QTLs and 12 SD QTLs were detected with a total phenotypic variation of 35 and 49%, respectively. Shattering QTLs were localized on four chromosomes and SD QTLs were mapped onto nine chromosomes. The contributions of each SH and SD QTL were substantially smaller with a range of 5-9% and 2-6%, respectively. Cypress was the donor for increased SH in one QTL but increased SD in eight QTLs. Comparison of the QTL positions revealed that two QTLs each for SH and SD were consistent in both populations. Chromosomes 3 and 7 harbored most of the QTLs in BR-RIL population with four SH QTLs and two SD QTLs on chr 3, and three SD and one SH QTL on chr 7. The direction of parental contribution from opposing parents at closely linked QTLs for both traits provided evidence for close linkage rather than pleiotropy. Complex genetic basis for both shattering and seed dormancy was evident with involvement of major and minor genes whose expression was modulated by epistasis and genetic background.

Since some QTLs identified in this study localized to the same positions as the *Sh4, Rc*, and *Sdr4* loci and the red rice allele contributed to increased SH or SD, the key segments of these genes were sequenced and compared to shed further light on the molecular basis of SD and SH. However, the sequence analysis could not validate earlier reported nucleotide polymorphisms associated with the phenotypic variation at *Sh4* and *Sdr4* loci in our materials.

Close association between red pericarp, seed dormancy, and seed shattering, which increase fitness in weed populations, allows red rice to persist in rice fields over years. However, no association was noticed among these traits in our population. The preponderance of red rice alleles of marker loci, including the *Rc*, suggests operation of a unique genetic mechanism for evolution, persistence, and expansion of red rice. Our results are compatible with the hypothesis that evolution of red rice is more likely through hybridization events involving *O. rufipogon.* Analysis of QTL architecture for seed shattering and dormancy will not only advance our understanding of weed biology and plant domestication process but also provide opportunities to breed improved rice cultivars.

Associating Root Morphology and Physiology with Molybdenum Uptake of Three Rice Varieties Grown in Three pH Regimes

Ratnaprabha, R., Pinson, S.R., and Tarpley, L.

Molybdenum (Mo) is an essential micronutrient required in very low amounts (0.1-1 µg g-1 dry weight) in plants. It acts as a co-factor of certain enzymes carrying out redox reactions and is required for various physiological, biochemical and metabolic processes. However, its accumulation in excess levels in different plant parts is detrimental for plants. The accumulation patterns in different parts of the plants may be due to alterations in external-environment factors, such as acidification of the growing media, or due to changes in morphology of plant parts including roots. In 2007 and 2008, preliminary field trials in both flooded and unflooded conditions identified varieties with high Mo content in rice grains. Most of the high Mo varieties were from Malaysia, where they are likely grown in naturally acidic soils. Our hypotheses are that high seed Mo content reflects acid tolerance of those varieties and that these varieties exhibit different root morphology and physiology attributes. The objectives of this study were to 1) determine if the high-Mo varieties are adapted to high soil-solution acidity and 2) compare root morphology and physiology of high-Mo varieties with a low-Mo standard U.S. variety when grown hydroponically at different solution pH. Preliminary leaf sampling from 2-week-old seedlings to 2-month old plants showed strong association between leaf and grain Mo levels suggesting similar inter-variety accumulation patterns in different tissues. Hence, this study was conducted on 4-week old seedlings transplanted into hydroponics at 2 weeks of age. One high-Mo Malaysian variety (US core 356), one high-Mo non-Malaysian variety (US Core 823) and one low-Mo variety (Lemont) were grown in solution pHs 4.7, 5.4 and 6.1 for 2 weeks with six replications per run and three runs. The following parameters were measured: photosynthesis and chlorophyll (as a positive correlation exists between molybdenum-stimulated chlorophyll content and net photosynthesis rate), root exudation (as solution pH influences root exudation, which in turn influences nutrient availability and uptake) and detailed root morphology (as solution pH determines relative growth rate and thus, root morphology).

Development of Hybrid Rice in Louisiana – A Progress Report

Sha, X.Y., Li, W.K., Linscombe, S.D., Oard, J.H., Groth, D.E., Theunissen, S.J., and Henry, B.J.

Rice heterosis was first reported in the United States about a century ago, nonetheless, successful commercialization of hybrid rice didn't occur until the early 1970s when Chinese scientists discovered the cytoplasmic male sterility from a wild abortive biotype of *Oryza rufipogon*. Through the use of Chinese germplasm, RiceTec successfully commercialized hybrid rice production in the southern United States in 1999. In 2011, RiceTec hybrid rice accounted for over 30% of the southern U.S. rice acreage. By incorporating the important hybrid rice sterility and fertility traits from Chinese germplasm into elite U.S. genotypes, or even direct test-crossing between Chinese sterile lines and Louisiana cultivars or lines, we hope to be able to develop adapted hybrids with competitive yield, comparable milling, and acceptable grain quality in the near future. Breeding objectives include 1) creating and/or identifying male sterile (Cytoplasmic A or environmental sensitive (S) lines and restorer (R) lines adapted to the Louisiana and southern U.S. environmental conditions, 2) development of elite cross combinations (hybrid varieties) through extensive test-crossing and yield trials, and 3) development of an effective and economical hybrid seed production technology for Louisiana by modifying or perfecting available technologies.

During last two years, research has been focused on the development of adapted male-sterile, maintainer, and restorer lines; production of a large number of test crosses between Chinese male sterile lines and elite Louisiana long-grain genotypes; observational trial of over 600 test crosses; multi-location hybrid yield trials; and both mini- and small-scale concept hybrid seed production. Breeding populations have been significantly increased and rapidly advanced for the development of adapted male sterile, maintainer, and restorer lines by the extensive use of both the greenhouse and Puerto Rico winter nursery. About 3,000 progeny rows, ranging from F_3 to F_5, were grown in summer 2011 for line development. From observational test cross trials, we have identified and harvested 118 cross combinations, which include 45 three-line and 73 two-line hybrids, for further milling and cereal chemistry evaluation. A total of 31 southern long-grain varieties/lines were found to have either partial or full restoring ability to Chinese CMS male sterile lines. A number of test crosses showed good agronomic characteristics and were chosen for re-evaluation in 2012. In multi-location advanced hybrid yield trials, medium-grain hybrids LAH10 and LAH20 developed by using introduced Chinese hybrid lines at Louisiana State University AgCenter's Rice Research Station, along with two experimental long-grain hybrids 10TC447 and 10TC151 (a Louisiana Clearfield line was used as pollen parent), demonstrated good yield potential compared with both CL151 and Caffey. Meanwhile, LAH10 also was tested and has shown excellent yield potential in several trials that included the uniform regional rice nursery, Louisiana commercial advanced yield trial, date of planting, and variety x nitrogen trials. A 1/8 acre concept hybrid seed production of indica long-grain hybrid LAH12 was successfully conducted by using the method similar to that developed last year but with a reduction in labor involvement. To facilitate future research needs, several different mini- and small-scale seed production methods were also proposed and tested.

Dissecting the Genetic Diversity in African Rice

Sreerekha, M.V., Sanchez, P.L., and Eizenga, G.C.

African cultivated rice, *Oryza glaberrima*, and its progenitor, *O. barthii,* are excellent sources of important genes for rice improvement. Accessions of *O. glaberrima* are tolerant to abiotic and biotic stresses, including drought, aluminum toxicity, iron toxicity, and soil acidity, as well as resistant to yellow mottle virus, stripe necrosis virus, and nematodes. *O. barthii* accessions exhibit drought tolerance and are resistant to rice blast, bacterial blight, bacterial leaf streak, brown spot, and green leafhopper. Development of advance backcross (ABC) populations between an unadapted donor parent and adapted recurrent parent facilitate the introgression of agronomically important traits from the donor parents into the recurrent parent background. Subsequent development of backcross inbred line (BIL) sets from ABC populations provides genetic stocks for translational genomics studies. Selection of diverse donor parents is crucial for successful population development and introgression of desired traits into cultivated rice. The objectives of this study were to assemble and determine the genetic diversity of *O. barthii* and *O. glaberrima* accessions, evaluate the collection for reaction to sheath blight disease, and develop a set of founder lines for developing at least six sets of BILs with *O. barthii* and *O. glaberrima* genetic backgrounds.

A collection of 107 *O. glaberrima* and 57 *O. barthii* accessions was assembled that originated from 16 different African countries. Sixty-four Asian rice (*O. sativa*) accessions representing the five subpopulation groups (*indica*, *aus*, *temperate japonica*, *tropical japonica*, *aromatic*) were included as controls. To determine the genetic diversity in this collection, genotyping was done using 36 SSR (simple sequence repeat) markers selected from across the rice genome. The genetic diversity in this African rice collection was evaluated using the following software packages: STRUCTURE 2.3.3 to identify the different population groups, GenAlEx 6.4 to perform a principal component analysis (PCA), and PowerMarker 3.5 to dissect the relatedness of the accessions through different cluster analyses.

Four population groups were identified from the STRUCTURE analysis: "population 1" composed of mostly *O. glaberrima* and some *O. barthii* accessions; "population 2" composed of a genetically diverse set of *O. barthii* accessions; "population 3" composed mostly of *O. glaberrima* accessions with a few *O. barthii* accessions; and "population 4" composed of the control *O. sativa* accessions and some *O. glaberrima* accessions which were genetically similar to *O. sativa.* PCA analysis confirmed populations 2 and 4 but grouped populations 1 and 3 together using the first three components. These results agree with the most distinct clusters observed in the cluster analyses. All analyses confirmed the genetic distinctiveness of African rice (*O. glaberrima* and *O. barthii*) from Asian rice (*O. sativa*). Also, we observed greater genetic diversity in *O. barthii* accessions as compared with the *O. glaberrima* accessions.

This African rice collection was evaluated for reaction to sheath blight disease caused by the *Rhizoctonia solani* fungus using the micro-chamber method. Briefly, the method involves culturing *R. solani* on potato dextrose agar (PDA) media, inoculating seedling plants that are 4-6 weeks old with PDA plugs containing fungal mycelia, covering the inoculated seedlings with a 2-liter soft drink bottle (micro-chamber) to create a humid environment, and 7 to 9 days post-inoculation measuring the culm length, length of the disease lesions and rating the disease severity. Preliminary data indicated five *O. glaberrima* accessions and three *O. barthii* accessions exhibited resistance to sheath blight disease. After confirming this resistance, crosses will be made to incorporate this resistance into the background of U.S. rice cultivars through BIL development.

To develop founder lines for the BILs, *O. glaberrima* and *O. barthii* accessions that are genetically distinct based on the diversity analyses were selected as donor parents. Two U.S. rice (*O. sativa*) cultivars were selected as recurrent parents: M-202, a medium-grain t*emperate japonica* cultivar developed in California, and LaGrue, a long-grain, *tropical japonica* cultivar developed in Arkansas. Due to the extreme sterility observed in the F_1 hybrids making it difficult to produce BC_1F_1 seeds, CG-14, a popular *O. glaberrima* which has genome sequence information, was added as a recurrent parent. The observed sterility was confirmed by observing the pollen grains after aceto-carmine staining under a microscope. To date, BC_1F_1 seeds have been produced from crosses with 12 *O. barthii* accessions and three *O. glaberrima* accessions as donor parents and at least one of the *O. sativa* recurrent parents. Crosses with CG-14 are being made with the *O. barthii* and *O. glaberrima* accessions that were successfully crossed with the *O. sativa* parents and are genetically distinct. These BILs will provide a rich genetic resource for crop improvement and translational genomics.

Using a Rice Diversity Panel for Association Mapping and Its Validation

Eizenga, G.C., McClung, A.M., Ali, M.L., Tung, C.-W., Wright, M.H., Mezey, J.G., and McCouch, S.R.

Cultivated Asian rice (*Oryza sativa* L.) has tremendous phenotypic and genotypic diversity that traces back to ancient times. A "Rice Diversity Panel" composed of 413 diverse rice accessions from 82 countries was assembled to explore this genotypic and phenotypic variation. The objectives of this study were to purify the accessions in the panel, collect phenotypic data from the panel accessions in a replicated study, genotype the panel with 44,100 SNP (single nucleotide polymorphism) markers, and conduct a genome-wide association study (GWAS).

The accessions in the panel were purified by single seed decent and grown as space plants in a randomized complete block design with two replications for two years. Phenotypic data were collected at Stuttgart, Arkansas, for 32 traits related to plant development, plant morphology, grain size, grain quality and stress tolerance. The 44,100 (44K) SNPs for the Affymetrix array were selected from the *Oryza*SNP project database (www.oryzasnp.org) and BAC-end sequences of the closely related wild *Oryza* species, *O. nivara* and *O. rufipogon* (www.omap.org).

Analysis of the population structure using principle component analysis (PCA) identified the five rice subpopulations plus those that were admixtures of two or more subpopulation groups. The accessions were placed into subpopulation groups as follows: *indica* (87 accessions), *aus* (57 accessions), *aromatic* (14 accessions), *tropical japonica* (97 accessions), *temperate japonica* (96 accessions) and admixture of two or more subpopulation groups (62 accessions). The first four components accounted for almost half of the genotypic variation in the panel with the first component partitioning the subspecies *Indica* and *Japonica*; the second partitioning *Indica* into the *indica* and *aus* subpopulations; the third partitioning *Japonica* into *temperate* and *tropical japonica* and the fourth separated the *aromatic* subpopulation from the other *O. sativa* subpopulations and admixtures.

The results of GWAS revealed the most significant marker-trait associations with the traits days to heading, plant height, panicle length, panicle branching, seeds per panicle, grain shape (length, width, length:width ratio, volume), pericarp color, amylose, alkali spreading value and rice blast disease. A survey of the literature revealed many of the associations identified in this study could be traced to previously reported genes or QTLs affecting the trait.

To validate the results of the GWAS, four bi-parental mapping populations within *Japonica* are presently under development. The parents in these populations represent the extremes of the phenotypic variation observed for days to heading, plant height, panicle length, number of panicles per plant, primary branch number per panicle, filled grain number per panicle, spikelets per panicle, grain length, grain width, grain length:width ratio and seed weight.

A new Affymetrix SNP array with one million (1M) SNPs has been developed utilizing new SNP data obtained from resequencing 150 diverse accessions (www.ricesnp.org) representing the five *O. sativa* subpopulations, as well as *O. glaberrima* and three wild *Oryza* species (*O. barthii*, *O. nivara*, *O. rufipogon*). Currently, our diversity panel is being genotyped with this new array. Once the genotyping and allele calling are completed, another GWAS will be undertaken using the 1M SNPs and the phenotypic data to determine if improved resolution or additional marker-trait associations can be identified. Preliminary results of this analysis will be presented.

Using the genotypic data from 44K SNPs, GWAS are in progress for additional traits by other individuals or groups. These traits include reaction to aluminum tolerance, panicle architecture, root architecture and ionomics, in which 18 elements are followed during the plant development using ICP-MS (inductively coupled plasma mass spectrometry) technology. Also, the International Rice Research Institute (IRRI) in the Philippines has expanded the number of accessions being genotyped with the 1M SNP array to 2,000 by including an additional 1,440 accessions funded under the GRiSP (Global Rice Science Partnership) network coordinated by IRRI, AfricaRice and the International Center for Tropical Agriculture (CIAT).

Various Mutants Derived from 'Khao Dawk Mali 105' Using Gamma Radiation

Yan, W.G., Hu, B.L., Zhang, Q.J., Jia, L.M., Jackson, A., Huang, B.H., Yan, Z.B., and Deren, C.W.

Mutations induced by radiation and chemicals have been widely used for genetic studies and cultivar improvement. Khao Dawk Mali 105 (KDM105), an aromatic cultivar from Thailand, is globally known for its premium quality. Seeds of KDM105 were obtained from the International Rice Research Institute (IRRI) in 1995. Each seed was given an identification number and grown out in quarantine. Seed harvested from each individual plant was grown in panicle rows to verify uniformity and purity and panicle rows were bulk harvested. One hundred grams of seed derived from a single seed identified as KDM 95-14 were irradiated using gamma radiation generated from Cs-137 inside a gamma cell 1000 at 30 kilorads (KR). After growing an M_1 population in the spring 2000 in Puerto Rico nursery, 2,000 panicles were harvested and the M_2 generation was planted in panicle rows in July 2000 at the University of Florida. Numerous mutants were identified and selfed for three generations for seed increase and characterization in this study. Mutant lines exhibited variation that included changes in plant architecture (height, leaf angle), glume size, and leaf anomalies such as necrotic tips, rolled leaves, white variegation, and extreme stunting. This paper describes the inheritance and characterization of some of these traits.

1). Plant architecture. The mutant exhibits an altered architecture with shorter height, and leaves and panicles that are more erect than the KDM105 wild type. Notably, all characteristics seem to be influenced by a simple, single mutation at a single locus. Crosses between the wild type and the mutant line segregated 3:1 in the F_2 generation (132:46, Chi-square 0.067, p=0.795). The flag leaf on mutant plants was much more erect, such that the angle between the flag leaf and culm was reduced by 104 degrees compared with the wild type. The leaf below the flag leaf was 46 degrees more erect in the mutant than the wild type. The lengths of the flag, 2nd and 3rd leaves were 22, 24, and 16 cm shorter than the wild type, respectively. Plant height, as measured from soil surface to flag leaf tip, was reduced by 44 cm, while plant height measured from soil to panicle tip was reduced by 29 cm in comparison with the wild type.

2). Enlarged glume: Glumes of rice are very reduced and located at the base of the lemma and palea (the hull). The mutant line had greatly enlarged glumes, such that they extended roughly the length of the grain and were lighter in color. In crosses with the wild type, segregation in the F_2 was 3:1 (244:69, Chi-square 0.329, p= 0.566), indicating monogenic inheritance of the recessive mutant type.

3). Necrotic leaves: At about the five-leaf stage, the distal one third of leaves became necrotic. Mutant plants grew more slowly and less vigorously than the wild type. This trait segregated 3:1 in the F_2, again indication monogenic inheritance of a recessive trait (129:42, Chi-square 0.018, p=0.895).

4). Rolled leaves: Commencing at the three-leaf stage, all leaves rolled inwardly all the way to maturity. The F_2 segregation was 114:37, wild type: mutant, with a Chi-square 0.020 and p=0.888.

These mutants were identically monomorphic to the wild type and F_1 hybrid for all of 11 SSR markers covering seven chromosomes, indicating true mutations.

The simple inheritance and easily recognized morphology of these mutant lines, in the background of one of the world's most popular commercial rice types, may have utility in genetic studies or breeding line development.

Genetic Diversity for Rice Grain Mineral Concentrations Observed among Genetically and Geographically Diverse Rice Accessions

Pinson, S.R.M., Tarpley, L., Yeater, K., Yan, W., Lahner, B., Yakubova, E., Guerinot, M.L., and Salt, D.E.

With about half of the world's people dependent on rice as their main food source, improving the nutritional value of rice could have major impact on human health. While rice in the USA is often artificially fortified, natural enhancement of the rice grain's nutritional value, i.e. from genetic improvement, could open new marketing strategies for the nutritionally enhanced, value-added products. Biofortification is a term referring to natural enhancement of the grain/food product through traditional breeding. Since biofortification does not require genetic engineering, it is acceptable to many consumers, and is able to acquire organic certification if grown under organic field conditions. The first step toward breeding rice cultivars with enhanced element composition (ionomics) is to understand the genetic diversity available to breeders in germplasm collections. Furthermore, the element × element interactions and element × plant trait relationships observed therein can implicate mechanisms of mineral uptake, transport, and grain accumulation influencing grain nutritional quality and rice plant nutrition.

A core subset of 1640 accessions from among the 17,000+ rice accessions in the USDA National Small Grains Collection was grown over two years in Beaumont, TX. Because soil redox is known to significantly alter the availability of soil mineral nutrients to plant uptake, the diverse rice accessions from more than 100 countries of origin were grown under both flooded and unflooded (flush irrigated) field conditions, two replications per treatment per year. ICP-MS was used to analyze the harvested brown rice for grain concentrations of Mg, P, K, S, Ca, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Mo, and Cd.

Fifteen repeated check-plots per replication documented that environmental variance was low compared with genetic variance but also revealed a gradient among the rice grains harvested throughout the plots that may have been due to soil variance or water depth, both of which varied in a north-south direction within the present study. To account for this environmental trend in the subsequent calculations, subsequent analyses were based on best linear unbiased estimates (BLUEs) calculated for each genotype and element.

Wide differences (from 2x to 100x) in grain concentration were seen among the diverse rice genotypes for all 16 elements. Unflooded fields generally provided greater ionomic variance than did flooded fields, but spatial analysis indicated that for many of the elements, this increased variance was due to environmental variance rather than enhanced genotypic variance. None of the elements were strongly associated with plant height, heading time, or grain shape, suggesting that genetic differences in mineral uptake/transport/accumulation have more effect on grain mineral concentrations than these plant and grain traits.

Statistically significant element × element correlations included P×K (r = -0.97 across both flooded and unflooded conditions), P×Mg (r = 0.95), and Sr×Ca (r = 0.64). K and Mg were more directly correlated with P than each other (r = -0.89). The high association between Ca and Sr was expected because these elements are chemically similar and known to follow the same routes of plant uptake and transport. Although *Arabidopsis* seed studies have also found high correlations between P, Mg, and –K, no underlying chemical network or physiological cause of a P-Mg-K complex are known. All element histograms were skewed with more accessions having low grain concentrations than those having notably high concentrations. This skewing plus the 2- to 100-fold range in grain concentration observed for each element among the set of diverse rices suggests that the high-concentration phenotypes result from a change in one or few genes, and such simply inherited traits can often be molecularly mapped among F_2 progeny. Accessions high in specific elements were sometimes found to have similar genetic or geographic origins. For example, genotypes high in Ca, Mg, P, or K were more likely to be of the *japonica* than of the *indica* subspecies. Other elements were more associated with tropical vs. temperate origins, e.g., high Cu was less prevalent among the temperate *japonicas* than among the tropical *japonicas* or *indicas*, and low As was most common among the temperate *japonica* accessions followed by the tropical *japonica* group, then *indicas*. Four of the five lines highest in Mo-concentration originated from Malaysia, suggesting they share a heritable mechanism underlying their high Mo-concentration. Accessions exhibiting extreme grain mineral concentration for one or more of the observed minerals were crossed to develop segregating progeny populations in which to molecularly map genes affecting rice grain nutritional value and rice plant nutrition.

***Oryza rufipogon* as a Source of Yield Improvement in Cultivated Rice**

Imai, I., McClung, A., Yeater, K., and McCouch, S.

Oryza rufipogon is a wild relative of the cultivated species, *Oryza sativa*, and has been found to possess genes associated with yield improvement and resistance to biotic and abiotic stresses. We have been exploring the use of *O. rufipogon* as a genetic resource for yield improvement in the USA rice gene pool. The aus-like *O. rufipogon* accession, IRGC 105491, which has no apparent agronomic traits of interest, was crossed with the tropical japonica cultivar, Jefferson, which had been released in 1998. Backcrossed progeny (BC2F2) were evaluated in a yield trial and six yield enhancing QTLs were identified on chromosome 1 (1.2), 2 (2.1), 3 (3.2), 6 (6.1), 8 (8.1), and 9 (9.1). Marker-assisted selection was used to backcross to Jefferson in an effort to reduce the size of the targeted introgressions and eliminate the presence of any other background introgressions. In 2007 and 2008, BC3 progeny were evaluated at four flooded field locations, and in 2008, two additional aerobic locations were included. Fifty introgressed lines containing the targeted QTLs (4 to 12 lines per QTL) and 20 controls (sib-lines lacking the targeted QTL) were tested along with Jefferson, Cocodrie, Trenasse, and XL723. Under flooded conditions, at least two introgression lines from each QTL were observed to have significantly higher yield than Jefferson. Although under aerobic conditions the introgressed lines were not significantly different than Jefferson, the highest ranking lines were similar across the two irrigation methods. Lines derived from QTL 2.1 and 6.1 averaged 25% higher yield than Jefferson and lines from QTL 1.1, 2.1, 6.1, and 8.1 had significantly greater resistance to sheath blight disease as determined using an inoculated micro-chamber method. One line from QTL 2.1 (43-2-1) and 6.1 (219-2-9) were tested in the 2009 Uniform Regional Rice Nursery and the QTL 2.1 family was confirmed to have yield potential comparable with cultivars Cocodrie, Trenasse, and Templeton. This demonstrates that *O. rufipogon* improved the yield potential of Jefferson to the level of varieties that were released some 10 years after Jefferson was released. Additional, marker-assisted selection and backcrossing was performed using introgressions lines possessing QTL 2.1 and 6.1. In 2010, eighteen BC4F4s of these QTLs, seven of their original BC3F8 sources, Jefferson, and three check cultivars were evaluated in replicated yield trials at two locations. All but five of the BC4 families had significantly higher yield than Jefferson with lines derived from QTL 2.1 being ranked the highest. However, the BC3F8 line (43-2-1) had the highest yield potential indicating that the background introgressions that were eliminated with subsequent backcrossing (BC4) may have actually contributed to enhanced yield. A set of introgression lines from this study are being made available to the public through the Genetics Stocks *Oryza* collection. In addition, genetic markers linked to the targeted QTLs as well as other *O. rufipogon* background introgressions will be published. These genetic resources can be used by the USA rice breeding community to increase yield of new cultivars through the incorporation of novel genes derived from this wild related species of rice using marker assisted selection.

History of the Arkansas Rice Research and Extension Center

Moldenhauer, K.A.K., Wilson Jr., C.E., and Ahrent, D.K.

The University of Arkansas Division of Agriculture Rice Research and Extension Center began in 1925 when the Arkansas legislature created funding to establish three branch experiment stations to expand the research capacity of the University of Arkansas College of Agriculture. A local consortium of farmers and businessmen in the Stuttgart area realized the importance of having the experiment station located in their area to assist in providing answers to their problems. In 1924 -1925, H.D. Dilday, Homer Dilday, Charles McDougall, and Charles Spicer lead efforts to collect donations from farmers for the purchase of land for an experimental station. A trust was established in Stuttgart to purchase a 160-acre farm from Samuel H. Taggart. Mr. Taggart was paid $14,000 for 160 acres with buildings in July of 1926. On October 21, 1926, George Heartsill Banks was hired as the first Assistant Director of the Rice Branch Experiment Station. On December 13, 1926, he moved into the Taggart house located on the property and the experiment station began operation.

In 1927, the first rice experiments were conducted at the Rice Branch Experiment Station. The first rice researcher employed in 1930 was Dr. Roy Adair, a USDA agronomist who developed five rice cultivars. To date, 41 rice cultivars have been released by the University of Arkansas rice breeding program, many in cooperation with the USDA. Researchers have worked collaboratively using an interdisciplinary approach to solve rice production problems. This allowed a management package with production recommendations to be available to rice growers as new cultivars were released. The cooperation among researchers was expanded by the addition of an extension component. Mr. Bobby Huey, a Rice Extension Specialist, joined the team in 1970. Over the years, research has encompassed the areas of rice breeding and genetics, weed science, physiology, soil fertility, pathology, entomology, and water resources.

The Rice Branch Experiment Station has seen 11 leadership changes since its commencement. Director George Heartsill Banks was followed by L. Clyde Carter in 1937 who remained in charge of the station until 1944. Dr. John W. White was Assistant Director in 1944 through 1948. At that time, he moved to the U of A Fayetteville campus and later became Vice President for Agriculture. He was replaced at the Rice Branch Experiment Station by J. O Dockins who served until 1951. James Campbell served as Director of the Rice Branch Experiment Station until 1953 when Francis J. Williams took over leadership as the Resident Director until 1988. Dr. Thomas Evard served as Interim Director 1988-1989 until Dr. John Robinson was hired in 1989. Dr. Robinson served as Resident Director from 1989-2001. After Dr. Robinson's retirement, Dr. Karen Moldenhauer served as Interim Director 2001-2002. Dr. Christopher Deren was director from 2002 until 2010 and currently Dr. Charles Wilson Jr. is the Director.

During the course of time, there have been several changes to the Station. The original tract of the Rice Branch Experiment Station included 160 acres, and in 1944, an additional 326 acres of land on the west side of the property were purchased. Approximately 166 acres of additional land were acquired on the east side of Arkansas Highway 130 in 1958. Of that, 108 acres were used to provide a reservoir for good water quality. In 1960, another 28 acres was added to the property. The last acquisition of 320 acres was in 1964, which brings the center to its current size of 1,000 acres. The Rice Branch Experiment Station became the Rice Research and Extension Center in 1981 when it was given the dual mission of research and extension of the research to rice producers. Other crops, such as oats, corn, cotton, soybeans, other legumes, and wheat have been included in research projects at the Rice Research and Extension Center.

Rice Kernel Image Analysis using a Statistical Analyzer S21

McKenzie, K.S., Andaya, V.C., and Jodari, F.

The Analyzer S21, (Agromay, Madrid) is a cereal grain inspector that through image processing and subsequent statistical analysis allows the quantification of defects in a sample. The instrument is used for testing white rice and cargo rice but should have application for rice breeding and research.

Exploitation and Utilization of Rice Germplasm Induced by Space-Flight

Wang, H., Guo, T., Liu, Y.Z., Xiao, W.M., Zhang, J.G., and Chen, Z.Q.

Many factors such as high-energy particles, cosmic rays, microgravity, super-high vacuum, magnetic field, etc., in space can induce mutagenesis in plants' seeds traveling with space-flight. Some of the mutations are inheritable and useful for cultivar development. Since 1987 when China lunched breeding programs using space-flight mutation, 69 cultivars have been developed, officially certificated, and commercialized successfully, including rice, wheat, tomato, watermelon, sweet pepper, lotus, cucumber, etc. These achievements have demonstrated that space-flight treatment can be another source to expand genetic diversity and create some mutants that are not resulted from other mutation sources.

The National Engineering Research Center of Plant Space-induced Breeding (NERCPSB) of South China Agricultural University (SCAU) has conducted research on returned rice seeds carried into space by recoverable satellites, high-air balloons, and flying boats and used those mutants in breeding programs for ~15 years. Phenotypical changes due to physiological damage could be observed in M_0 generation. Inheritable mutation could be found from M_1-M_3 generations, which frequency (No. of mutants/No. of investigated plants) was affected by different space environments and rice genotypes. The mutated traits included plant height, tillers, leaf size, panicle size, grain size, disease resistance, grain quality, leaf color, stress resistance, fertility, and so on. For example, the mutated lines with either large panicles or enhanced resistance to blast disease and bacterial blight disease, reduced height, improved grain quality, various colors of leaf, restoring ability to male sterile lines have been identified. Genetic analysis and gene mapping were also carried out using these mutants as materials. Theses mutated traits could be controlled by either single or multiple gene loci. Several genes were identified and mapped from the mutants, including a blast resistance gene *Pi46(t)* in the long arm of chromosome 11 from a mutant H4, a dwarf gene *hd-1* which is different from *sd-1* in chromosome 1, *lac-1(t)* affecting grain amylose content in chromosome 6, *hw-1(t)* controlling green-revertible albino at seedling stage in chromosome 4, etc. A facility is under construction for screening mutated genes more efficiently than our current conditions.

Up to date, 14 rice cultivars have been developed by our research group using space-induced mutants directly or indirectly. Hua-Hang-1 was the first cultivar developed by space-induced breeding in China, which was released in 2001. In average, it yields 6.75~ 8.25 x 10^3 kg/hm^2 and up to 10.54 x 10^3 kg/hm^2 in favorable conditions. Pei-Za-Tai-Feng, a super-hybrid rice made from male parent Tai-Feng-Zhan released from our space-flight breeding with female parent Pei-Ai-64S, has been successfully commercialized since 2005 because of its premium quality, high yield, stress tolerance and wide adaptability. This hybrid yields 8.25~ 9.00 x 10^3 kg/ hm^{2,} in general and up to 10.68 x 10^3 kg/ hm^2 in some cases. Hua-Hang-31, released in 2010, has a premium grain quality, broad resistance to blast, and strong resistance to lodging and coldness with a yield of 8.23~ 9.12 x 10^3 kg/ hm^2 in most cases. Many elite lines are under the pipe-line to become either commercial cultivars or germplasm for breeding and genetic research.

Our studies demonstrate that mutations induced by space-flight are unique to other means of mutation strategies, mutants derived from space-flight could be utilized in gene location and cultivar improvement for yield, and resistances to biotic and abiotic stresses.

Practical Line Screenings and Evaluations of Japonica Rice Mutant Stock

Shin, Y., Jeung, J., Kim, M., Kang, K., Park, H., and Kim, Y.

To establish mass mutant stock to induce modified alleles for elite breeding lines, the Korea japonica cultivar Suweon472 was mutagenized by sodium azide and ethyl methane sulfonate (EMS) at the National Institute of Crop Science. The original cultivar has high yield potential, but it is susceptible to biotic and abiotic stresses like blast, brown plant hopper (BPH), salinity, and so on. The mutant lines were subjected for the screenings against blast, BPH, and salinity. Among 2,500 M3 lines, five resistant mutant lines were detected in the blast nursery. The mutants showed resistance to all seven major isolates of blast pathogen in Korea. One of lines resistant to blast disease was designated as 'Suweon535'. The 2,100 M_6 lines from the original cultivar were screened for BPH and salinity. Only one line among them has shown resistance reaction against Korean biotype 1 of BPH. Three of 45 tentative tolerant lines showed moderate tolerance in salt-added nutrient solution experiment at the seedling stage. The selected mutant lines show that conventional approaches to induce useful allele types could be another cost effective way to acquire favourable allele types, which would have practical breeding values for improving the current leading rice cultivars in Korea.

Hybrid Seed Production Tests at Stuttgart, AR

Deren, C.W., Yan, Z.B., and Yan, W.G.

Hybrid seed production is complicated and difficult compared with seed increase of conventional inbred rice varieties. Some factors to be considered in hybrid seed production include hybrid type (2- or 3-line), geographic location, isolation, parent line planting sequence, spacing, panicle exertion, stigma exertion, and method of pollen distribution. A preliminary seed production test of some 2- and 3-line hybrids was done at Stuttgart, AR, in 2011 to assess some of these factors, particularly the timing of parent line planting. Four restorer lines were planted in single rows, 3 m apart and 15 m long. Thirty-fifty days later the five male-sterile lines were planted in the space between the restorer rows. Some male sterile seed were soaked in water for 2 d and then broadcast into a shallow flood. Other male sterile plants were transplanted at four different growth stages, 10 days apart. At heading, pollen distribution was aided by use of a patent-pending new technology, pushing against the restorer rows with bamboo poles at about 11 am - 1 pm. Seed production in some combinations was less than expected because heading was not synchronized and birds damaged some male-sterile stands. However, some combinations were timed well and produced as much as 2932 kg ha^{-1} of seed.

Diverse Germplasm to Develop Male-Sterile Lines for Hybrid Breeding

Yan, Z.B., Deren, C.W., and Yan, W.G.

Hybrid rice breeding in the United States has depended largely upon male-sterile lines originating in China or from other Asian sources. By contrast, the program in Arkansas has developed all of its male-sterile lines at Stuttgart, using germplasm accessions available in the U.S. Rice Germplasm Collection stored at Aberdeen, ID. Crosses between genetically diverse accessions have resulted in 18 two-line (EMS) and 6 three-line (CMS) male-sterile lines being developed and used in testing hybrid combinations. The accessions were obtained from Indonesia, West Africa, Madagascar, Japan, Sri Lanka, and United States. Several male-sterile lines cross well with locally bred restorers.

Sheath Blight Resistance Increases with an Increase of Putative-Resistant Alleles in Rice

Jia, L., Yan, W., Zhu, C., Jackson, A., Yeater, K., Li, X., Huang, B., Hu, B., McClung, A., and Wu, D.

Rice sheath blight (ShB), caused by the soil-borne fungal pathogen *Rhizoctonia solani* Kühn, is an economically important rice disease worldwide, especially in intensive production systems. Over the past two decades, great effort has been made to explore ShB quantitative trait loci (QTLs) using mapping populations. Over thirty ShB QTLs have been mapped using the methods under field conditions. For the first time, we adopted the strategy of association mapping (AM) to map ShB QTLs in a global germplasm collection from diverse backgrounds.

A mini-core collection of 217 accessions was used for the mapping and was derived from the United States Department of Agriculture (USDA) core collection of 1,794 accessions, representing the genetic diversity of the more than 18,000 accessions in the collection. The 217 accessions were evaluated for ShB resistance using the micro-chamber method (MCM) with checks, 'Lemont' (susceptible) and 'Jasmine85' (resistant), in a randomized complete block design, using six replications between 2008 and 2009. The phenotypic data used in the association mapping were the least square means (LSMs) of ShB severity ratings. Meanwhile, the 217 accessions were genotyped using 154 SSR markers and one indel that covered the entire rice genome with an average genetic distance of 10 cM.

Structure analysis divided the mapping panel into five subgroups and classified each accession to an appropriate subgroup. Inferred by our previous study, the five subgroups were denoted as *temperate japonica* (TEJ), *aus* (AUS), *aromatic* (ARO), *indica* (IND), and *tropical japonica* (TRJ). This conclusion was also supported by principal component analysis (PCA) and cluster analysis. Among the 217 accessions, IND had the most (86) accessions, followed by TRJ (49), AUS (39), TEJ (36), and ARO (7). Among 24 accessions having greater resistance to ShB than the resistant check 'Jasmine85', 20 belonged to IND, two to AUS and one each to TRJ and admix (TRJ-AUS-IND).

Using the best fit model in AM based on Bayesian Information Criterion (BIC) value, 10 marker loci were identified to be significantly associated with ShB resistance at the probability level of 5% or lower, three on chromosome (Chr) 11, two on Chr1, and one each on Chr2, 4, 5, 6 and 8. Ten alleles, each from the identified marker loci, were noted as the 'putative resistant allele' because of their greatest effect in decreasing ShB rating among all the alleles for their respective loci. Further analysis indicated a strong and negative correlation between the ShB severity rating and number of putative resistant alleles (r = -0.535, p<0.0001), indicating the greater number of putative resistant alleles that an accession has, the lower ShB rating and greater resistance it would have. Combined with structure analysis, we found the IND group contained the most accessions that have a large number of putative resistant alleles. The extreme case was the entry GSOR 310389 from IND having the most resistant alleles, eight out of ten.

Our study concluded that 1) marker-assisted breeding for ShB resistance could be conducted on an allelic level by pyramiding resistant alleles in a cultivar, 2) *indica* rice accessions contained most resistant alleles, which is consistent with a general observation that *indica* is more resistant than *japonica,* and 3) the AM showed the great statistical power and efficiency by confirming eight out of 10 identified ShB QTLs in our mapping with previous studies.

Cytoplasmic Effects on DNA Methylation between Male Sterile Line and Its Maintainer in Rice

Xu, P.Z., Yan, W.G., Zhang, H.Y., Jia, L.M., Pan, X.H., and Wu, X.J.

Hybrid rice is advantageous over the traditional one on food production, which is important to support the increasing world's population, especially in the developing countries. Three-line system that has played a major role since the 1970s in rice includes male sterile (A line), its maintainer (B line) and restoring (R line). A and B lines share same nucleus but have different cytoplasm, which is male sterile for the A and fertile for the B. Therefore, any differences between A and B lines are due to cytoplasm. Besides pollen sterility, A line heads 3-4 days later, exserts less portion of panicles, flowers less concentratedly, and is shorter in height than B line. Microarray analysis revealed a variation of expression levels for a large number of nuclear genes between A and B lines, indicating cytoplasmic effects on nuclear gene expression.

Recently, differences of cytosine methylation in DNA between reciprocal hybrids have been reported in rice. DNA methylation is known to play an important role on regulating gene expression in eukaryotes. Inspired by these reports, our objective for this study was to characterize cytoplasmic effects on cytosine methylation using popular A and B lines in Chinese hybrid rice production. Four different A lines (Jin23A, G46A, D62A and II-32A) representing four major cytoplasmic male sterile (CMS) types (WA-type, G-type, D-type and Yinshui-type), respectively and their corresponding B lines (Jin23B, G46B, D62B and II-32B) were comparatively studied.

Genomic DNA was extracted from same organ tissues of the experimental materials in seedling stage. Methylation-sensitive amplified polymorphism (MSAP) technique was applied to DNA digestion using two restricted enzyme combinations, *EcoR I+Msp I* and *EcoR I+Hpa II,* separately. Twelve pairs of primers were selected to detect cytosine methylation at 5'-CCGG site after electrophoresis. The methylation was indicated by either presence or absence of fragments in the gel.

Among the four pairs of rice lines, a total of 350 fragments were amplified. The degrees of DNA cytosine methylation ranged from 16.56 to 20.43% among the eight lines. All the A lines had lower cytosine-methylated degree than their corresponding B lines with the most difference of 3.05% for WA-type (Jin23A - 17.38 and Jin23B - 20.43), followed by 2.40% for Yinshui-type (II-32A - 17.96 and II-32B – 20.36), 1.23% for D-type (D62A - 18.94 and D62B – 20.17) and 0.62% for G-type (G46A – 16.56 and G46B – 17.18). A and B lines are polymorphic for a type of CMS if DNA methylation happens in only one of the lines for a fragment or restricted site. There were 20 polymorphic sites between the A line and B lines in WA-type and Yinshui-type, but only five polymorphic sites in G-type and D-type.

Indicated by the above results, we reached the following conclusions: 1) rice cytoplasm affected DNA methylation in the nuclear genome and male sterile cytoplasm decreased the degree of cytosine methylation in comparison with fertile cytoplasm; 2) decrease levels classified the four male sterile cytoplasms in two groups, high (WA-type and Yinshui-type) and low (G-type and D-type); and 3) the decrease level was positively associated with the number of polymorphic sites of DNA methylation. Thus, the number of polymorphic sites should be another estimator on cytoplasmic effect.

A previous study has shown that methylation polymorphism could also be taken as a useful tool to detect the genetic distance. Gambiaka Kokoum and Dissi D52/37, *indica* cultivars in Mali of West Africa, are the donors of male sterile cytoplasm to G-type and D-type, respectively. The donor to WA-type is a male sterile plant of common wild rice *Oryza sativa* L.f. *spontanea*. Yinshui-type's donor used to be a cultivar in Indonesia, Shui Tian Gu 6. Their donors for fertile cytoplasm and nucleus are all *indica* breeding lines in China. Therefore, the differences of cytoplasmic effects on DNA methylation and polymorphism may be related to the genetic distance of donor parents for male sterile cytoplasm and nucleus.

Heterosis in Grain Yield and Yield Components of Rice

Samonte, S.O.P.B., Wilson, L.T., and Medley, J.C.

Hybrids exhibit either positive or negative heterosis for grain yield and its yield components. This study was conducted to determine the significance and magnitude of midparent and standard heterosis levels of hybrids produced from cytoplasmic male-sterile line x restorer line crosses.

Check cultivars Cocodrie and Presidio and three hybrids and their parents, which were three restorers (IR64, Minghui 63, and IR30) and an *indica* cytoplasmic male sterile line, were evaluated in a replicated yield trial at the Texas AgriLife Research and Extension Center at Beaumont, TX, in 2011. These genotypes were evaluated for the mass and nitrogen content of leaves, stems, roots, and panicles of main culms and tillers, plant height, numbers of tillers and panicles per plant, number of days to heading, panicle length, and grain yield. Midparent and standard heterosis were estimated.

Hybrids produced using IR64, IR30, and Minghui 63 as restorers resulted in midparent heterosis levels for grain yield of -19.6, 12.1, and 46.3%, respectively. Standard heterosis levels for grain yield were -63.3. 1.0, and 13.6%, respectively, when compared with Cocodrie (8,067 kg/ha) and were -77.4, -7.6, and 6.1%, respectively, when compared with Presidio (8,764 kg/ha). Parameter values and heterosis estimates of the check cultivars, hybrids, and their parents will be presented for the other 21 yield-related traits estimated. Inter-relationships among traits of hybrids and their parents will also be presented. This study provides insights into the contribution of traits to grain yield in inbreds and hybrids.

Rice Cultivar Stability in Large Yield Trials

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

Stable rice cultivars are desired for use in commercial production or as checks in experiments. The Uniform Regional Rice Nursery (URRN) is a large yield trial, consisting of seven blocks that contain 40 plots each, and rice entries are compared within each block and across blocks. This study determined the significance and magnitude of variation in grain yield and yield-related traits within each check cultivar across blocks of the URRN.

Two replicated plots of each cultivar (Francis, Spring, Trenasse, and Wells) were added to each of the seven blocks of the URRN trials at Beaumont in 2009 and 2010. Soil analyses for pH and concentrations of N, P, K, Ca, Mg, S, Na, Fe, Zn, Mn, and Cu, and cultivar performance evaluations for 10 traits were conducted.

There were no significant differences among blocks based on the soil analyses results. Spring was the most stable cultivar in 2009 and 2010, as it showed no significant differences among the seven blocks in any of the 10 traits measured. Francis showed significant differences in number of days to heading in 2009 and in whole milled rice percentage in 2010. Trenasse and Wells showed significant differences for number of days to heading in 2009. In 2010, Trenasse showed significant differences in whole grain and total milling yield, whereas Wells showed differences in tiller and panicle densities. The trait that showed the most instances of significant differences among blocks was number of days to heading followed by whole grain milling yield. Traits that showed no instance of significant differences among blocks for all cultivars were mass per panicle, panicle length, chlorophyll reading, plant height, and grain yield. This study demonstrated the importance of analyzing the soil fertility levels in each block and the importance of evaluating the stability of check cultivars. Information from this type of study enables researchers to better interpret results from large yield trials or experiments.

Variation in Percent Green Grain after Heading of Elite Rice Lines and their Correlation with Main Crop Grain Yield and Milling Traits

Tabien, R.E., Harper, C.L., Samonte, S.O.P.B., and Frank, P.M.

Different plant organs are known to contribute photosynthates to grain or fruit development. However, the leaves are known to be the key organs for photosynthesis and carbohydrate production. Due to the presence of chlorophyll in non-leaf organs, such as stems, branches, leaf sheaths, floral parts, and fruits, these may have unique photosynthetic functions and may play an important role in grain and fruit production. It was reported that about 40 to 50% of the grain mass per year in wheat is contributed by non-leaf green organs, such as ears and peduncles. This was higher than the total contribution of the flag leaves and penultimate leaf blades. In rice, the flag leaf was reported to be the most important leaf in landraces, but the next two leaves were equally important in modern high yielding types. Rice panicles, particularly the florets, are all green at flowering. It is a hypothesis that the lemma and palea of the rice floret have an important contribution in filling the grain and milling quality. A study was conducted for three years using the entries at the Uniform Regional Rice Nursery (URRN) with the objective of determining the variation in the percentage of green grain among genotypes and their relation to main crop grain yield and milling traits. Days to 50% flowering (heading) and percent green grain of panicles in a plot were estimated at 30 and 37 days after heading (DAH). Yield was estimated at 12% moisture while milling traits (percent whole and total milled rice) were obtained using the standard protocol.

In 200 breeding lines that were evaluated for three years, only 41 entries were common across years and were included in the data analyses. Highly significant variations among years, entries, and their interaction were noted in percent green grain at 30 and 37 days after heading, percent change from 30 to 37 DAH, main crop yield, and percent whole and total milled rice. Analyses of the 41 entries by year revealed the same highly significant variation. Pairwise correlation analyses indicated that percent green grain at 30 and 37 DAH were positively correlated with whole and total milled rice percentages. Percent green grain at 37 DAH was positively related to main crop grain yield but not the percent green grain at 30 DAH.

Screening for Herbicide Tolerance and Evaluating Yield Performance in Herbicide-Sprayed Plots

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

Weeds are major constraints in direct-seeded rice, particularly weedy red rice. Being nearly like the cultivated rice, red rice is difficult to control. Presence of red grains in milled rice can greatly reduce price, thus red rice-free fields are ideal. Most of the recommended herbicide can spare red rice during weed control as these chemicals will not affect both rice and red rice. The identification of a gene called *bar* or *pat* gene which can tolerate the application of glufosinate, a non-selective herbicide and genetic engineering were considered to be the answer in the development of herbicide-resistant rice. However, the acceptability of genetically modified rice (GM rice) has not been realized. Screening rice germplasm, breeding lines, and mutants for tolerance to the application of glufosinate (Liberty herbicide) and glyphosate (Roundup herbicide) was conducted to identify donors for herbicide tolerance. Entries that were planted in panicle to a row were sprayed 4 weeks after emergence using the recommended rate. Several tolerant genotypes have been selected and advanced for Liberty but not for Roundup. The Liberty-tolerant materials had herbicide spray damage. The leaf desiccation can be observed in all cases but was significantly less severe than the susceptible genotypes. These materials can recover faster and produce fertile seeds. In 2011, these selections were sprayed using twice the recommended rate of Liberty herbicide. Several lines were killed but some had slow desiccation or were partially desiccated and were able to produce new leaves and tillers. Most of the survivors were shorter but were able to produce seeds. Some entries had more plant survivors than the rest, but a group of lines from a cross was found to produce more surviving plants.

Thirty-seven of the most tolerant lines to the application of Liberty herbicide and three checks were evaluated in replicated sprayed and not-sprayed plots in 2010 and 2011. The duplicate plots that were not sprayed were used as basis to evaluate the effects of spraying on several traits, including grain yield. Liberty herbicide was sprayed 4 weeks after emergence using the recommended rate. Significant variations among entries in plant height, heading date, main crop grain yield, percent total milled rice, and percent head rice both in sprayed and unsprayed plots were noted. Spraying caused reduction in plant height and delayed flowering and maturity in most of the entries. Similarly, grain yield and milling traits were mostly lower in sprayed plots. Comparison of means between sprayed and unsprayed plots, however, indicated that some entries had comparable main crop grain yield and or milling quality.

Identification of Expressed Genes in the Mapped QTLs for Yield Related Traits in Rice

Venu, R.C., Jia, Y., Liu, G., Jia, M.H., Nobuta, K., Sreerekha, M.V., Moldenhauer, K., Pellegrini, M.,
Jacobsen, S., McClung, A., Meyers, B. and Wang, G.-L.

Improvement of grain yield is a perpetual goal in rice breeding. Yield and its component traits are quantitatively inherited and controlled by many genes. To identify the Quantitative Trait Loci (QTL) involved in yield, a recombinant inbred line (RIL) population consisting of 259 progeny was developed from a cross between *japonica* cultivar Nipponbare and *indica* cultivar 93-11 using a single seed descent method. Phenotypic characterization of yield related traits (number of days to heading, lodging, tiller angle, number of tillers, number of days to harvest, panicle length, number of branches in the main panicle, number of kernels per main panicle, thousand grain weight and total yield per plant) in the RILs and parents was performed in field studies conducted at Dale Bumpers National Rice Research Center (DBNRRC), Stuttgart, Arkansas (Years 2009, 2010, 2011), and Rice Research Unit (RRU), Beaumont, Texas (years 2009 and 2010), and in a greenhouse study during 2010-2011 at DBNRRC. Transgressive segregation was observed among the RILs for number of days to heading, number of days to harvest, plant height, number of tillers per plant, number of kernels per main panicle and total grain yield per plant. A total of 259 F_5-F_7 RILs were genotyped with 131 simple sequence repeat (SSR) markers. Composite interval mapping (CIM) was conducted using Windows QTL Cartographer (version 2.5) to identify QTL affecting each yield-related trait. More than 60 QTL related to yield traits have been mapped. Several novel QTLs related to tiller angle, panicle length, days to heading, number of primary branches per panicle, number grains per panicle and grain yield per panicle have been identified. Using Massively Parallel Signature Sequencing (MPSS) technology, the leaf, root and meristem transcriptomes in the parents (Nipponbare and 93-11) and their F_1 hybrids were sequenced. Sequence analyses identified many up-regulated genes in F_1 hybrid located in the mapped yield QTL regions. Further characterization of these candidate genes in the QTL regions will lead the development of new DNA markers for rice yield improvement.

Breeding for Salt Tolerance in Rice

Subudhi, P.K., Sha, X., and Linscombe, S.

Salinity poses a major challenge for rice farmers in coastal areas of Louisiana due to salt water intrusion. It is expected to be more pronounced in the future due to the continuing process of climate change. Rice is an attractive model for genomic investigations of stress adaptation mechanisms due to availability of abundant public genomic and diverse germplasm resources. The long-term goal of this project is to develop rice varieties with enhanced salinity tolerance. However, to achieve this goal, clear understanding of the genetic basis of the complex salinity tolerance mechanisms is needed. This will be accomplished through the development and genetic characterization of several mapping populations developed from crosses involving well known salt-tolerant germplasm.

A preliminary salt screening experiment using seven rice genotypes in hydroponics demonstrated that Pokkali (IRRI Acc No. IRGC 108921) was the best performing genotype under 150 mM salt stress at seedling stage followed by Nonabokra (IRRI Acc. No. IRGC 22710) and Geumgangbyeo (PI 464588). Pokkali and Nonabokra are the most notable germplasm commonly used for breeding salt-tolerant rice varieties worldwide. Geumgangbyeo is a South Korean semi-dwarf variety listed as a salt-tolerant rice variety in the USDA-National Small Grains Collection Germplasm Resources Information Network (GRIN) database. Pokkali continued to survive even after 2 weeks, whereas the high yielding U.S. cultivar Bengal suffered serious damage to vegetative tissue resulting in death within 3-5 days. Bengal is most susceptible compared with other high yielding rice cultivars (Cypress, Cocodrie, and IR 29). Three days after exposure to 150 mM NaCl, growth of Bengal was severely reduced and most of the seedling attributes except root fresh weight showed higher reduction compared with Pokkali and Nonabokra. Root and shoot dry weights were affected the most in all three genotypes. In the case of root length and shoot dry weight, percentage reduction was significantly less in Pokkali and Nonabokra.

Three hundred thirty-five simple sequence repeat (SSR) markers were surveyed, and 65% of markers were polymorphic between Bengal vs Pokkali or Nonabokra. The polymorphic markers were distributed over all 12 chromosomes. High rate of polymorphism suggests that it would be practicable to assess the coverage and track the introgressed donor segments. To develop chromosome segment substitution lines of the salt-tolerant germplasm ‘Pokkali’, backcrossing was done multiple times using Bengal as female to develop advanced backcross generations. To ensure the coverage of donor genome in advanced backcross population, a set of BC_3F_1 individuals were genotyped. The mean number of introgressed Pokkali segments was six with 88% of their genomic composition from the recurrent parent. The graphical genotyping of these individuals indicated that whole Pokkali genome was represented and the CSSLs developed from these individuals should be adequate for genome-wide search for QTLs controlling salt tolerance attributes. One more backcross was performed and a BC_4F_2 population is now available to identify homozygous CSSLs with fewer donor segments for QTL mapping. In addition, a recombinant inbred line (RIL) population from ‘Bengal x Pokkali’ is also under development and currently it is in $F_{5:6}$ generation. The RIL and CSSL populations are developed simultaneously because both populations can complement each other toward successful QTL identification and QTL cloning. In case of another cross ‘Bengal x Nonabokra’, a BIL (Backcross Inbred Lines) population has been developed as a permanent genetic resource for QTL mapping and gene discovery.

The discovery of genes responsible for abiotic stress tolerance, as well as introgression lines, will provide excellent resources for the rice breeding program to transfer salinity tolerance traits to advanced breeding lines through conventional backcross breeding coupled with marker-assisted selection.

Can Rice Grain Mineral Concentrations Be Predicted at Seedling Stage?

Ratnaprabha, R., Pinson, S.R., and Tarpley, L.

The study investigated the possibility of using the mineral (ionomic) concentrations of rice (*Oryza sativa* L.) seedling leaves to predict genotypes that accumulate large amounts of certain minerals in their grains. This information will be used for genetically improving the nutritional value of rice grain and for improving our understanding of mineral uptake, transport, and accumulation in rice. In 2007 and 2008, preliminary field trials were conducted on a core subset of 1640 rice accessions from the USDA National Small Grains Collection. These flooded and unflooded trials identified germplasm with varying levels of grain mineral concentrations. The present study investigated association between seedling-leaf and grain mineral concentrations of 16 minerals within this diverse set of germplasm to determine if seedling leaf data could be used to predict grain concentrations. Such association could greatly accelerate breeding efforts aimed at developing rice genotypes with improved grain mineral composition (nutritional value). The 40 rice genotypes selected for their extreme grain mineral concentrations were grown in an outdoor potted plant study in 2010. All 40 genotypes were planted in 7- to 10-day intervals to provide, on a single sampling date, 70 days after planting of the first set, plants of a wide range of developmental stages. Leaf tips (5 cm) for ionomic analysis were collected from the most recently fully emerged leaf per plant. For molybdenum (Mo), several genotypes selected for their high grain-Mo concentrations, were found to consistently exhibit high leaf-Mo concentrations, implying that seedling leaf tips can be used to a) select among F_2s and b) select among diverse germplasm sets. For calcium (Ca), some genotypes selected for high grain-Ca concentrations exhibited high leaf-Ca concentrations. For Arsenic (As) and Cadmium (Cd), some genotypes selected for high grain-As or Cd concentration exhibited high seedling-leaf As or Cd concentrations. Enhanced seedling-leaf sodium (Na) concentrations seemed a better predictor of high grain potassium (K) than did seedling leaf K content. It is possible that different genotypes have different physiological mechanisms underlying their high-grain concentrations of particular minerals, some of which may be reflected in seedling leaves, others not. Observations of F_2 progeny leaf and grain mineral concentrations will be used to further investigate the relationship between grain and leaf concentrations of Mo, Ca, As and Cd. For the remaining 10 elements (Fe, Sr, Cu, Mg, Mn, Ni, P, Rb, S, and Zn), seedling leaf concentration did not appear predictive of grain element content, neither in the high nor low directions. Funded by NSF DBI 070111.

Is Early-Generation Selection for Aroma and Grain Appearance Effective?

Sha, X.Y., Linscombe, S.D., Theunissen, S.J., and Henry, B.J.

A small but productive breeding program is the only feasible and rational way for the development of aromatic rice cultivars for the fast-growing specialty rice niche market in the United States. To achieve this, we proposed a scheme in the 30th RTWG (2004) involving rigorous early-mid generation selection for aroma and grain appearance (measured by grain clarity and uniformity), as well as intra-crosses among different aromatic parents, which should enable us to concentrate limited resource only on the aromatic progenies throughout the breeding process. Since then, such schemes have been routinely practiced in our specialty rice breeding program. To closely examine the effectiveness and identify potential areas for further improvement, aroma and grain appearance scores of pedigree nursery selections from three consecutive generations (from 2009-2011) were compared to determine the efficiency of different cross combinations and selection methods for the recovery of target traits.

Cross combinations include aromatic x aromatic, conventional x aromatic, and three-way crosses that are made by crossing a conventional x aromatic F_1 with a different aromatic parent. Selection was carried out by using either pedigree or modified pedigree, which involved one or two generation bulks after F_2 before pedigree selection initiated. A small amount of F_3-F_7 seed was harvested by stripping from the selected panicle row after a certain number of panicles were picked. Freshly dehusked brown rice of those small samples was visually rated for grain clarity (translucency) and grain shape and uniformity before being evaluated for the presence of aroma. A modified test tube cooking method was used for the detection of aroma. The procedure involves placing 1 gram of brown rice in a 16 x 150 mm test tube containing 10 ml dH_2O, covering it with a stainless steel cap, cooking in a boiling water bath for 25 minutes, sniffing the sample after it cools down, and rating it either aromatic or non-aromatic. By analyzing aroma and grain appearance scores of 1058 lines of 2011 selections, efficiency of different cross combinations and selection schemes were compared. Furthermore, by comparing the aroma scores of the 1058 lines with that of their previous generations, the effectiveness of early generation selection was evaluated.

Our results indicated that 80% of 1058 tested lines were aromatic. Aromatic x aromatic crosses produced the most aromatic lines among three cross combinations at 89%, followed by three-way and conventional x aromatic crosses at 76 and 74%, respectively. About 83% of lines selected by the pedigree method were aromatic compared with 74% using modified pedigree selection that involves one or two generations of additional bulking. By comparing aroma scores of 418 different lines in consecutive generations, 88% of lines that were scored as aromatic the previous generation were again scored as aromatic, where 86% of lines maintained aromatic scores for three consecutive generations. Parent-offspring regression analysis of visual subjective ratings of grain appearance revealed that narrow sense heritability of grain clarity and uniformity was 0.28 and 0.03, respectively. Our results confirmed our previous claim that early generation selection for aroma may slightly reduce the chance of recovering aromatic genotypes; however, it is well compensated for by eliminating a majority of non-aromatic ones in the early generations.

Effects of Seeding Rates and Seed Treatments on Flowering Date and Flowering Duration of Hybrid Rice Parental Lines

Sha, X.Y., Li, W.K., Linscombe, S.D., Theunissen, S.J., and Henry, B.J.

Synchronized flowering of male and female parents must be achieved to ensure successful hybrid seed production. Even though maturity (date to 50% heading) of hybrid parental lines can be bred through pedigree selection, subtle differential reactions to changing environmental conditions over time and location will result in missing the narrow flowering window (7-10d) by either parents. Lowing seeding rate will stimulate more secondary or tertiary tillers that normally flower later than the main tiller; which also delays the initial heading and extends the flowering duration. Gibberellic acid (GA) has been routinely used as a seed treatment to enhance rapid and uniform germination and stand establishment. These two practices alone or in combination should be able to facilitate synchronized flowering in hybrid rice seed production. This study was designed to investigate how the heading date and flowering duration of selected hybrid parental lines were affected by different seeding rates, as well as seed treatment with GA.

Three hybrid rice parental lines used in the study were CL151, 08A, and 08B; the latter two are cytoplasmic male sterile (CMS)/maintainer paired isogenic sister lines. Two seeding rates used were the normal 112 kg ha^{-1} and a reduced 28 kg ha^{-1} (25% of normal rate). Prior to planting, all seeds were treated with a mixture of chemicals that was only different in the presence or absence of GA. A randomized complete block design with two replications was used. Plots measured 1.7 x 4.9 m and were planted at the Rice Research Station near Crowley, LA, on March 29, 2011. Typical recommended cultural practices were used in the study. Date of emergence, initial heading (10%), mid-heading (50%) and late-heading (80%) were visually estimated and recorded. Data were analyzed by using the proc glm procedure of SAS version 9.1 (SAS, Cary, NC).

Results from the analysis of variance indicated that seeding rate had a significant effect on both emergence, as well as days to 10, 50, and 80% heading. In contrast, seed treatment with GA failed to show any significant effects on both emergence and heading. Three parental lines were significantly different on days to 10, 50, and 80% heading but not on emergence. No significant interactions were found among different treatments except for seeding rates by GA on emergence. On average, the low seeding rate delayed initial heading by 2, 3, and 2 d; heading by 2.3, 3.3, and 2.3 d; and full heading by 3, 3.5, and 1.3 d of 08A, 08B, and CL151, respectively. Even though statistically insignificant, the low seeding rate numerically extended the flowering duration of 08A and 08B by 1 and 0.5 d, respectively. Our preliminary results suggest that heading dates of selected CMS A and B lines can be altered by applying lower seeding rates, which should facilitate the synchronized flowering of two parents that are slightly different in maturity.

Restoring Abilities of U.S. Long-Grain Rice Genotypes to Selected Chinese Cytoplasmic Male Sterile Lines

Sha, X.Y., Li, W.K., Linscombe, S.D., Oard, J.H., Theunissen, S.J., and Henry, B.J.

The landmark breakthrough of commercialization of hybrid rice can be primarily contributed to the accidental discovery of cytoplasmic male sterility (CMS) in early 1970s, which still remains the predominant form of male sterility some 40 years later and used by major hybrid rice growing countries throughout Asia. It is generally agreed upon by the science community that interaction between sterility gene(s) existing in the cytoplasm and two pair of fertility/sterility genes existing in the nucleus determines fertility of a given cross. A CMS A and its paired isogenic sister line B (also called maintainer line), which has normal cytoplasm therefore is fertile, lack the fertility genes in their nuclei, and the hybrid between them remains sterile and identical to female CMS A line. This process is called (A line) multiplication. In order to develop a commercial hybrid, a pollinator (restorer line) has to be identified or bred, which once crossed to a CMS A line will produce a hybrid with normal seed set. Right after the discovery of the wild abortive type CMS, Chinese researchers launched a massive test cross program to identify rice varieties/lines that would either maintain or restore the sterility. It was found that some varieties/lines introduced from tropical southeast Asia, as well as some of their derived lines were able to serve as pollinators to produce hybrids with normal seed set, some early season Chinese indica varieties/lines were able to maintain the sterility, however, most varieties/lines fell in between. A large scale test crossing study has been carried out at the Louisiana State University Agricultural Center's Rice Research Station (LSU AgCenter RRS) since the introduction of Chinese CMS lines in early 2009. By crossing those Chinese CMS lines with all available U.S. long-grain germplasm and evaluating the fertility/sterility of the hybrids, we should be able to identify potential maintainer and restorer lines that would be used in further test crossing or in the breeding of adapted new hybrid lines and to develop potential hybrids for direct commercial production.

In last two years, a total of 462 test crosses were made between six recently introduced Chinese CMS lines and 221 different varieties or lines from southern United States and California. All of them were evaluated in the Observational Hybrid Yield Trials planted by using a Hege row planter at the LSU AgCenter RRS near Crowley, LA, in both 2010 and 2011. The fertility/sterility of all test crosses were evaluated by the visual estimation of seed set, while some of them were also checked for pollen sterility. Test crosses with more than 35% seed set were also hand-harvested for yield, milling, and physicochemical analysis, while days to 50% heading and plant height of these test crosses were also recorded. Results indicated that about 70 or 32% U.S. genotypes were able to at least partially restore the fertility to the Chinese CMS lines, while the rest appeared to be maintainer lines to those CMS lines. A close examination of 11 U.S. long-grain lines that produced hybrids with normal or close to normal seed set suggested that their nucleic fertility gene(s) most likely were derived from ancestral lines, such as Teqing, Zhe 733, IR36, and Taducan. Even though further evaluation, especially bagged selfing and pollen sterility validation, is needed to verify our findings, the newly identified lines should serve as critical building blocks for further test crossing and the development of adapted restorer lines.

Engineering Rice for Elevated Vitamin C Content

Lisko, K.A., Wilson, G.A., Hubstenberger, J.F., Underwood, J., Srivastava, V., Phillips, G.C., and Lorence, A.

Statement of Rationale: Engineer elevated vitamin C content in rice to enhance biomass, growth, and stress tolerance.

Vitamin C (ascorbic acid, AsA) is an important antioxidant for both plants and animals. Ascorbate is the most abundant water-soluble antioxidant and is involved in several key processes in plant physiology, including photosynthesis, cell division, growth, flowering, and senescence. In addition, AsA is also an enzyme cofactor. During exposure to abiotic stresses, AsA counteracts excessive reactive oxygen species within the cell and protects key molecules, including lipids, proteins, and nucleic acids from irreversible damage. In this study, we focus on understanding how vitamin C levels are controlled in rice and using this knowledge to engineer elevated AsA levels in this important crop.

In order to understand how vitamin C content is regulated in rice, we have taken two approaches. First, we have established how foliar AsA content varies as plants develop and age. In order to do this, we have grown multiple rice varieties in soil and have measured foliar AsA content at various developmental stages. Total, reduced, and oxidized AsA has been measured using an enzyme-based spectrophotometric method we recently adapted to a 96-well plate format. Next, we have performed feeding studies on detached leaves using a suite of stable intermediates that participate in the four known biosynthetic pathways leading to AsA formation. Substrate feeding was performed at the V3 and V4 developmental stages supplementing the media with 5 mM of substrate, and collecting samples after 0, 4, 8, 12, 16, or 24 h. We have also developed constructs where a *myo*-inositol oxygenase (MIOX) or an L-gulono-1,4-lactone oxidase cDNAs have been placed under the control of the ubiquitin promoter. These constructs were transformed in rice varieties Nipponbare and Taipei by the Srivastava group.

Our results indicate that vitamin C metabolism in rice has a very unique pattern compared with other species studied by the Lorence group. The steady state foliar AsA in several rice varieties increases during development and peaks at the V2 and R4 stages, whereas in Arabidopsis, tobacco, tomato, morning glories, and lupins foliar AsA content declines with age. Preliminary results from substrate feeding show that *myo*-inositol, L-gulose, and L-galactose are converted to AsA by detached leaves, indicating the operation of the D-mannose/L-galactose, L-gulose, and *myo*-inositol pathways in rice. We have confirmed the presence of the transgene in the MIOX and GLOase rice over-expressers by PCR. In addition, we have confirmed that these lines are expressing the genes of interests by RT-PCR. Our AsA measurements indicate that MIOX and GLOase over-expression leads to enhanced vitamin C content in these rice varieties. Our future plans include completing the feeding studies and analyzing the expression of key genes that participate in the various routes involved in AsA synthesis via quantitative RT-PCR. We also plan to determine if as in Arabidopsis, in rice MIOX and GLOase expression leads to enhanced biomass, growth, tolerance to abiotic stresses.

Development of Quantitative Trait Loci (QTL) Mapping and Breeding Programs to Improve Rice Resistance to Bacterial Panicle Blight and Sheath Blight

Shrestha, B.K., Karki, H.S., Groth, D.E., Sha, X., Subudhi, P.K., Utomo, H., and Ham, J.H.

Diseases caused by a variety of pathogenic microorganisms are important limiting factors for stable rice production, and significant amount of resources is wasted annually for chemical control of diseases and pests. In this regard, growing disease-resistant cultivars is a cost-effective and environment-friendly method for disease management. Especially, it would be ideal if a rice line could possess disease resistance traits against multiple diseases. In Louisiana, bacterial panicle blight (BPB), caused by the bacterial pathogens *Burkholderia glumae* and *B. gladioli*, and sheath blight (SB), caused by the fungal pathogen *Rhizoctonia solani*, are chronic rice diseases producing severe economic damages. The medium-grain variety, Jupiter, and the long-grain line, LM-1, show high levels of partial resistance to both BPB and SB. The objectives of this study are to characterize the QTL for the disease resistance traits of Jupiter and LM-1 to BPB and SB and to develop new disease-resistant lines using Jupiter and LM-1 as genetic sources of broad-spectrum disease resistance to BPB and SB.

For genetic mapping of the QTL associated with the partial disease resistance to BPB and SB, four mapping populations have been generated with the following procedure. Jupiter and LM-1 were initially crossed with Trenasse and Bengal, which are both highly susceptible to BPB and highly susceptible and moderately susceptible to SB, respectively. By the end of the 2011 growing season, 300 F_5 recombinant inbred lines (RILs) derived from each of LM-1/Trenasse, Jupiter/Trenasse, LM-1/Bengal and Jupiter/Bengal crosses, have been obtained by generation advancement at both the field of the LSU AgCenter Rice Research Station and a greenhouse on the LSU Baton Rouge campus. For each RIL population, segregation patterns of the partial resistance to BPB and SB were determined as well. For marker-assisted QTL mapping, screening of 900 simple sequence repeat (SSR) markers resulted in 142, 185, 154, and 148 markers showing polymorphism between Trenasse and LM-1, Trenasse and Jupiter, Bengal and LM-1, and Bengal and Jupiter, respectively. More SSR markers are being screened to obtain enough numbers (> 200) of polymorphic markers for QTL mapping with each mapping population from different parental sets.

For developing new rice lines resistant to both SB and BPB, Jupiter and LM-1 were crossed with disease susceptible commercial cultivars, Trenasse, Bengal, and Cocodrie, and with each other. In 2009, more than 3,000 F_2 plants from the above cross combinations were tested for disease resistance to BPB and 411 F_2 plants showing relatively higher levels of disease resistance were primarily selected. In 2010, ~ 6,000 F_3 progenies from the selected F_2 plants were grown in the field and challenged with both *R. solani* and *B. glumae* at different growth stages. In 2011, F_4 progenies from 396 F_3 plants, which showed high levels of disease resistance to both SB and BPB in 2010, were grown as panicle rows and each row of F_4 plants derived from individual F_3 plants was tested for the resistance to both SB and BPB. Finally, ~ 30 F_4 RILs showing good disease resistance phenotypes were selected in the 2011 growing season. Their agronomic traits, including yield, grain quality and milling characteristics, as well as disease resistance, will be tested next year to select promising lines.

Rich Phenotypic and Genotypic Variation Found in a "Rice Diversity Panel"

Ali, M.L., Hancock, T.A., DeClerck, G.A., McClung, A.M., McCouch, S.R. and Eizenga, G.C.

A "Rice Diversity Panel" composed of 413 purified accessions originating from 82 countries was fingerprinted with 36 SSR (simple sequence repeat) and 44,100 SNP (single nucleotide polymorphism) markers. Based on both SSR and SNP markers, the accessions were grouped into five distinct subpopulations, *indica*, *aus*, *temperate japonica*, *tropical japonica*, *aromatic* (Group V), or admixture, which has two or more subpopulation groups represented. Both marker types grouped the accessions into nearly the same subpopulation groups. Phenotypic data were collected from three representative plants of each accession in two replications grown in the field for two different years. This panel was systematically phenotyped for 34 agro-morphological traits, including three quality traits, amylose content, protein content, and alkali spreading value (ASV) which is a measure of gelatinization temperature.

Differences between the accessions and subpopulations were assessed based on eight agro-morphological traits (plant height, panicle number per plant, panicle length, flag leaf width, grain length, grain width, grain length:width ratio, and grain volume) using canonical discriminant analysis (CDA) in procedure CANDISC (SAS software) and between the pairs of subpopulation group means for the individual traits by t-tests and LSD values using procedure ANOVA (SAS software). These traits were the main discriminatory traits based on our initial CDA analysis. The five subpopulations exhibited very significant differences for these eight traits based on t-tests and LSD values. Analysis of the phenotypic data indicated a close relationship between the *aus* and *indica* subpopulations and between the *tropical* and *temperate japonica* subpopulation groups. Phenotypically, the small *aromatic* group was more closely related to both *aus* and *indica* than to the *tropical* or *temperate japonica*.

Data on the three grain quality traits, amylose content, ASV, and protein content analyzed by both CDA and t-tests revealed significant differences between all the subpopulations except *aus* and *indica*. *Aus* had the highest amylose content (25.11%) whereas *temperate japonica* had the lowest (15.93%) and *tropical japonica* had an intermediate amylose content (19.52%). *Temperate japonica* and *indica* had low gelatinization temperatures whereas *aus* and *tropical japonica* had intermediate gelatinization temperatures. Based on t-tests and LSD values, there were significant differences for the quality traits between the 10 geographic regions the panel accessions originated from. Accessions originating from South Asia had the highest amount of amylose (24.16%) while cultivars originating from Central Asia, Europe, and East Asia had amylose content ranging from 16.01 to 17.75%. Accessions from West Asia showed the highest ASV (6.3, low gelatinization temperature) while accessions from Central Asia revealed the lowest ASV (5.17, intermediate gelatinization temperature). The mean differences between accessions from the other regions showed only small differences. With regard to protein content, accessions from Central and West Asia had significantly higher protein content (9.92-9.14%) than accessions from South Asia, Oceania, and East Asia (8.25-8.43%).

Digital images of the panicles and seeds were taken as a reference for the individual accessions and archived. The images of the panicles are available at the Genetic Stocks – *Oryza* (GSOR) website under the miscellaneous collection entitled "NSF Rice Diversity Panel" (http://www.ars.usda.gov/Main/Docs.htm?docid=18825). From the USDA-ARS GRIN (Germplasm Resources Information Network) website (http://www.ars-grin.gov/npgs/acc/ acc_queries.html), the individual accessions can be queried by GSOR number, then select the "Observations" heading to visualize the peak heights for 36 SSR markers and phenotypic data [days to flowering, plant height, lodging, awn type, plant type, panicle type, hull color, bran color, kernel (or grain) length, kernel (or grain) width, kernel (grain) length:width ratio, amylose content, ASV, protein content, reaction to straighthead, and reaction to rice blast disease]. Also, from the Observations link, select "NSF Project" to view the phenotypic data or "RiceDiversity 2011CropSci" to view the SSR data on the entire panel. All data can then be downloaded. (This SSR data is the first molecular data for rice uploaded into the GRIN database.)

Images of the seed are part of the Seed Photo Library (http://www.ricediversity.org/photolibrary/). In this library, images of rough and dehulled seed from several different accessions can be compared side-by-side. Also, the phenotypic data and genotypic data based on the 1,536-SNP Illumina assay and 44,100-SNP Affymetrix array for the panel accessions can be downloaded from the same website (www.ricediversity.org) under "Data Sets". Seeds for all the accessions in this panel are now available for public distribution through GSOR, Stuttgart, Arkansas, and the International Rice Research Institute in the Philippines.

Identification and Validation of QTLs Associated with Concentrations of Mineral Nutrients in Unmilled Grain of Two Mapping Populations Derived from 'Lemont' × 'TeQing'

Pinson, S.R.M., Zhang, M., Tarpley, L., Huang, X., Lahner, B., Yakubova, E., Guerinot, M.L., and Salt, D.E.

Research into the mineral contents of cereal grains and vegetables is motivated by interest in improving their nutritional value. Biofortification refers to natural enhancement of the grain/food product through traditional breeding. Since it does not require genetic engineering, it is acceptable to many consumers, and readily acquires organic certification if the crop is grown under organic field conditions. Enhancing the nutritional value of rice is of particular interest because rice is a primary dietary component for more than half of the world's population, and especially so in underdeveloped parts of the world that have higher rates of malnutrition. But new marketing strategies could be employed in developed countries as well, for value-added products naturally high in consumer-desired minerals such as Ca, K, and Fe or strategically low in undesirable elements such as As or Cd. One critical step toward developing nutritionally improved rice varieties is to identify where the underlying genes reside along the rice chromosomes.

In this study, quantitative trait loci (QTLs) affecting the concentrations of 16 human and plant nutritional and antinutritional elements in whole, unmilled rice grain were identified. Two rice mapping populations were used so that putative QTLs could be identified in one, and verified in the other. The first population analyzed was a set of 280 'Lemont' x 'TeQing' recombinant inbred lines (LT-RILs), complemented by analysis of a set of 123

TeQing-into-Lemont backcross introgression lines (TILs). To increase opportunity to detect and characterize grain-mineral QTLs, the TILs were grown under two contrasting field redox conditions, flooded and unflooded (flush-irrigated). Soil redox is known to alter mineral availability, and so it was expected to affect grain mineral concentrations. The LT-RILs were grown flooded over 5 years, one replication per year, while the TILs were grown under flooded and unflooded conditions over 2 years, two replications per treatment per year. ICP-MS was used to analyze the harvested brown rice for variation in accumulation of 16 elements, namely Mg, P, K, S, Ca, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Mo, and Cd. Correlations between the individual elements and between each element with grain shape, plant height, and time of heading were also studied.

Transgressive segregation was observed among the LT-RILs for all 16 elements. We identified 127 QTLs that affect the grain concentration of individual mineral elements. More QTLs were found significant among flooded TILs (92) than among unflooded TILs (42) or among flooded LT-RILs (40). The 127 QTLs identified as associated with a single-element were found clustered into 40 genomic regions, with each region being often associated with multiple grain elements. Nearly all of the grain element loci were linked to QTLs affecting additional elements, supporting the concept of element networks within plants. Several of the grain element QTLs co-located with QTLs for grain shape, plant height, and days to heading but did not always differ for grain elemental concentration as predicted by those traits alone. A number of interesting element × element patterns were found, including a strong P-Mg-K complex.

Gene-identification studies such as this one are considered exploratory studies. Learning which chromosomal regions contain genes affecting grain element concentrations is a critical first step toward understanding how those genes can be most effectively used to improve grain nutritional value or rice plant nutrition. The fact that chromosomal regions were often associated with more than one element suggests the importance of studying multiple elements at a time as well as the importance of carefully controlling factors such as soil fertility, temperature, and pH that can affect the ability of plants to take nutrients up from the soil when conducting further studies. Grain shape, heading time, and plant height proved to have much less direct influence on rice grain mineral concentrations than was anticipated.

Molecular Analysis in an Aromatic Rice Breeding Program

Boyett, V.A., Ahrent, D.K., Moldenhauer, K.A., Booth, V.L., and Thompson, V.I.

Rice breeding at the U of A Rice Research and Extension Center is using DNA marker analysis to enhance the development of rice (*Oryza sativa* L.) cultivars for market. To determine the genotype, seed purity, and value as a parent in aromatic breeding, analysis was conducted in 2010 using markers linked to the traits of aroma, kernel elongation, amylose content, plant height (*sd1* gene), and rice blast disease resistance (genes *Pi-ta*, *Pi-b*, *Pi-z*, and *Pi-k*). Twenty-five advanced breeding lines and seven F_2 generation populations were included in the parental screening. Initial analysis on pooled samples of each entry showed that 20 of the 25 advanced breeding lines were homozygous for the predicted alleles and were ready to use as parents. Four of the F_2 populations were segregating for the desired alleles. The initial analysis also revealed that six of the 32 entries, or 19%, had either seed purity issues or amplified non-aromatic alleles, and a second screening of individual samples from these "problem lines" was conducted. It was determined from the second screening that three of the lines had seed of unknown germplasm mixed with the cultivar comprising up to 20% of the seed total. In 2011, two F_4 populations of 7,865 samples were processed through marker-assisted selection for aroma and amylose. Selecting only the families with homozygous aromatic genotype eliminated 63% of the progeny from further development, saving resources for material with greater commercial potential. Analysis of the progeny for amylose content with the microsatellite marker RM190 revealed that 16% of the entries were heterozygous for the trait on average. Approximately 45% of the entries were homozygous long-grain class and 37% were homozygous jasmine-type quality. Only 1% of the entries amplified non-parental alleles and they were discarded regardless of aroma status.

Rice Straighthead Performance of 12 Lines for Three Years in the Natural Conditions

Huang, B.H, Yan, Z.B. and Yan, W.G.

Straighthead severely reduces grain yield in rice and all previous studies have induced straighthead symptoms using arsenic chemicals. Evaluation of this disease on natural conditions is practically important for cultivar improvement. Twelve lines, including three commercial cultivars and nine breeding strains of long-grain rice, were selected to evaluate straighthead disease in a natural field. Experiments were conducted at the farm of University of Arkansas Pine Bluff (UAPB) (Latitude: 34° 15' N, Longitude: 92° 01' W, Elevation: 232 feet). Selection of the 12 entries was based on the experiment in 2008 where they demonstrated either high yield or high tolerance to straighthead or both. These experimental materials were planted on April 28, May 8, and May 18 in 2009, and repeated in 2010 and 2011. The experiment was in a randomized complete block design, three replications with three-row plot, 5 ft long spaced 1 ft each year. Grain yields of cultivars and strains which were affected by straighthead were greatly reduced. Breeding strains PB-11 and PB-12 showed high tolerance to straighthead consistently for the three years, indicated by a low score 1-2 for straighthead symptoms. Strain PB-2 showed a fair tolerance to straighthead with the scores ranging 3 to 5 in the three years. However, similarly with PB-11 and PB-12, the yield of PB-2 was significantly greater than the control cultivar Francis in three years ($P<0.001$). Francis is a commercial cultivar, fairly susceptible to straighthead. Straighthead performance of strain PB-13 was unstable among three years with a variation 1 – 7 for its straighthead scores. Consequently, its yield reduction increased along with an increase of its straighthead score each year. Our findings suggest that genetic variation of straighthead resistance is enough to cope with straighthead disease in rice production. Consistent performance of some strains on straighthead symptoms demonstrates a feasibility to establish a natural site at the UAPB to evaluate straighthead disease for cultivar improvement.

Evaluation of Sterility and Fertility of Male Sterile Lines in the UAPB Farm

Huang, B.H., Yan, Z.B., Deren, C.W., Yan, W.G., and McClung, A.M.

Hybrid rice has proven its yield advantage of 15–20% over the best inbred cultivars in commercial scale worldwide. At present, two systems have been successfully commercialized, three-line and two-line systems. Three-line system consists of male sterile, maintainer, and restoring lines. The two-line system has only male sterile (MS) and restoring lines because sterility and fertility shifts in the MS line. The two-line system is advantageous of the three-line system on 1) simplifying seed production of hybrid and reproduction of MS line itself and 2) improving the level of heterosis because no restoring genes are required and selection pool for the restoring lines is expanded.

In a two-line system, male sterility and fertility of MS line are controlled by environmental factors such as temperature, day-length, or both. MS lines are male sterile when they head in summer with average day's temperature >23ºC and become male fertile when they head in autumn with the average day's temperature between 23ºC and 13ºC. Therefore, seed production of hybrid can be conducted in summer and reproduction of MS line should be done in autumn. A good MS line should be completely male sterile in summer and highly male fertile in autumn.

We tested six MS lines selected from our breeding program for a shift between male sterility and fertility in the UAPB farm in 2011. The experimental lines were planted nine times, a week apart for a continuous heading from Aug. 13 to Oct. 8, 2011. Ten panicles of each line at each planting date were bagged as soon as heading occurred to keep off other pollens. The seed setting rates of the bagged panicles were recorded.

The seed setting rates were identically 0 for all the lines that headed between Aug. 13 and Sep. 4. Average rates over the six lines were 1.73, 5.9, 25.7, 20.6, and 17.9% when heading occurred on Sep. 10, 17 and 24, Oct. 1 and 8, respectively. The best line had a seed setting rate of 53.6 and 48.8% when they headed on Sep. 24 and Oct. 1, respectively. The second best line had a seed setting rate of 46.2 and 27.4% when they headed on Sep. 24 and Oct. 1, respectively.

These results suggest that 1) there is a genetic diversity of shift ability among breeding lines and further selection should be applied, 2) seed production of hybrid is effective for a heading within August, and 3) reproduction of an MS line is effective for a heading after mid-September. UAPB farm is an ideal place for breeding two-line hybrid rice because it is isolated from rice production fields.

Comparison of Seeding Rates in Water-Seeded Yield Plots

Stogsdill, J.R., Greer, C.A., and McKenzie, K.S.

Differences in varietal seed weight and grain type dramatically affect the number of seeds planted per plot at standard seeding rates based on weight. A factorial design experiment with four replications, including three different seed rates 484, 592, and 700 seeds m^{-2} (45, 55, and 65 seeds ft^{-2}) and six lines (M-206, S-102, Calhikari-201, L-205, Calmati-202, and 06Y575) was conducted in 2011 at the Rice Experiment Station to evaluate the effect of seeding rates of California rice lines in water-seeded plots. Seedling counts and seedling vigor were evaluated at 2- to 3-leaf stage. Tiller counts were taken before heading, and panicle counts, lodging, height, harvest moisture, and grain yield were taken at harvest. The effect of seeding rate on seedling count, seedling vigor, and tiller count was statistically significant, however, seeding rate did not significantly affect plot yield. Rice lines had statistically significant differences in seedling vigor, height, heading, harvest moisture, and yield. Tiller count had a non-significant F value (> 0.07) with tiller number increasing with increasing seeding rate. There was not a statistically significant interaction between seed rate and lines. Results would be expected to show more differences if much lower seeding rate treatments were use. These results indicated that differences in seed size did not appear to impact agronomic performance in these yield tests.

Mapping Stem Rot Resistance from *O. rufipogon* using an Advanced Backcross Population

Andaya, C.B., Oster, J.J., Yeltatzie, G.B., and Andaya,V.C.

Stem rot remains to be an important disease in California reducing yield by as much as 25%. To improve the CA rice varieties, the resistance gene from *O. rufipogon* was transferred to long-grain rice designated as 87Y550. This line was extensively used in crosses at the Rice Experiment Station (RES). The genetic basis and the location of the stem rot resistance genes have not been fully determined. An advanced backcross recombinant inbred line mapping population from the cross 87Y550/M206*2 was developed to map the stem rot resistance genes in rice. The identification and development of markers for stem rot resistance should be very useful in the RES breeding program.

A mapping population consisting of 188 BC_1F_5 lines between the cross of 87Y550 and M206 were used to genotype 100 polymorphic microsatellite markers. The lines were planted in a replicated trial in 2010 and 2011. The stem rot scores for the three replicates were averaged and the stem rot scores were used in the genetic analysis. Linkage analysis was done using Mapmaker EXP 3.0. QTL analysis was performed using Qgene 4.3.7. Data were analyzed using the composite interval mapping (CIM) and multiple-trait multiple interval mapping (MT-MIM) methods of the Qgene program. Four QTLs were identified to contribute to the stem rot resistance. These QTLs are in Chromosomes 4, 5, 6, and 10. Progress towards mapping stem rot resistance will be reported.

Arkansas Rice Breeding, a Group Effort

Blocker, M.M., Moldenhauer, K.A.K., Wilson, Jr., C.E., Deren, C.W., Yan, Z., Ahrent, D.K., Bulloch, J.A., Castaneda, E., McCarty, D., Kontham, S., Frizzell, D., Boyett, V.A., Booth, V.L., and Thompson, V.I.

The release of a new rice variety is a complex process that involves time, trials and experiments, and the hard work of dedicated of people. Surveys were sent to cooperators to determine the information gathered during the process. From the moment a cross is planned, many people are involved in the development of a rice variety. Once the number of seed from the cross is increased, evaluations of the new line begin. Starting with phenotypic selections and advancing to yield evaluations, selections are made throughout the life of the cross. Fertilizer requirements and resistance to pathogens and insects are determined. Testing intensifies at each advancing level from the panicle rows to preliminary yield trials at the RREC and locations in the rice growing regions of Arkansas. Selected lines are advanced to the Arkansas Rice Performance Trials and the Uniform Regional Rice Nursery, culminating in the release of a new variety.

The Effects of Nitrogen Fertilizer on Aromatic Rice

Ahrent, D.K., Moldenhauer, K.A.K., Grimm, C., Wilson, Jr., C.E., and Frizzell, D.

Rice imports have doubled in the last 10 years and are composed mainly of aromatic rice. In 2009, 87.4 million cwt of rice were consumed domestically, of which 15% was imported. The largest quantity of imported products were Jasmine rice from Thailand and Basmati rice from India. Information regarding successful cultural practices of aromatic rice varieties is very limited for the southern United States growing regions, and especially for Arkansas. With the development of an aromatic rice breeding program in the University of Arkansas Division of Agriculture, evaluating cultural practices is essential for the advancement of the breeding program, as well as for the growers. Beginning in 2010, an experiment was established at the Rice Research and Extension Center, Stuttgart, AR, to determine the effect of different rates of nitrogen fertilizer on the aroma and yield of aromatic rice varieties. In this test, six nitrogen rates were applied to seven aromatic rice varieties and one non-aromatic rice variety. Agronomic and yield data have been collected. Hulled and milled seed were tested for the analysis of 2-acetyl-1-pyrroline (2a-p) concentration conducted at USDA-ARS Southern Regional Research Center, New Orleans, LA.

The Art of Crossing Rice

Bulloch, J.A., Moldenhauer, K.A.K., Ahrent, D., Boyett, V., Curtis, D.,
Ellenburg, H., Griffith, J., and Blocker, M.M.

New varieties are developed using artificial rice hybridization. Because rice is a self-pollinated plant having a perfect flower, all plants can be used as either the male or female. In this process, selected female and male plants are crossed together to produce the desired F_1 seed. For best results, this occurs in a protected area, which in our case is the greenhouse. Parental lines are planted in the field and wait for desired flowering to be used in the crossing process. Female plants are potted and taken to the laboratory for emasculation. During the emasculation process, the male parts of the flower, which are called anthers, have to be either removed or made sterile for a successful cross to take place. We use a vacuum pump for anther removal. A glycine bag is placed over the female panicle and the plants are kept overnight to await pollination the following day. The panicles of the male parent are picked from the field each morning and brought into the crossing room to sit in a controlled temperature and humidity environment to encourage flowering. At the time of flowering, the pollen from the male parent is dusted over the panicles of the female parent to make the cross. A glycine bag is again placed over the newly crossed panicle and left to produce a new seed, which you should be able to see in approximately 1 week. A successful cross will be ready to harvest in about 30 days from the date of pollination.

Application of Restriction Enzyme Site Comparative Analysis (RESCAN) to the Genotyping of California Rice Varieties

Kim, S.I., Monson-Miller, J., Fass, J., Ngo, K., Comai, L., and Tai, T.H.

Several studies have demonstrated that short read sequencing of reduced representation DNA libraries, constructed by ligation of adapters to restriction fragments, is an efficient approach for identifying SNPs. Sequencing of such DNA libraries enables the discovery of restriction sites not present in the reference genome sequence (type I SNP discovery) and the comparison of multiple reads of the same genomic region (type II SNP discovery).

Restriction Enzyme Site Comparative Analysis (RESCAN) is method for detecting and genotyping single nucleotide polymorphisms (SNPs) using restriction enzyme-phased sequencing to reduce genome complexity. Molecular and bioinformatics methods for the construction, multiplex sequencing, and scoring of reduced representation DNA libraries have been developed. We have demonstrated the reliability and efficiency of SNP discovery by scoring of single type I reads as well as reliable construction of libraries that optimize type II discovery. Progress in applying the RESCAN method to identify genotype SNPs in California rice varieties is presented.

Development of Seedling Cold Tolerant Conventional Rice Cultivars for Texas

Tabien, R.E., Samonte, S.O.P.B., Harper, C.L., and Franks, F.

Rice is very sensitive to low temperature. Cold weather affects rice germination and seedling establishment, which may lead to non-uniformity in maturation, and lower yield and quality at harvest. Hence, rice seedling cold tolerance is very important in the direct-seeded rice currently practiced in U.S. rice growing areas, particularly the early-planted rice. Early planting is being practiced in Texas. In the last five years, 5 to 28% of farmers planted rice before the recommended planting time of March 15 to April 21. Early planting is feasible in the rice growing areas of Texas based on a 10-year weather pattern, but since none of the Texas-released rice cultivars were developed for early planting, unexpected cold weather can be financially devastating for the farmers. Several donors for germination and seedling cold tolerance have been reported, and the current state breeding program being supported by the Texas Rice Research Foundation (TRRF) has identified potential new donors and recipients for this trait. One hundred lines were selected from this pool and evaluated for several traits known to be adversely affected by cold stress. These verification trials of germination and seedling cold tolerance of reported donors of this trait and cold-tolerant lines identified in the state breeding project were conducted in both natural and controlled environments, and initial crosses for the backcrossing program were developed.

Among the 100 entries evaluated for germination in three seeding times (February, March, and July), three entries (Cocodrie selection, Chuncheongbyeo, PR26875-B4-7-9-2) had more than 48% germination at very early seeding, 15 entries showed 10% or less seedling height reduction when exposed to cold temperature, and seven emerged faster and sustained growth in colder temperatures. The best entries that could be donors for three cold tolerance traits (low germination reduction, high survival, and low plant height reduction) include six entries. The response of the same 100 genotypes when exposed to ambient cold temperature at seedling stage was also determined. The cold had less effect on established seedlings compared with direct seeding; several entries had taller plants when grown in colder temperature. Several entries had early germination in both growing conditions and are potential donors for high germination rate. Nine entries had consistently low height reduction in dry seeding and seedling tests for cold tolerance but verification is needed through further characterization of these genotypes.

The same 100 entries were evaluated for germination and seedling growth at controlled temperatures of 10^{o}C and at 25^{o}C and 14 entries had less than 40% reduction in germination when kept at 10^{o}C. Three of these entries performed well in very early seeding experiments. Germination rates were faster at room temperature, with about 2 weeks for most seeds to germinate at 10^{o}C compared with 1 week at room temperature. Embryo growth rates at 10^{o}C, however, were considerably reduced, with most lines showing insignificant growth after 7 days. Among the seven entries with best growth at lower temperature, four were also best when seedlings were exposed in February cold air temperature.

Ten of the best performers in the ambient air studies and two checks were selected for germination testing and seedling growth at 5, 10, 15, 20, and 25^{o}C and varying duration of cold exposures (2, 4, and 6 days). Results showed that Chuncheongbyeo (Entry 14) was the most cold tolerant, as it consistently showed positive germination percentage at 5 10, 15, and 20^{o}C relative to 25^{o}C. Entry 73, an elite breeding line, showed cold tolerance at shorter cold exposure. Four entries (112, 14, 73, and 68) had high embryo weights after 6 days of 5^{o}C while seven entries (39, 14, 3, 36, 34, 73, and 112) showed above-average embryo weight after 6 days of 10^{o}C exposure. Entry 73 and 14 performed best in both germination and seedling test at lower temperatures.

Continued screening of breeding materials will facilitate identification of new donors for cold tolerance and the inheritance studies will help breeders in efficiently transferring the trait.

Protein Differential Expression and Modification in Response to Cell Wall Removal and Regeneration in Rice (*Oryza sativa*)

Mujahid, H., Tan, F., Nallamilli, B.R., Zhang, J., and Peng, Z.

The nucleus is a highly complex structure containing proteins ranging from highly abundant ribosomal proteins and histones to low copy transcription factors. Although proteomics approaches have been extensively used to study the nuclear proteome in plants, detection of low abundance nuclear proteins remains highly challenging. Here, we present an improved method for nuclear protein extraction and mass spectrometry analysis. We found that a combination of acid and phenol extractions lead to a much improved coverage of the nucleoproteome. With the method, a total of 1674 proteins including 90 putative transcription factors were identified. We further examined the nucleoproteome responses to enzymatic removal of cell wall and the cell wall regeneration process. A total of 529 up-regulated proteins and 637 down-regulated proteins were identified, including 45 differentially expressed transcription factors. Pathway Studio analysis of the differentially regulated proteins indicated that proteins in various pathways were involved in cellular response to the removal of cell wall and in cell wall re-synthesis. Our studies provide an improved method for proteome analysis of nuclear proteins and substantially advanced our understanding on cellular response to cell wall damage and cell wall regeneration in plants.

Construction of a Yeast Two-Hybrid Library in a Compatible Interaction of Rice with an *AVR-Pita1*-Containing Isolate

Zhang, Z., Jia, Y., Wang, Y., Liu, F.Q., and Sun, G.C.

To control rice blast, the utility of host resistance has been proven to be the most effective and economical method. The resistance is mediated by the interaction of a single R gene from the host and the corresponding AVR gene from some races of *M. oryzae* after infection. *Pita* and *AVR-Pita1* are a matched pair of R/AVR genes, and the Pita-mediated resistance, directly binding to the effector protein AVR-Pita1, has been used to manage rice blast in the southern United States. Recently, accumulation in the Biotrophic Interfacial Complex (BIC) and cell-to-cell movement of effectors proteins during invasive growth of the blast fungus have been demonstrated using fluorescent protein tag technology by others. This raises the possibility that these effectors proteins prepare rice cells for subsequent fungal entry and biotrophic growth. Our goal in this project is to identify proteins that interact with AVR-Pita1 using yeast two-hybrid technology. As the first step toward this goal, we constructed a yeast two-hybrid library. Rice cultivar Nipponbare without *Pita* and *M. oryzae* isolate ZN61 with *AVR-Pita1*, belonging to race IB49, were used. Firstly, 3- to 4-leaf stage seedlings of rice were grown in a greenhouse and the isolate ZN61 were grown on oatmeal agar at 25C for 7 days for spore production. The second youngest leaf of the seedlings were removed and cut into 5-cm segments for spot inoculation. Each detached leaf was inoculated four to five times with 500 spores each time. After 24h, 48h, and 72h post-inoculation, leaf tissue surrounding the lesions were cut, immediately frozen with liquid nitrogen, and stored at -70C. Total RNA was extracted using Trizol reagents and mRNAs were purified by Qiagen Oligotex mRNA Midi Kit. Approximately 2 ug mRNA were used to construct a library with CloneMiner**TM II cDNA Library Construction Kit. A primary library with bacteria of 1.1 × 10**7 colony forming unit carrying prey plasmid of the yeast two-hybrid system was constructed. Plasmid DNAs were isolated from random 18 bacterial colonies and digested with restriction enzyme BsrGI, and results showed that the range of the insert size was from 0.3-2.2Kb, and the average insert size was 0.9Kb. Progress on the identification of AVR-Pita1 interacting proteins will be reported.

Identification of miRNAs and Their Target Genes in Y-type Cytoplasmic Male Sterile Line and Its Maintainer by Deep Sequencing

Liu,Y.Z., Wang, H., Guo, T., and Chen, Z.Q.

MicroRNAs (miRNAs) is a newly identified class of non-protein-coding, endogenous and short (20~24 nt) RNA molecules that regulates the expression of target genes by means of complementary base pair interactions with roles in many plant biological processes, including plant growth development, cellular differentiation, and abiotic and biotic stress resistance. As one of the most important cereals and a completely sequenced species, rice (*Oryza sativa* L.) becomes a good choice for high-throughput small RNA analysis. So far, there are 240 miRNAs distributed in 62 families reported in the Sanger miRBase Register in rice, which are involved in rice root development, grain development, aleurone cells and flower development, shoot development, and panicle architecture. Cytoplasmic male sterility (CMS) led by a mitochondrial mutation is a common phenotype in higher

plants that provides a convenient way to exploit heterosis in crops. The report that overexpression of miR172b in rice resulting in floral lower fertility and seed developmental defects reminds us that further exploring of rice microRNA would have great potential in unvealing the mechanism of CMS related to microRNAs' multifunction in plants.

In the present study, the identification of microRNA was carried out in Cytoplasmic Male Sterility rice and its maintainer line by small RNA deep sequencing technology in order to identify possible miRNAs regulated CMS rice. Two rice small RNA libraries were constructed using RNAs obtained from mixture of tetrad stage anthers and monocaryon stage anthers of Y-type cytoplasmic male sterile line Y-huanong A and its maintainer line.

A total of 9,623,314 and 10,078,344 reads genome-matching small RNAs were obtained, respectively, wherein, 495 known miRNAs were identified in both the CMS line and the maintainer line by bioinformatic analysis. Among the 495 known miRNAs, 371 and 359 miRNAs were expressed in the CMS line and the maintainer line, respectively. The expression of the known miRNAs displayed great differences between the two lines. Sixty-five miRNAs were upregulated much more significantly in the CMS line than in the maintainer line. Interestingly, the expression of miR160f targeting DNA cytosine methyltransferase, which can delay the flower development, was upregulated 6.95 times in CMS line. And miR1884a was also upregulated 7.54 times in the CMS line, which targets some fertility-related genes such as secondary cell wall-related glycosyltransferase, calmodulin binding protein, and leucine-rich repeat receptor protein kinase EXS precursor. On the contrary, 28 miRNAs were found down-regulated in the CMS line compared with the maintainer line. Among them, miR1318 and miR1432 were both down regulated 8.80 times, and their target genes, functioning in pollen germination such as calcium-binding allergen, calcium-binding protein, calmodulin-like protein, and plasma membrane-type calcium-transporting ATPase 9, were closely bound up to pollen germination. In addition, 101 and 86 novel miRNAs were discovered in developmental pollens of the CMS line and the maintainer line, respectively. This study, for the first time, revealed the differences in composition and expression profiles of miRNAs in developmental pollens between the cytoplasmic male sterility line and the maintainer line, with novel and known miRNAs as the main contributors. It gave clues in the important roles of the miRNA pathway in pollen development and broadens our perspectives on the important regulatory roles of miRNAs in rice cytoplasmic male sterility.

Characterization and Fine Mapping of a Novel Gene Controlling Dwarfism, Tillering and Green-revertible Albino in Rice (*Oryza sativa* L.)

Guo, T., Wang, H., Huang, R.X., Huang, X., Liu, Y.Z., Zhang, J.G., and Chen, Z.Q.

HFA-1 was a space-induced rice mutant and showed white leaves at the young seedling stage. The emergence of white leaves was hardly affected by environments, and the white leaves could return green gradually when the plants grew up. Compared with the wild type, the space-induced rice mutant HFA-1 has more tillers, and this trait may result from breaking tiller buds dormancy and initiating more higher-order tiller buds. The study revealed that the levels of endogenous ABA, IAA, and GA of HFA-1are similar to those of the wild type and the increased tillers in mutant HFA-1 may not be the result of inhibiting endogenous hormone synthesis of ABA, IAA, and GA, respectively. Treated by exogenous GA, both the elongation length and the elongation ratio of the second leaf sheath were similar for the HFA-1 mutant and the wild type (3.23±0.00 vs. 3.17±0.00; 2.17±0.00 vs. 2.10±0.00), respectively. Additionally, the height of HFA-1 was ～70 cm, which was reduced largely by 30% compared with that of the wild type.

We crossed HFA-1 with normal high rice accessions and analyzed their segregating F_2 and F_3 populations using Chi-square test. The results indicated that dwarfism, high-tillering and green-revertible albino were co-segregated, and these characteristics were controlled by a recessive nucleic gene, which was named *hw-1(t)* tentatively. After development of mapping populations and molecular markers, gene *hw-1*(*t*) controlling the green-revertible albino trait, high-tillering and dwarfism was finely mapped into a 24.9-kb physical interval flanked by two InDel markers HW36 and HW7 on chromosome 5, where five open reading frames (ORFs) were predicted based on the corresponding sequence of reference cultivar Nipponbare. Sequencing the five ORFs in both mutant and the wild type, only one nucleotide change was found in an ORF between the mutant and wild type. This one may be the gene *hw-1(t)*, its function was under analysis.

Space-induced mutation provided a new opportunity to create rice mutants, which involves changes in many traits, such as height, resistance to disease, grain quality, leaf color, etc. The mutants expanded germplasm for rice breeding and research on gene function. Mutant HFA-1 showing green-revertible albino character was different from the other green-revertible albino mutants reported previously.

Characterization and Fine Mapping of *iga-1*, a Semi-dwarfing Gene in Rice

Wang, H., Guo, T., Huo, X., Rao, D.H., Zhang, S.T., Liu, Y.Z., Zhang, J.G., and Chen, Z.Q.

A dwarf rice mutant CHA-2 was identified in 2003 from the progeny of space-mutagenized Te-xian-zhan-13 (TXZ13), which was an *indica* cultivar containing the famous semi-dwarfing gene *sd-1*. The plant height of CHA-2 (52.8 cm) was reduced to 48.7% of that of wild type (108.4 cm), and 10 of the other 12 agronomic traits were changed too. Additionally, CHA-2 showed 1) wide, erect, and dark green leaves; 2) small and round grains; and 3) a growth period that was 15 days less than that of the wild type.

The result of genetic analysis revealed that CHA-2 contained two semi-dwarfing genes, *sd-1* and an unknown gene named *iga-1* tentatively. For characterization of the *iga-1* gene, a semi-dwarfing line CHA-2N only carrying the dwarf gene *iga-1*, was isolated from hybrid progeny of CHA-2 and Hui-yang-zhen-zhu-zao (HYZZZ), a tall *indica* accession with an height of ~120 cm. Further research unveiled that the dwarfisms of CHA-2 and CHA-2N were not caused by reduction of internode numbers but shortening in internodes length. Treated with exogenous GA3, the length of the second-leaf sheath and the shoot growth rates of semi-dwarf line CHA-2N (*SD-1SD-1 iga-1 iga-1*) were significantly lower than those of TXZ13. Therefore, *iga-1* may be independent of endogenous GA3 biosynthesis and signal transduction and was not involved in the regulation of GA3.

After mapping work, *iga-1* was delimited at a region flanked by markers DL17 and DL19 at genetic distances of 0.033 and 0.067 cM on chromosome 5, respectively. The region spanning *iga-1* locus was ~94.36 kb. In total, 15 putative genes were annotated according to the corresponding genome sequence based on GRAMENE database. Among them, LOC_Os05g26890 had been identified as the *Dwarf1* (*D1*) gene, which maybe an allele of *iga-1*. The agronomic and biochemical traits controlled by *iga-1* were different from those by *D1*, which implied that the dwarf gene may be involved in an unrevealed dwarfism mechanism. New dwarf rice accessions could be created by space-induced mutation.

Causal Agents of Bacterial Panicle Blight of Rice and Evaluation of Disease Resistance of Rice Cultivars to the Disease in Mississippi

Lu, S.E. and Allen, T.W.

Bacterial panicle blight (BPB) of rice caused by *Burkholderia* spp. is an emerging rice disease in the South. The bacterial disease causes seedling blight, sheath rot, and panicle blight. The disease has been reported to cause 10 to 40% yield loss. Previous studies revealed that the primary pathogen of the disease is *B. glumae*. Clearfield rice cultivars have had a significant impact on rice production in the Southern rice growing states, and it is believed that more rice acres will shift towards Clearfield varieties. However, disease resistance of the Clearfield varieties to the causal organisms of BPB has not been previously investigated.

During the 2010 rice growing season, field trips were made to survey disease occurrence in the Mississippi Delta. In total, 58 rice fields in seven Mississippi counties were scouted. Survey results revealed that BPB occurred rarely and did not cause significant impact on rice production statewide this year. Total genomic DNA of bacteria recovered from suspect plant samples was extracted, and PCR with *Burkholderia* species-specific primers were used for detection of pathogenic bacteria. Of the 58 symptomatic plant samples collected in 2010, 84.48% tested positive for *Burkholderia glumae* and 11.76% were positive for *B. gladioli*. These data suggest *B. glumae* is the primary pathogen for BPB and the pathogenic bacteria are widely distributed in the Mississippi rice fields.

The 10 cultivars (CL111, CL131, CL151, CL161, CL171, Bowman, Catahoula, Cheniere, Cocodrie, and Sabine) were used for disease resistance evaluation. Firstly, the seedlings were injected with *B. glumae* 189gr-4. All of the cultivars showed water soaked lesions at the injection sites 2 days after inoculation followed by necrosis approximately 5 days later. However, reactions of the cultivars showed significant differences regarding the lesion sizes 10 days after inoculation. Of the 10 cultivars, CL111 responded to inoculation with the smallest lesions; and inoculation of CL161, CL171, and Catahoula resulted in smaller lesions than the other cultivars. The largest lesions were observed on CL131, Bowman, and Cocodrie. Secondly, rice plants at heading stage were sprayed with the strain 189gr-4. Florets turned to light brown 1 week after spray inoculation and resulted in typical panicle blight symptoms 3 weeks after inoculation. The results indicate that CL111, CL161, and CL171 were the most tolerant compared with the other cultivars. In contrast, CL131, CL151, and Cocodrie were susceptible to the bacteria. These data suggest that some Clearfield varieties, such as CL111 and CL161, may be tolerant to the disease under greenhouse conditions.

To investigate primary inoculum of the disease in rice fields, seeds, soils, water, and plant materials were tested for the presence of the bacterial organisms responsible for BPB (*B. glumae*, and *B. gladioli*) using PCR analysis. The seeds of all 10 commercial cultivars tested negative for the presence of both bacteria, suggesting that seed may not serve as a primary source of inoculum for the disease. In the surveyed fields, 82.76% of the collected soil samples tested positive for *B. glumae* and 1.72% tested positive for *B. gladioli.* In addition, 85.37% of the water samples collected were *B. glumae* positive and 2.44% were positive for *B. gladioli*. Our data suggest *B. glumae* is the primary pathogen causing bacterial panicle blight of rice, and the bacterium is present in most rice fields either in the soil and the water in Mississippi but not in the seeds tested.

The results generated by this research project could lead to specific varietal choices, depending on field history in Mississippi. Pathogen free seed is critical for preventing introduction of highly virulent strains of the pathogen. New rice varieties with greater disease resistance to the causal organisms are needed. However, the data from greenhouse trials can only be considered to be preliminary at this point. Continuous efforts are needed to understand the disease and its management thoroughly in rice fields.

Beneficial *Bacillus* Bacteria: A New Potential Management Option for Bacterial Panicle Blight in Rice

Zhou, X.G.

Bacterial panicle blight, primarily caused by *Burkholderia glumae*, poses an increasing threat to rice production in the southern United States and other rice-growing countries of Central and South America and Asia. The losses in rice grain yield and milling quality caused by the disease vary with year and location. The estimated yield loss can be as great as 50%. The disease was widespread in Texas, Arkansas, and Louisiana in 2010. Currently, there are no rice varieties with high levels of resistance and no registered chemicals to use for control of the disease in the U.S. We initiated a biocontrol research program with the aim of utilizing antagonistic bacteria as one of the effective components in an integrated management program for bacterial panicle blight on rice. The *Bacillus subtilis* strains 99-101, EXTN-1, and MBI-600 are plant growth-promoting rhizobacteria (PGPR) that have been demonstrated to have strong antagonistic activity against *Burkholderia glumae* on agar plates and to reduce disease severity on rice under greenhouse conditions in our previous studies. The objectives of this study were to determine the length of time in which the beneficial bacterial strains can effectively protect rice from pathogen infection under greenhouse conditions and to evaluate efficacy of these beneficial bacteria for suppression of bacterial panicle blight under field conditions.

A greenhouse experiment was conducted on rice variety Cocodrie at the stage of panicles fully emerged. Strains 99-101 and EXTN-1 were individually sprayed to the panicles. Sprays with sterile water served as the control. At 0, 4, 8, 12, 16, and 20 days of post inoculation of the beneficial bacteria, treated panicles were challenge sprayed with *B. glumae*. Disease severity on treated rice panicles was assessed 2 weeks after challenge inoculation using a scale of 0 to 9, where 0 represents no symptoms and 9 represents 100% kernels affected. Both strains significantly reduced disease severity at 0 through 12 days after heading of rice compared with the water control. No differences in disease severity among treatments were observed at 16 and 20 days following heading. These results suggest that both strains can effectively protect rice from pathogen infection up to 12 days.

A field experiment was conducted in 2010 and 2011 at Beaumont, TX. In 2010, strains 99-101 and EXTN-1 were sprayed individually or in combination into plots of rice variety Cocodrie at the heading stage. Plots applied with oxolinic acid (antibiotic) served as the positive controls, and untreated plots served as the negative controls. After one day of the sprays of beneficial bacteria, all plots were challenge sprayed with *B. glumae*. In 2011, an additional *Bacillus subtilis* PGPR strain MBI-600 that has been demonstrated to be effective in suppressing rice sheath blight in our previous studies also was included. Disease severity on panicles was assessed at 2 weeks before harvest using a scale of 0 to 9 described before. Plots were harvested and yield determined.

In both years, the strains 99-101, EXTN-1, and MBI-600 (2011 only) significantly reduced disease severity and increased yield compared with the untreated control. These strains decreased disease severity by up to 50% and increased yield by up to 17%. A mixture of these two strains did not further increase yield compared with each strain alone. Treatment with oxolinic acid reduced disease severity by up to 89% and increased yield by up to 21%. Use of beneficial *Bacillus* bacteria may provide a new practical management option to minimize the damage caused by bacterial panicle blight in rice.

Characterization of Genetic Diversity of Rice Blast Fungus in Arkansas Field Isolates

Jia, Y., Xing, J., Correll, J., Lee, F.N., Cartwright, R., Cao, M., and Yuan, L.

The rice blast resistance gene *Pita* has been deployed for preventing blast disease in the southern U.S. for the past two decades. To date, at least 11 rice cultivars, Katy, Drew, Madison, Kaybonnet, Banks, Ahrent, Spring, Cybonnet, Catahoula, CL111, and Templeton, carrying *Pi-ta* were developed by rice breeders using classical plant breeding. In an effort to examine the stability of resistance mediated by *Pi-ta* in deployed rice cultivars, a total of 200 Arkansas field isolates of the rice blast fungus were obtained from 1996-2009 from rice cultivars with *Pi-ta* and without *Pi-ta* and were characterized using an international rice differential system, Rep-PCR, and pathogenicity assays on the *Pi-ta* containing rice cultivar, Katy. The races IB49, IC17, and IB1 were found to be the three predominant races among all isolates characterized. In each race, one major Rep-PCR pattern was identified. All of these races were found to contain the corresponding avirulence gene *AVR-Pita1* as determined by the *AVR-Pita1* gene specific primers YL149 and YL169 in polymerase chain reaction. Sequence analysis of the *AVR-Pita1* alleles from avirulent isolates revealed that most of point mutations led to amino acid substitutions. These *AVR-Pita1* containing races were unable to infect Katy, as would be expected, and demonstrates that *Pi-ta* is effective in preventing blast disease caused by the predominant races in Arkansas. However, 15 isolates from both *Pi-ta* and non *Pi-ta* containing rice cultivars were able to infect Katy and were classified to the race IC1. The *AVR-Pita1* alleles were not amplified in these virulent isolates suggesting that mutations at the *AVR-Pita1* locus may alter recognition specificity to *Pi-ta*. Our findings suggest that the *AVR-Pita1* alleles in field isolates in Arkansas is under diversified selection and the impact of this finding on crop protection will be presented.

Progress in Screening for Sheath Blight, Blast, and Bacterial Panicle Blight

Groth, D.E., Sha, X., and Linscombe, S.D.

Sheath blight (*Rhizoctonia solani*), blast (*Pyricularia oryzae*), and bacterial panicle blight (*Burkholderia glumae*) are the most important diseases of rice. The development of disease-resistant rice cultivars will allow producers to use less fungicide to avoid significant reductions in grain and milling yields. Among cultivars currently in cultivation in the southern United States rice-producing region, resistance levels range from very susceptible to resistant to these diseases. The Breeding and Pathology projects have been actively screening for disease resistance for the last 28 years. Often, inoculated disease nurseries are needed to accurately characterize varietal response to these diseases. Sheath blight is inoculated using a *R. solani* culture grown on a rice grainhull mixture. Neck and panicle blast inoculum is from natural sources but the flooded plots are drained at mid-tillering for 1 week to encourage disease development. Bacterial panicle blight is inoculated by spraying a *B. glumae* suspension at heading. Leaf blast is evaluated in an upland nursery that is filled with a 1:1:1 mixture of sand, soil, and organic matter. Cultural management practices to encourage disease development include late planting, high N rates, thick seeding rates and planting at high disease pressure locations around Louisiana. Blast nurseries are planted in a field with light soil and surrounded by trees on three sides. Sheath blight nurseries are planted early in the season while bacterial panicle blight, blast, and Cercospora nurseries are planted mid- to late season. In an average year, 12,000 to 14,000 rows are inoculated for sheath blight, 6,000 to 8,000 rows are inoculated for bacterial panicle blight and 2,000 to 4,000 rows are evaluated for blast resistance. Most of the time plants are evaluated for multiple diseases. Lines from F_2 to F_{10} generation have been tested. Rating scales for each disease ranging from 0-9 where 0 indicates immune and 9 indicates very susceptible are used. The proportion of very susceptible and susceptible lines is decreasing in the breeding material each year. Recently released varieties have better disease ratings than older varieties. Work is continuing.

Comparison of Insecticide Seed Treatments and Foliar Applications for Control of Rice Water Weevil

Fortner, J.W., Lorenz, G.M., Taillon, N.M., Plummer, W.A., Colwell, C.K., and Thrash, B.C.

Several studies were conducted to compare selected insecticide seed treatments with selected foliar insecticides for control of rice water weevil (RWW) in Arkansas.

Trials were conducted throughout the rice producing areas of the state. Plot size was 1.52 by 7.62 meters in a randomized complete block design with four replications. RWW larvae were evaluated by taking three core samples per plot with a 60.96 cm cylinder core sampler 21 to 28 days after permanent flood. Each core was washed with water to loosen soil and remove larvae from the roots into a 40 mesh sieve. The sieve was immersed in a saturated salt solution to float the larvae for counting. All samples were evaluated at the Lonoke Agricultural Extension and Research Center. Seed treatments were applied prior to planting using recommended slurry rate. Foliar applications were applied with a hand boom utilizing compressed air as a propellant. Yield was taken with a small plot combine and adjusted to 13% moisture. Selected seed treatments included: Dermacor X-100, Cruiser Maxx Rice, and NipsIt Inside. Seed treatments were applied at labeled rates for selected seeding rate. Foliar applications of Karate and Belay were applied at different specified rates and application timings for control of RWW.

Results indicated an overall increased efficacy of insecticide seed treatments compared with foliar treatments. Foliar applications tend to show no benefit because applications must be applied in a perfect window to control adults before female RWW lay eggs. A yield increase was established with the use of insecticide seed treatments.

A Review of the NipsIt Inside Insecticide Rice EUP in 2011

Everett, M., Carey, F., Odle, B., and Arthur, K.

Valent USA was granted an Experimental Use Permit for NipsIt INSIDE rice seed treatment in February 2011. The EUP was not to exceed 16,187 ha (40,000 acres) total and was split between the following states: Arkansas (8,094 ha, 20,000 acres), Texas (4,047 ha, 10,000 acres), Louisiana (2,023 ha, 5,000 acres), and Mississippi (2,023 ha, 5,000 acres). All fields were monitored throughout the growing season for grape colaspis and rice water weevil control. Yield data were collected where possible. Fields were combinations of whole field trials and split fields with untreated rice and rice treated with standard rice seed treatment insecticides. In split fields, data were taken from untreated and/or standard treatments for comparisons. A variety of rice cultivars/hybrids were evaluated at their appropriate seeding rates.

No grape colaspis larvae were detected in any trial in 2011. NipsIt INSIDE insecticide provided excellent rice water weevil control. When data were averaged across cultivar and seeding rate, rice water weevil larvae were detected at an average population of 1.4 larvae per core. When data were separated by variety and/or seeding rate, no differences between rice water weevil control treatments were detected. Rice yields reflected rice water weevil control.

NipsIt INSIDE registration is expected in May 2012. Since this will not be in time for the 2012 rice planting season, Valent USA will continue the EUP for NipsIt INSIDE insecticide for the 2012 growing season.

Recent Research on Insecticidal Rice Seed Treatments

Way, M.O., Pearson, R.A., Nunez, M.S., and Vyavhare, S.

Insecticidal rice seed treatments are effective pest management tools for increasing numbers of Texas rice farmers. Currently, Texas rice farmers can employ three insecticidal seed treatments – Dermacor X-100, (active ingredient rynaxypyr), CruiserMaxx Rice (active ingredient thiamethoxam), and NipsIt INSIDE (active ingredient clothianidin). The recommended rate of Dermacor X-100 is approximately 0.067-0.078 kg ai/ha (0.06-0.07 lb ai/acre), regardless of seeding rate, which means as seeding rate decreases, more rynaxypyr is applied per seed to achieve the recommended rate on a per hectare (acre) basis. On the other hand, the recommended rates of CruiserMaxx Rice and NipsIt INSIDE are 0.14 kg ai/100 kg seed (7 fl oz/cwt seed) and 0.075 kg ai/100 kg seed (1.92 fl oz/cwt seed), respectively, which means as seeding rate decreases, less thiamethoxam and clothianidin are applied per seed.

In 2010 and 2011, these seed treatments were evaluated for rice water weevil, *Lissorhoptrus oryzophilus,* and stalk borers (sugarcane borer, *Diatraea saccharalis* and Mexican rice borer, *Eoreuma loftini*) control. In 2010, Dermacor X-100 was applied to Cocodrie seed at 0.07 kg ai/ha (1.75 fl oz/cwt seed). Plots were planted at 67, 101, and 135 kg/ha (60, 90, and 120 lb/acre). All Dermacor X-100 treatments provided excellent control of rice water weevil and good control of stalk borers as measured by the number of whiteheads in plots. At 67, 101, and 135 kg/ha seeding rates, Dermacor X-100 plots yielded statistically more than the corresponding untreated controls – 995, 1046, and 1233 kg/ha (888, 933, and 1100 lb/acre), respectively. In 2011, Dermacor X-100, CruiserMaxx Rice, and NipsIt INSIDE were applied to hybrid XP753 seed at recommended rates. Plots were planted at 16.8, 28.0, and 39.2 kg/ha (15, 25, and 35 lb/acre). All seed treatments performed well against the rice water weevil. On average, the seed treatments produced 1268 kg/ha (1131 lb/acre) more grain than the control.

Impact of Insecticide Seed Treatments in Large Block Field Trials in Arkansas, 2009-2011

Plummer, W.A., Lorenz, G.M., Colwell, C.K., Taillon, N.M., Fortner, J.W., and Thrash B.C.

Rice water weevil (RWW) is one of the most destructive insect pests of rice production in the mid-south. It is estimated 90% of southern fields are infested each year with this pest. Larvae cause severe root pruning that results in stand loss and yield reduction. Large block trials were conducted in grower fields from 2009-2011 to evaluate the impact of insecticide seed treatments on the rice water weevil. Plot design was randomized complete strip blocks with three or four replications. Treatments in 2009 and 2010 included Cruiser (Thiamethoxam) and Dermacor (Rynaxypyr). In 2011, NipsIt Inside (Clothianidin) was added. At each location, soil cores were taken to estimate RWW numbers and yield data were taken to measure the impact of the seed treatments. Cruiser, Dermacor, and NipsIt reduced RWW numbers by 79, 74, and 81%, respectively. The seed treatments also increased yield by 5, 5, and 10% compared with the untreated check. Results will be discussed.

Interactive Effects of Salt Stress and Thiamethoxam on the Rice Water Weevil, *Lissorhoptrus oryzophilus*

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

A major factor limiting global agricultural productivity is salinity, which is believed to affect nearly one-fifth of the world's irrigated land and causes 10^7 irrigated hectares to be abandoned each year. Rice is considered to be a salt-sensitive crop, and salinity has been shown to impair root and leaf development, reduce chlorophyll content, and significantly reduce grain weight and yield. While salt stress and its implications on rice have been well documented, less is understood regarding the interactions between salt stress and insect herbivory in rice.

In addition to their insecticidal activity, neonicotinoid insecticides have also been reported to alleviate stress in plants. Plants treated with thiamethoxam are reported to exhibit faster emergence, increased root mass and earlier canopy development. The mechanism behind this enhanced response to stress stems from increased biosynthesis of functional proteins within treated plants, allowing plants to handle stressful growing conditions, such as drought, low pH, heat stress and high soil salinity.

Given the importance of salt stress in much of the rice production areas of Louisiana and the increasing use of neonicotinoids in rice, it is crucial to understand the interactions among salt stress, thiamethoxam, and *L. oryzophilus* herbivory in rice. The objectives of this study were to 1) quantify the effects of salt stress and thiamethoxam on the growth and development of rice seedlings and 2) quantify the interactions between salt stress, thiamethoxam, and *L. oryzophilus* herbivory.

Our data show that salt stress has no significant effect on germination. In two of three experiments conducted, thiamethoxam was found to have a significant effect on seed germination. In these experiments, seeds treated with 60 g a.i. of thiamethoxam had higher germination success compared with either untreated (12% increase) or those treated with 120 g a.i. Salt stress did significantly reduce root weight in both untreated and treated plants, though the percent reduction was less in those plants treated with thiamethoxam. While salt stress had no effect on the dry shoot weights, thiamethoxam treatment did lead to an increase in shoot weights in the absence of salt stress. Plants that were treated with thiamethoxam had mixed responses to salt stress, and these results will be discussed.

The effect of salt stress did not significantly affect *L. oryzophilus* adult mortality after 48 hrs of feeding on excised plant material. However, adults that fed on plants that had been watered with 250 and 750 ppm salt water solutions experienced reduced mortality by 15 and 27%, respectively. Both rates of thiamethoxam significantly increased adult mortality compared with plants that were untreated. The interaction between salt and thiamethoxam was also significant.

Salt stress had no effect on *L. oryzophilus* oviposition. Although salt stress did not significantly reduce the number of eggs per plant, plants that were watered with 750 ppm salt water received 42 to 46% fewer eggs than plants watered with control water or 250 ppm salt water. Thiamethoxam also significantly reduced *L. oryzophilus* oviposition. While the interaction between salt stress and thiamethoxam was not significant, plants treated with thiamethoxam received fewer eggs as salt stress increased. In untreated plants, the number of eggs per plant was higher on those watered with 250 ppm salt solutions, but stress induced by 750 ppm salt solutions reduced the number of eggs per plant from 7.67 (in unstressed) to three, a decrease of 61%.

The numbers of early instar larvae emerging from plants were not significantly reduced by salt stress. While not statistically significant, fewer larvae were recovered from plants subjected to 250 ppm salt water (reduction of 30%) and 750 ppm salt water (reduction of 77%) than from control. The effect of thiamethoxam was highly significant and the interaction of salt stress and thiamethoxam was also found to be significant. In untreated plants, the number of larvae per plant was significantly reduced as salt stress increased – indicating that salt stress induces resistance to early instar feeding.

Efficacy of Selected Insecticide Seed Treatments at Various Seeding Rates for Conventional, Clearfield, and Hybrid Cultivars

Taillon, N.M., Lorenz, G.M., Fortner, J.W., Colwell, C.K., Plummer, W.A., and Thrash, B.C.

In 2010 and 2011, insecticide seed treatments were evaluated for control of rice water weevil in conventional, Clearfield, and hybrid cultivars at various seeding rates to determine if the efficacy of the seed treatments were consistent within each cultivar and seeding rates. Trials were set up in a randomized complete block design with four replications. Data were processed using Agriculture Research Manager Version 8 and Duncan's New Multiple Range Test (P=0.10). Results indicated weevil control in most cases was similar within the same type cultivars and across seeding rates.

PGPR: A Novel Strategy for Sheath Blight Control and Fungicide Use Reduction in Rice

Zhou, X.G., Kumar, K.V.K., Reddy, M.S., Kloepper, J.W., Jia, Y., Allen, T.W., Lu, S., and Way, M.O.

Sheath blight caused by *Rhizoctonia solani* is the most important rice disease in Texas, Arkansas, Mississippi, and other parts of the southern United States. Due to the lack of sheath blight resistance in most commonly planted cultivars, southern rice famers apply more than 454,000 kg (1 million pounds) of fungicides annually to control diseases of rice, primarily for sheath blight control. Rice farmers are in need of the development of alternative or complementary management options to reduce their heavy reliance on fungicides. The combination of biocontrol agents with reduced rates of fungicides may afford protection equivalent to that obtained with full rates of fungicides. The results of our previous studies indicate that the *Bacillus subtilis* Plant Growth-Promoting Rhizobacteria (PGPR) strain MBI-600 was effective in suppressing sheath blight and was compatible or tolerant to azoxystrobin and other fungicides commonly used for sheath blight management. MBI-600 is an active ingredient in the biofungicide Integral®. Azoxystrobin is the commonly used fungicide for control of sheath blight in rice. The objectives of this study were to determine the optimum rates of combined use of the biocontrol agent with azoxystrobin under greenhouse conditions and to evaluate efficacy of their combined use for sheath blight control and yield increase in the field.

A greenhouse experiment was conducted as a 5 × 7 factorial with five concentrations of MBI-600 (0, 10^3, 10^6, 10^9 and 10^{11} CFU/ml) and seven rates of azoxystrobin [0, 17, 33, 50, 67, 83, and 100% of the recommended rate (0.16 kg a.i./ha)]. Seeds of variety Cocodrie were treated with MBI-600 at aforementioned concentrations and were air-dried prior to seeding. At the 3-leaf stage, plants were sprayed with MBI 600 and azoxystrobin (Quadris 2.08 SC) at different concentrations. After 24 h, sclerotia of *R. solani* were inoculated at the base of treated seedlings near the soil line. Inoculated seedlings were covered with transparent soft drink bottles for maintaining inside moisture. Applications of MBI-600 at 10^9 and 10^{11} CFU/ml were effective in reducing disease severity with the later concentration completely eliminating the disease. Sheath blight severity was reduced with applications of azoxystrobin at 67, 83, and 100% of the recommended rate. The optimum rates of MBI-600 and azoxystrobin for combined use to achieve maximum sheath blight control were 10^9 CFU/ml and 50% of the recommended rate, respectively. A dose response model describing the efficacy of combined use of MBI-600 with azoxystrobin for sheath blight reduction was developed.

A field trial was conducted in 2010 and 2011 on a research farm land at Beaumont, Texas. *R. solani* inoculum was introduced into each plot measuring 5.4 m long and 1.2 m wide at panicle differentiation. MBI-600 was applied to seed prior to planting and the foliage at 10^9 CFU/ml at the boot stage. Foliar applications of azoxystrobin at 0.08 or 0.16 kg a.i./ha were made at the boot stage. Two additional combined treatments of MBI-600 with azoxystrobin at either rate, as well as untreated control, were included for each trial. In each year, applications of MBI-600 resulted in a significant reduction in sheath blight severity over the untreated control. The combined use of MBI-600 with azoxystrobin at 0.08 kg a.i./ha further reduced disease severity. The efficacy of this combined treatment was comparable with that of azoxystrobin at 0.16 kg a.i./ha (the full recommended rate). The combined treatment tended to have higher grain yield than the untreated control and have similar yield to azoxystrobin at 0.16 kg a.i./ha. In summary, the combined use of the biocontrol agent with a reduced rate of fungicide can provide a novel practical means to minimize yield losses caused by sheath blight while reducing fungicide use on rice by 50%. This research is financially supported by the USDA/NIFA SRIPM Grant (2010-34103-21156).

Influence of Planting Date, Fungicide Timing, and Varietal Resistance on Development of Narrow Brown Leaf Spot of Rice

Kaur, K., Hollier, C.A., and Groth, D.E.

Narrow brown leaf spot of rice is a fungal disease caused by *Cercospora janseana* L. Miyake. It causes long narrow lesions on leaves, sheaths, glumes, and seeds of rice plants. Investigations on epidemiological aspects of *C. janseana* have been sparse due to low incidence of disease in the past few decades. Recent increases in disease pressure have been reported and are a serious concern for growers and researchers. Studies have been conducted to determine the effect of planting date, fungicide timing, and varietal tolerance on development of narrow brown leaf spot disease at the Rice Research Station, Crowley, LA. To accomplish the objectives, five varieties, Della, Cheniere, CL111, CL131, and CL151, were planted in Mid-April and Mid-May. Fungicide treatments of propiconazole [Tilt at 437 ml/ha (6 fl oz/A)], plus an untreated check, were applied at panicle initiation, early boot, and late boot stages. Weekly observations were recorded on disease incidence and disease severity in the lower, middle, and upper canopy. Preliminary results of this study have shown significant differences among varieties, treatments, and planting dates. Disease severity was significantly higher in rice of the May planting date compared with the April planting date. Among the varieties, disease severity in all levels of the canopy was found higher in CL111 and lowest in Della at both the planting dates. Significantly lower yield loss was found at the April planting date with treatment at the early boot stage and on the May planting date at panicle initiation stage.

Detection of *Rhizoctonia solani* Isolates with High Tolerance Levels to QoI Fungicides

Olaya, G., Pearsaul, D., Edlebeck, K., Tally, A., Zaunbrecher, J., and Lanclos, D.

Isolates of *Rhizoctonia solani* (causal agent of sheath blight disease on rice) with high tolerance levels to QoI fungicides have been identified in several fields located in Acadia Parish, Louisiana. A slight decline of Quilt Xcel™ (azoxystrobin + propiconazole) in the control of sheath blight was observed in 2010, and a major loss of performance was detected in 2011. Twenty *R. solani* isolates were retrieved from rice sheath blight samples that were collected from four fields where performance of Quilt Xcel™ was compromised. The *Rhizoctonia solani* isolates collected were all identified to be in the anastomosis group AG-1 IA. The sensitivity to propiconazole and azoxystrobin of the 24 *R. solani* isolates was determined under laboratory and greenhouse conditions. Four azoxystrobin and propiconazole baseline sensitive isolates collected before the commercial introduction of Quadris®, Tilt®, or Quilt Xcel™ were included in the fungicide sensitivity studies.

No changes in the propiconazole sensitivity of the *R. solani* isolates were detected. The sensitivity (ED50 values) of the four baseline isolates ranged from 0.00147 to 0.00497 (mean: 0.00262) mg/L. The propiconazole sensitivity of the 20 isolates collected from the four fields with Quilt Xcel performance issues ranged from 0.00016 to 0.00489 (mean: 0.00109) mg/L.

Changes in the azoxystrobin sensitivity of the *R. solani* isolates were detected. The sensitivity (ED50 values) of the four *baseline* isolates ranged from 0.450 to 0.914 (mean: 0.583) mg/L. The azoxystrobin sensitivity of 20 isolates were collected from the four fields, with Quilt Xcel™ performance issues ranging from 4.322 to >10 mg/L.

The mutation in the cytochrome b gene associated with QoI resistance is being determined. The frequency of resistant isolates is this rice and soybean growing area of Louisiana is also being quantified. This is the first report of QoI fungicide resistance in *R. solani* isolates from rice.

Azoxystrobin (Quadris® and Quilt Xcel™) Best Use Guidelines in Areas of *Rhizoctonia solani* Resistance

Black, D., Tally, A., Olaya, G., and Lanclos, D.

Azoxystrobin, a fungicide belonging to the strobilurin chemical class (QoI), is very active on *Rhizoctonia solani* and an important tool in the production of potatoes, sugarbeets, many other vegetables, and turfgrass. It has been extremely useful for control of sheath blight in rice and aerial web blight in soybeans. While resistance to other fungi has been reported, the development of resistance in *R. solani* was unexpected. There are very few reports of resistance in *R. solani* to any fungicides and thus the risk of resistance is considered low by the Fungicide Resistance Action Committee. From previous experience with soil-borne pathogens becoming resistant (mefenoxam/*Pythium*, mefenoxam/*Phytophthora*), the spread of resistance is usually not as fast as with foliar diseases. It is also known that selection of resistant isolates can occur independently, i.e. spread from this site is not needed per se to have resistance in other locations. Because QoI fungicides have been used for many years in both rice and soybeans, new tools need to be incorporated to manage other areas where resistant isolates may be present, as well as manage the problem site. A variety of cultural and agronomic practices, including planting less susceptible rice varieties, lower rice seeding rates, efficient nitrogen management, and effective equipment sanitation, to prevent moving debris to non-affected fields may be the key in managing this situation. As there are more fungicide options in soybeans, it may be important to alternate to a non-strobilurin fungicide to decrease the selection pressure, or use a more robust rate of the partner. As in soybeans, more robust rates and/or multiple applications of non-strobilurin fungicides may be important in rice.

Xemium® Fungicide for Disease Control in Rice

Guice, J.B. and Youmans, C.D.

Xemium® fungicide (fluxapyroxad) is a broad spectrum, highly efficient fungicide with high mobility within plant leaves. Xemium is in the carboxamide chemical family and is being developed in numerous crops worldwide by BASF. Xemium has been evaluated in small plot research trials for control of sheath blight (*Rhizoctonia solani*) in rice. Xemium demonstrated excellent efficacy against sheath blight. A single Xemium application, at panicle differentiation to the early boot rice growth stage, reduced the number of sheath blight infected tillers relative to the check. The Xemium application, in these research trials, also significantly increased rough rice yield compared with the untreated check.

The Louisiana Rice Water Weevil Demonstration Program

Hummel, N.A., Mészáros, A., Stout, M.J., Beuzelin, J.M., Burns, D.R., Clark, T.P., Courville, B.A., Deshotel, V.P., Ferguson, R.E., Fontenot, K.A., Gauthier, S.J., Lee, D.R., Levy, R.J., Martin, M.A., Meaux, J.M., and Zaunbrecher, D.J.

Rice water weevil (RWW), *Lissorhoptrus oryzophilus* Kuschel, management demonstrations were conducted in the 2008, 2009, 2010, and 2011 production seasons. The purpose of these demonstrations was to evaluate the use of currently available insecticides to control RWW in rice fields. The RWW is the most injurious insect pest in Louisiana rice production. Yield losses in excess of 25% can occur from severe infestations. The demonstration tests, conducted on commercial farms throughout Louisiana, compared the efficacy of a variety of insecticides to control RWW. In many ways, this demonstration program functioned as a verification program to assess recommended best management practices. Farmer cooperators were identified by County Agents in rice producing parishes. Insecticides were provided by the farmer's chemical distributor. In most locations, a Crop Advisor or Dealer Representative assisted in managing the on-farm location during the season.

The insecticides used each season varied depending on what was recently released on the market. During the demonstration program, we compared standard pyrethroid treatments with three larvicidal seed treatments, CruiserMaxx (2010 to 2011), Dermacor X-100 (2008 to 2011), and Nipsit INSIDE (2011). All of these treatments were compared with an untreated check. We collected RWW core samples 4 weeks after application of permanent flood to assess insecticide efficacy. Each season, the test was replicated across locations in multiple rice producing Louisiana parishes. We concluded that Dermacor X-100 significantly reduced the RWW infestation by comparison with an untreated check.

A variety of methods were used to inform the rice industry about observations both during and after each season. These included on-farm field days, winter meetings, newsletter, websites, posts on the Louisiana rice insects blog, twitter, and Facebook. Survey results found that producers that participated in the program were much more likely to adopt LSU AgCenter recommended management practices. Furthermore, during this demonstration program, we documented an increase in adoption of recommended RWW management practices and a corresponding decrease in practices that are discouraged by the LSU AgCenter research and extension program.

Incorporating Reduced Risk Insecticides into Management of Key Insect and Invertebrate Pests of California Rice

Godfrey, L.D., Goldman, E.B., and Aghaee, M.

Studies were conducted on management of rice water weevil (RWW) and tadpole shrimp in 2010 and 2011. Studies were done in 1 m^2 (10.7 sq. ft.) ring plots, small basins, and 0.1 ha (0.25 acre) plots to evaluate experimental insecticides versus registered standards for RWW control and in ring plots for tadpole shrimp. The ring plots allow numerous treatments to be evaluated in a small area under very controlled conditions. Twenty-four treatments (a total of six different active ingredients) were evaluated in ring plots for RWW. Adults were introduced into each ring, along with a moderate naturally-occurring infestation, resulting in a high infestation. In summary, Dimilin®, Warrior® II, and Mustang® Max, the registered products, are all still viable products for RWW control. In addition, in 2011, Declare® was evaluated as it entered the market. Among these products, Dimilin was the least effective but still provided moderate to good control. Application of Warrior preflood was a very effective treatment for RWW and produced results equal to or perhaps even better than the standard 3-leaf application. This application was "stretched" to 6 days before flooding and the activity against RWW was still high. Results with Mustang Max preflood application were erratic. Given the re-evaluation of pyrethroid registrations due to possible off-site movement, it is important to continue to develop alternative active ingredients and classes of chemistry. Belay® (clothianidan) and Dermacor® (rynaxypyr) were evaluated as seed treatments in previous years and control of RWW was moderate, at best, even with the highest rate tested. The water-seeded production system in California is not conducive for seed treatments. Belay® was also tested with preflood, soil applied and post-flood, 3-leaf timings and the efficacy against RWW was good to excellent. The post-flood method was superior to the preflood method, and this was especially true under poor spring conditions for rice germination and establishment. Clothianidan appears to have significant potential for RWW management and is progressing towards registration. Rynaxypyr also showed excellent activity against RWW via preflood and post-flood applications. Studies in 2011 concentrated on evaluating rynaxypyr efficacy against a natural infestation of RWW in small open field plots using various rates of a preflood timing. The RWW infestation was very severe and a definite yield response was seen with rynaxypyr application rates. A "rescue" treatment, i.e. applied at about the 5-leaf stage when the RWW larval infestation has already began, of clothianidin and of rynaxypyr was also shown to be effective. The control provided was in the 70% range but this is admirable given the demands placed on a product at this time. The final insecticide evaluated against RWW was a Bt product. *Bacillus thuringiensis galleriae* has shown activity against other coleopteran species, including some weevils. Studies are ongoing in the greenhouse. Tadpole shrimp has emerged as a significant pest of California rice with the reduced use and efficacy of copper sulfate. Several treatments were evaluated in 2010 and 2011 for tadpole shrimp mortality and protection of rice seedling stands. Copper sulfate, Warrior preflood and post-flood, and rynaxypyr preflood produced the most tadpole shrimp mortality. Belay, rynaxypyr, and Warrior, all applied preflood, were equally effective for protection of rice stands.

Efficacy of Selected Insecticides for Control of the Rice Stink Bug, *Oebalus pugnax,* in Arkansas

Thrash, B.C., Lorenz, G.M., Fortner, J.W., Taillon, N.M., Plummer, W.A., and Colwell, C.K.

Trials were conducted to evaluate the control of the rice stink bug (RSB) with selected insecticides. These trials indicated that several compounds are very effective for control of this insect pest. During the 2010 and 2011 growing season, small block and large block trials were conducted to evaluate the efficacy of certain insecticides for control of the RSB. Trials were located in fields where RSB exceeded the extension threshold of 5 per 10 sweeps in heading rice. All small plots were sprayed with a hand boom and large blocks were applied by air. Standard insecticides used to control the RSB hold up well in situations when low populations of this pest are present. In years with extremely high pressure, such as 2011, stinkbug numbers can increase rapidly in just a few days. During these instances, the insecticide selected and the rate applied can have significant effects on control. Multiple applications at these times may also be required to reduce numbers to acceptable levels. Results of tests will be discussed.

Comparing Efficacy of Tenchu 20 SG to Karate Z against the Rice Stink Bug, *Oebalus pugnax* (F.)

Blackman, B.D., Stout, M.J., Adams, B.M., and VanWeelden, M.T.

Currently, three families of insecticides (carbamates, organophosphates, pyrethroids) are labeled for use by the EPA to prevent rice stink bugs, *Oebaluspugnax* (F.), from damaging rice panicles during the vulnerable period of grain development. In July 2011, the EPA approved a Section 18 label in Louisiana allowing application of the neonicotinoid pesticide Tenchu 20 SG to a limited number of rice acres for control of rice stink bugs. Tenchu 20 SG is in the neonicotinoid family of insecticides, which work at different insect target sites than pyrethroids, carbamates, or organophosphates. Because of the unique action of the chemical, Tenchu 20 SG is believed to have a safer environmental profile with less damage to non-target organisms and very low mammalian toxicity.

In August 2011, spray trials were conducted to compare the efficacy of Tenchu 20 SG (a.i. Dinotefuran) and Karate (a.i. Lamda-cyhalothrin) against the rice stink bugs at the Rice Research Station in Crowley, Louisiana. A field of Cocodrie rice was divided into four blocks of three plots and managed according to LSU AgCenter recommendations. Plots (5.49 m x 1.22 m) were randomly assigned a treatment of Karate, Tenchu, or unsprayed control. A calibrated sprayer was used to apply the recommended rate of a treatment to each group of plots in that treatment. To ensure chemicals were applied effectively, a nylon mesh cage (6 cm x 20 cm) of three stink bugs was put in each plot prior to spraying, and mortality was recorded 2 hours after spraying. Three cages containing four adult rice stink bugs were put on randomly selected rice panicles for three time points - 2 hr, 72 hr, and 120 hr. The number of insects alive and dead was recorded for each cage at each time point in each plot. The experiment was replicated in four blocks. Treated effects were seen between treated and untreated plots, as well as treatment times (d.f. = 2 F= 4.55 p=0.0129; d.f.=4 F= 5.36 p=.0006, respectively). However, treatments of Karate and Tenchu were not significantly different, indicating that neither chemical provided significantly better control than the other.

Chemical Ecology of the Rice Stink Bug, *Oebalus pugnax*, and Implications for Pest Management

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

When disturbed, Pentatomids release pungent odors from metathoracic glands that can have several functions, such as serving as an alarm and/or aggregation cues, as well as affording protection from predators and pathogens. Laboratory and field experiments were undertaken to characterize the chemical composition of *O. pugnax* metathoracic glands and to gain insight into the multifunctional role of these chemicals. The host plant on which *O. pugnax* was reared had a significant influence on the amount of (*E*)-2-octenal, (*E*)-2-hexenyl acetate, *n*-dodecane and *n*-tridecane found in metathoracic gland extracts. Behavioral responses of adult *O. pugnax* to gland extracts in a y-tube olfactometer showed that adults were significantly deterred at a concentration of one stink bug equivalent, while a concentration of 0.125 individual equivalents was attractive to adults. Two field experiments were conducted using a synthetic mixture containing four of the most abundant metathoracic gland components – (*E*)-2-hexenal, (*E*)-2-hexenyl acetate, (*E*)-2-octenyl acetate, and *n*-tridecane. A synthetic mixture of these compounds was applied to 6.6m^2 plots of rice and sampled for *O. pugnax* 30, 60, and 120 minutes after spraying. While there was no overall treatment effect on the number of *O. pugnax* per plot in either of the experiments, the interaction between time and treatment was significant. The potential to incorporate metathoracic gland extracts into novel management strategies is discussed.

Development of the RiceScout Mobile Application

Hummel, N.A., Mészáros, A., Cartwright, R.D., Fiser, S.M., Groth, D.E., Harrell, D.L., Hollier, C.A., Piazza, F.P., Saichuk, J.K., Schultz, B.R., Way, M.O., and Webster, E.P.

American agricultural production faces a critical juncture. Fewer farmers are managing more acreage, the Cooperative Extension Service (CES) across the U.S. is being forced to reduce staff due to budget constraints, and there is an increasing reliance on private industry to support farming operations. Farmers across the U.S. are rapidly adopting smartphone technology to stay current with market trends and access information online. Smartphones are small and convenient to carry while moving around the farm, making them an excellent information delivery platform for CES information.

Fewer decisions are more critical during the production season than accurately diagnosing the cause of crop damage quickly enough to resolve the problem. Often a delay of one or two days can result in substantial yield reduction, or even entire crop loss. Due to the threat of crop loss from insects, disease, weeds, and nutritional deficiencies, there is great demand for production guides, pocket flip guides, and quick access to CES personnel via text messaging, e-mail and voice from cell phones. Recently, there is also an expectation that CES personnel be accessible through social networking tools (e.g. Facebook and Twitter). Unfortunately, while demand for support from CES personnel has increased, we have also been forced to reduce staff and printing budgets due to budget cuts, but CES personnel continue to be passionate about assisting producers in crop production. This means learning to work smarter and more efficiently using fewer people and less resources is absolutely necessary. Development of tools, such as crop-focused iPhone apps, is an efficient way to aid with identification, deliver recommendations, and educate producers about best management practices. The goal of app development is not to replace the CES personnel in the field but rather to complement the diagnostic process.

One way to address personnel reductions and demand from the public is to create electronic, mobile decision tools. This requires an up-front investment in staff time, equipment, and technology to create the tool but can be quickly and easily updated with minimal additional cost. In the case of a smartphone application (app), revenue for maintenance can be self-generated from download fees. Thus, with proper maintenance and management, mobile decision tools virtually never go out of date. This is an advantage over print publications, which are often immediately out of date after publication. The objective of this project has been the development of the beta version of the “RiceScout” web-based mobile application. “RiceScout” is a comprehensive mobile pest (arthropods, weeds, diseases) and nutritional deficiency identification and decision tool for use in southern rice production. After the app launches and is distributed through the iTunes store and Android marketplace, annual subscription fees will be used to update the app.

The “RiceScout” app was programmed using HTML 5 coding so that it could be launched as a web-based application, an iPhone app, and an Android application. The first section of the “RiceScout” app is an electronic flip-guide that includes four items: rice arthropods (insects, mites), diseases, weeds, and nutritional deficiencies. In each section, users have access to a series of pictures, descriptions, diagnostic characteristics, and useful links. The second menu of the “RiceScout” app features two diagnostic keys. The first diagnostic key is used to identify crop injury symptomology that will allow the field scout to differentiate between injury due to arthropods, diseases, or nutritional deficiencies. This will be an expansion of the “Online Louisiana rice insect identification guide” that is housed at www.lsuagcenter.com. The second diagnostic key is a weed identification key that is a mobile conversion of LSU AgCenter publication 3055.

If funds are secured, this app could be adapted to become a data-gathering tool. The GPS and image uploading capabilities of smartphones can be used to gather data from users on their insect, disease, weed, nutritional deficiency problems, and management decisions during the production season. This reporting system could be used to create alert systems through which subscribers will be alerted when a user uploads a pest report. The potential use of these apps is only limited by our creativity and programming capabilities. Data captured on pest problems and management decisions can be used to measure impact of extension programs and also develop directed programs to address emerging problems.

Characterizing Variation in Resistance among Commonly Grown Rice Cultivars in Louisiana against the Sugarcane Borer, *Diatraea saccharalis*

Sidhu, J.K., Stout, M.J., and Hummel, N.A.

Rice is grown over an area of approximately 184,132 ha (455,000 acres) in Louisiana. The stem borer complex attacking rice in the southern U.S includes stalk borer, *Chilo plejadellus*, sugarcane borer (SCB), *Diatraea saccharalis,* and Mexican rice borer*, Eoreuma loftini (*Dyar). With the increasing impact of stem borers on rice production and the arrival of the Mexican rice borer in Louisiana, an urgent need exists to develop strategies for management, including host plant resistance and chemical control. At present, SCB is a major pest that is posing a serious threat to the rice industry. Currently, no IPM program is in place for SCB in Louisiana rice. The primary goal is to develop an IPM program for SCB.

The greenhouse and lab studies were undertaken to characterize variation in resistance among commonly grown cultivars in Louisiana that may help in development of resistant varieties. Eight widely grown cultivars were used: Cocodrie, Priscilla, XL723, Cheniere, Jazzman, Bengal, CL151 and CL161. All these cultivars were grown in 15-cm diameter pots containing standard soil mix (peat moss: sand: top soil in 1:1:2 ratios). Five seeds were sown per pot. Plants were thinned 15 d after sowing to one plant per pot. Slow release fertilizer was applied at the rate of 0.79 g/pot, 3 weeks after emergence. A randomized complete block design was used with one plant of each rice variety within each block.

In these experiments, compensation, relative growth rate, and boring success of larvae in eight commonly grown cultivars was studied. Results revealed significant differences among cultivars for these three parameters. The hybrid XL723, Clearfield cultivars, and the medium-grain Bengal showed lower relative growth rates and boring success. In the compensation experiments, the infested plants produced more number of tillers and more seeds per panicle compared with the control plants, and also, there were differences among cultivars for compensation.

Quantifying Toxicity of Thiamethoxam against Rice Water Weevil by Combining Adult Feeding with Residue Determination Approaches

Lanka, S.K., Stout, M.J., Ottea, J.A., and Davis, J.A.

Thiamethoxam is a systemic insecticide toxic to adult weevils. Its adulticidal mode of activity warrants basic understanding on the susceptibility in weevil populations. Studies were conducted to determine systemic lethal dose (LD_{50}) by combining adult feeding data with insecticide residue data. Also, to understand the dynamics of insecticidal activity of these seed treatments, bioassays for residual toxicity were undertaken at distinct stages of rice growth.

Cruiser 5FS™ was applied to the CL131 rice variety at different rates (0, 4, 7, 14, 28, 41, 53, and 61 µg ai/seed). For lethal dose determination, top two leaves of treated seedlings were used. Our standardization trials revealed acute toxicity of seed treatments at seedling stage (2-3 leaf stage) and 1-hour feeding period was found to be adequate to distinguish different seed treatment rates. In lethal dose determination bioassays, leaves after weevil damage were scanned using desk top scanner. Such scanned images were processed using Sigma Scan pro® to measure leaf area lost due to weevil feeding. Since leaf weights consumed by weevils were needed in these experiments, regression of weight loss was done on leaf area lost due to feeding. For this, leaf weight loss determination assay was conducted. Insecticide residue levels determined by LC/MS/MS methods were combined with predicted weight loss to estimate consumption of both thiamethoxam and clothianidin. The consumption estimates of both the chemicals with corresponding adult mortalities were used to determine LD_{50} values by analyzing the data using probit analysis.

To conduct residual toxicity of seed treatments, plantings were staggered in the greenhouse facility. All seed treatment rates were used in this experiment. Plants at seedling (5-6 leaves) and tillering (4-5 tillers) stages were tested in a 96-hour feeding period. Only the top two leaves of main stems were excised separately for feeding and leaf residue estimation. Three determinations were done on consecutive days for mortality. Concentrations of thiamethoxam in leaves were determined using an ELISA kit for thiamethoxam. The ELISA kit was calibrated and residue levels were determined in both groups of plants.

Loss of leaf area due to weevil feeding impacted weight reduction in leaf pieces and most variability in weights in damaged leaves was accounted due to weevil feeding. This enabled the use regression equation to estimate foliar losses. Seed treatments rates impacted foliar concentrations of active substances (thiamethoxam and clothianidin). Toxicity of seed treatments on adults depended on the consumption of active substances when weevils feed on leaves. Our residual toxicity experiments revealed that both plant growth and seed treatment rates impacted adulticidal activity. Feeding on leaves at seedling stage yielded greater mortality in weevils than at tillering stage. This growth related dilution of effects was consistent with residues estimated by the ELISA method.

Beyond Rice Field Boundaries and Harvest: Mexican Rice Borer and Sugarcane Borer IPM

Beuzelin, J.M., Mészáros, A., Way, M.O., Reagan, T.E., and Wilson, L.T.

The Mexican rice borer, *Eoreuma loftini* (Dyar), and the sugarcane borer, *Diatraea saccharalis* (F.), are crambid stem boring pests of sugarcane and rice in the Gulf Coast region. *D. saccharalis* is the key pest of sugarcane in Louisiana, and pest severity has increased in rice-growing areas of Louisiana and Texas during the past decade. While *D. saccharalis* has been established in the southeastern United States since the 1850s, *E. loftini* has expanded its range in a northeasterly direction since its first detection in south Texas during 1980. In 2008, *E. loftini* adults were collected for the first time in Louisiana, where annual economic losses in sugarcane and rice are projected to be as severe as $220 million and $40 million, respectively. In spring 2011, *E. loftini* adults have been consistently collected in pheromone traps throughout Calcasieu Parish. The first *E. loftini* larval infestations in Louisiana rice were reported in July 2011. Stem borer management in rice mainly relies on insecticides, with chlorantraniliprole seed treatments (Dermacor X-100®) and foliar applications of pyrethroids. Thus, in an effort to provide rice producers with a more comprehensive management strategy, studies were conducted to better assess the role of selected rice production practices and weedy hosts impacting stem borer populations.

A 2-year field study in Texas compared stem borer infestations as affected by rice main crop harvest cutting height and the production of a ratoon crop. Lowering harvest cutting height from 40 to 20 cm reduced *E. loftini* infestations in the stubble by 70 to 81%. However, *D. saccharalis* infestations were not affected. Plant dissections showed that compared with *D. saccharalis* larvae and pupae, relatively more *E. loftini* immatures were located above 20 cm from the base of rice culms. *E. loftini* and *D. saccharalis* densities during the late production season and over the winter showed that substantial stem borer infestations could occur in rice whether or not main crop stubble was managed for the production of a ratoon crop.

Three farms in the Texas rice Gulf Coast production area were surveyed for 2 years every 6 to 8 weeks to compare stem borer infestations in non-crop grasses adjacent to rice fields. While *D. saccharalis* densities were relatively low, *E. loftini* average densities ranged from 0.3 to 5.7 immatures per m^2 throughout the 2-year period. Early annual grasses, including ryegrass (*Lolium* spp.) and brome (*Bromus* spp.), were infested during the spring whereas johnsongrass and vaseygrass were infested throughout the year. Johnsongrass was the most prevalent host but vaseygrass harbored as much as 62% of the recovered *E. loftini* immatures during the winter. This study showed that non-crop grasses are year-round sources of *E. loftini* in the Texas rice agroecosystem and have the potential to increase pest populations.

This research provides a foundation for management targeting stem borer populations occurring after the rice production season and in non-crop habitats. However, because *E. loftini* and *D. saccharalis* somewhat differ in their biology, successful management may demand a more complex strategy than one targeting a single pest species. In addition, there is still a critical need to determine the extent to which manipulation of non-crop hosts and implementation of selected late-season cultural practices can decrease stem borer crop damage and be cost effective.

Effect of Silica on Resistance of Two Rice Cultivars against the Sugarcane Borer; *Diatraea saccharalis*

Sidhu, J.K., Stout, M.J., and Datnoff, D.E.

The stem borer complex attacking rice in the southern U.S. includes the rice stalk borer *Chilo plejadellus*, sugarcane borer (SCB) *Diatraea saccharalis,* and the Mexican rice borer*, Eoreuma loftini (*Dyar). Research on the resistance of rice cultivars to stem borers in the United States has been sparse due to the low past incidence for many years. However, with the increasing impact of stem borers on rice production in the last few years and the arrival of the Mexican rice borer in Louisiana, an urgent need exists to develop management strategies, including host plant resistance and chemical control. Currently, no integrated pest management program is in place for SCB in Louisiana rice and research has been initiated to develop an integrated pest management program for SCB. The initial phase of this research was focused on characterizing variation in resistance among commonly grown cultivars in Louisiana. Based on those studies, we chose Cocodrie and XL723 for silica amendment study.

Greenhouse studies were undertaken to investigate the borer success and the relative growth rate of SCB larvae on treated and untreated plants of these two cultivars. The two cultivars were grown in 15-cm diameter pots containing standard soil mix (peat moss: sand: top soil in 1:1:2 ratios). Five seeds were sown per pot. Plants were thinned 15 d after sowing to one plant per pot. After thinning, calcium silicate was added to the pots as a source of silica. Half plants of each variety were treated with calcium silicate and the other half were untreated controls. Slow release fertilizer was applied at the rate of 0.79 g/pot, 3 weeks after emergence. There were five replications. Two weeks after application of calcium silicate, the borer success and relative growth rate experiments were conducted.

In the borer success experiments, early second instar SCB larvae were released on treated and untreated plants of each cultivar at the rate of five larvae per plant. Number of larvae that bored into the stems after 24 and 48 hours were recorded.

For the relative growth rate study, second instar larvae were used. The larvae were taken out of diet and starved for 2 hours in the lab. The larvae were then weighed to record the initial weight. Infestations were done using one larva per plant. The larvae were recovered 7 days after infestation and the final weight of the larvae were recorded. Relative growth rate of the larvae were calculated. Plant samples were also sent to the lab for estimation of silica in the treated and untreated plants. Effects of silica amendment on levels of phenolics were also studied for the two cultivars.

Relative growth rates of SCB larvae were lower on plants treated with calcium silicate than on untreated plants. Lower number of larvae bored into the stems of plants treated with calcium silicate compared with the untreated plants. Silica contents were higher in the treated plants compared with the untreated plants but Cocodrie responded better than XL723 to silica amendment. There was no significant difference in the amount of phenolics in the treated and untreated plants of the two cultivars.

Patterns of Insecticide Use in California Rice

Espino, L.

In the past two decades, significant changes have occurred in the arthropod pest complex and pattern of insecticide use in California rice. Currently, the rice water weevil (RWW) and tadpole shrimp (TPS) are considered key pests; the rice seed midge, rice leaf miner, aster leafhopper, and armyworms are considered secondary pests. The major insecticides used to control these pests during the 1990s have been replaced by less toxic products due to environmental concerns. To identify changes and new patterns of insecticide use, the California Department of

Pesticide Regulation databases (Pesticide Use Reports) from 1990 to 2009 were used. Counties used were Butte, Colusa, Glenn, Sutter, Yolo, and Yuba. The rice acreage planted in these counties accounts for 95% of the total rice acreage in California.

Percentage of acres treated: Insecticide use was divided in two groups according to timing of application: early (April-June) and late (July-October). Early applications target rice seed midge, TPS, RWW, and rice leaf miner; late, leafhoppers, and armyworms. For early applications, carbofuran use stopped in 2000 and was replaced by λ-cyhalothrin and s-cypermethrin (the pyrethroids) and diflubenzuron. Parathion and methyl parathion were used until 1999 and 2000, respectively, and were replaced by the pyrethroids. Malathion use decreased significantly. The total percentage of acres treated early for all active ingredients decreased from 60.5% in 1990 to 15.7% in 2009. In late applications, carbaryl and methyl parathion were replaced by the pyrethroids. The average percentage area treated per year with an insecticide late in the season has remained constant, averaging 2.4%.

Insecticide Use Intensity (IUI): In the past 20 years, IUI (kg a.i./ha planted) for all counties decreased substantially, from 0.3729 in 1990 to 0.0075 in 2009. This is mainly because of the replacement of carbofuran, a granular insecticide used at a rate of 0.56 kg a.i./ha, with the pyrethroids, liquid insecticides used at rates of up to 0.045 kg a.i./ha; and the halt in use of methyl parathion. During the 1990s, there were differences in IUI among counties but in later years, differences were small.

Percentage of field treated per application: Averaging across years, for early applications, 58% of carbofuran, 68% of pyrethroids, and 79% of diflubenzuron applications were made to less than 40% of the treated field. These treatments target mainly the RWW (RWW infestations are limited to field borders and levees). Sixty-seven percent of malathion, 70% of parathion, and 71% of methyl parathion applications were made to more than 80% of the treated field. For late applications, 58% of all applications were made to more than 80% of the treated field.

Timing of RWW applications: The timing of RWW insecticide applications changed after carbofuran use stopped. With carbofuran, the average median RWW application date was 10.3 days earlier than when 50% of the California rice acreage was planted. With the pyrethroids and diflubenzuron, the average median RWW application date was 11.7 days later than when 50% of the California rice acreage was planted.

Effect of Thiamethoxam Seed Treatment on Rice Water Weevil Control in Drill-seeded Conventional and Hybrid Rice Varieties

Mazzanti, R.S., Bernhardt, J.L., and Ntamatgiro, S.

Seed treatment with insecticide is a convenient method for farmers to prevent a select group of insects from causing damage to rice (*Oryza sativa* L.) and minimize yield losses. Thiamethoxam is a neonicotinoid insecticide that is new to rice and is recommended as a seed treatment. While being tested using pure-bred (conventional) rice varieties, thiamethoxam seed treatment at a low rate was found to provide adequate control of early-season pests but required a higher rate to control midseason insect pests. Another seed treatment, rynaxypyr, when tested for control of rice water weevil (*Lissorhoptrus oryzophilus* Kuschel) on hybrid and conventional rice seed was found to have less control in the hybrid even when both varieties were treated with similar amounts of insecticide.

A study was conducted at the Rice Research and Extension Center, near Stuttgart, Arkansas, to compare the effect of seed treatment with thiamethoxam on rice water weevil infestations on a conventional and a hybrid rice variety. Treatments were arranged in a split-split plot design with four replications with seed treatments (untreated and treated with 128.75 g of thiamethoxam per 100 kg of seed) as main plots, varieties (conventional 'Roy J' and hybrid 'CL XL745') as subplots, and seeding rates (50.4, 75.6, and 100.8 kg/ha for Roy J, and 22.4, 33.6, 44.8 kg/ha for CL XL745) as sub-subplots.

Overall, thiamethoxam treatment significantly reduced rice water weevil infestation, but percent control (averaged over seeding rates) was 91% for Roy J and 62% for CL XL745. Weevil densities (averaged over varieties and seed treatment) were the same regardless of seeding rate. This was unexpected but most likely was due to the physical arrangement of plots and levees. All sub-subplots of a variety and insecticide treatment were contained within the same paddy and irrigation water, thus allowing adult weevils to easily move between sub sub-plots. Grain yield was not significantly different between treated and untreated seed, but the percentage yield loss was 0.7% (86.0 kg/ha) for CL XL745 and 2.6% (253.9 kg/ha) for Roy J. The conventional variety averaged 13.6 larvae per core in the untreated while the hybrid averaged 16.6 larvae per core. The conventional variety was more susceptible to damage by moderate levels of rice water weevil than the hybrid even with a lower percent control (62%). The hybrid had significantly more biomass (tillers and vegetative growth) 3 weeks after permanent flood than the conventional and perhaps the dispersal of available thiamethoxam into a larger plant compromised control of weevil larvae. Even with more rice water weevil larvae causing damage to plants, CL XL745 tolerated the moderate levels of weevils better than Roy J.

LSU AgCenter Statewide Residual Spray Demonstration: Comparing Tenchu 20SG to Pyrethroids in the Field

Blackman, B.D., Hummel, N.A., Stout, M.J., Collins, K.R., Courville, B.A.,
Erwin, T.L., Ferguson, R.E., Huff, N.K., and White, L.M.

In July 2011, the EPA approved a Section 18 emergency exemption in Louisiana allowing application of the neonicotinoid pesticide Tenchu 20SG to a limited amount of rice acreages for control of rice stink bugs. Efficacy of Tenchu 20 SG had been previously documented in small plot studies conducted in Arkansas, Louisiana, and Texas. Large scale field trials in multiple locations had not been performed to compare the efficacy of Tenchu 20SG with commonly used pyrethroids in the southeastern U.S.

The LSU AgCenter coordinated a large-scale demonstration program to compare the efficacy of Tenchu 20SG with pyrethroids commonly used for rice stink bug control. Nine field sites in various locations in northern and southern Louisiana were identified by Extension Agents and consultants. Sites were divided into two adjacent fields or two cuts within a field that could be sprayed, sampled, and harvested separately. Each field consisted of the same variety of rice, planting date, and management practices. Fields were sampled (100 sweeps with 38 cm. sweep net) between anthesis and hard dough stage to determine relative populations of rice stink bugs. The two fields were then treated by crop duster with a labeled rate of either a pyrethroid (Karate or Mustang Max) or Tenchu 20 SG. Follow-up sampling was performed at 72 hours and 120 hours to attempt to capture residual deterrence of rice stink bugs among treatments. Rough rice samples were taken at harvest and dried before being hulled and graded for percent pecky rice by a USDA certified rice inspector. Statistical analysis was performed using ANOVA (Proc Mixed) in SAS to determine if correlations existed between treatments and time or treatments and pecky rice. No significant difference was found between either treatment for any sampling time point or for percent pecky rice.

The Effects of Seeding Rate and Variety on the Impacts of Rice Water Weevil (RWW) in California Rice

Goldman, E.B., Godfrey, L.D., and Espino, L.E.

Studies to evaluate the effects of variable seeding rate and different varieties on the impact that rice water weevil (RWW) has on yield and tiller number were conducted in 2011. Two different varieties (M-202 and M-206) were planted at four different seeding rates, 56, 112, 168, 224 kg/ha (50, 100, 150, and 200 lb/acre), in two different plot types. One type was an undivided 3 x 6 m (10 x 20’) rectangle (Type X), the other was a 3 x 6 m (10 x 20’) rectangle, divided in half crosswise (Type Y). On one half, there were three 1 m^2 (10.7 sq. ft.) ring plots; the other half remained undivided. In total, there were 16 treatments replicated six times. The “X” plots received a preflood treatment of Warrior® II and were planted Dermacor®-treated seeds to minimize RWW. The open half of the “Y” plots were left untreated to become naturally infested with RWW. The rings in the “Y” plots received one of three treatments: infestation with 0.2 adult RWW/plant, infestation with 0.6 adult RWW/plant, and no infestation following a preflood treatment of Warrior® II on rice grown from Dermacor®-treated seed. Results indicate that there wasn’t a correlation between tiller density (number of tillers/m^2) and yield. Likewise, it appears that tiller density is independent of seeding rate. An interesting trend that was observed was the tendency for rings receiving the high rate of infestation to have fewer larvae than those that received the low rate of infestation. This is likely due to the fact that the high rate was too high, meaning that RWW larval numbers were reduced due to competition for resources. Yield data support this theory as rings receiving the high infestation regularly outperformed those with a low infestation. In general, treated plots had higher yields than untreated plots. In M-202, this held true except for the 224 kg/ha (200 lb/acre) seeding rate. For M-206, yields were higher in treated plots than untreated plots, except at the high rate of infestation. This suggests increased resiliency of M-206; once the larval levels drop (presumably due to too much competition), M-206 is able to bounce back and yield nearly the same as the “zero weevil” treatment.

New Rice Insects and Diseases Pages at www.lsuagcenter.com

Mészáros, A., Groth, D.E., Hollier, C.A., Hummel, N.A., Saichuk, J.K., and West, L.

LSU AgCenter scientists have recently restructured the layout of their web content to make it more accessible to their clientele. The rice diseases and insects pages are now organized in an enhanced user-friendly format. The content was updated to include basic information, photo galleries, presentations, management recommendations, and trainings.

Disease damage to rice can greatly impair productivity and sometimes destroy a crop. Direct losses to disease include reduction in plant stands, lodging, spotted kernels, and fewer and smaller grains per plant and a general reduction in plant efficiency. Indirect losses include the cost of fungicides used to manage disease, application costs, reduced yields associated with special cultural practices that reduce disease but may not be conducive to producing maximum yields. Disease control is based on several steps, including correct identification, understanding the disease’s epidemiology, and utilizing host resistance, cultural management, and chemical control.

Rice can be injured by a variety of invertebrate pests (insects and mites). The major invertebrate pests of rice in Louisiana are the rice water weevil and the rice stink bug. In addition, stem borers, rice seed midges, rice leafminers, chinch bugs, billbugs, sugarcane beetles, South American rice miners, and armyworms can be severe rice pests. Under heavy infestation levels, all of these pests can cause economic losses. The scouting and management recommendations are based on the best available information and may be modified as additional research is conducted. The preferred approach to controlling insect pests is by developing and following an integrated pest management plan. An effective integrated pest management plan relies on knowledge of the important pest species attacking the crop, appropriate sampling for pests, proper identification of species, and utilization of a variety of control tactics. These tactics can include cultural practices, application of insecticides, biological control, and breeding for resistance. The use of multiple tactics has the potential to result in a more effective and less expensive control program.

The revised LSU AgCenter rice diseases homepage (www.lsuagcenter.com/ricediseases) provides access to different sections of information: Plant diagnostic center, rice disease training presentations, rice diseases photo galleries, rice fungicide links, Louisiana plant pathology series (rice), and rice disease publications and identification. Rice disease training presentations include the most common diseases such as sheath blight, blast, stem rot, bacterial panicle blight, grain smuts, the Cercospora complex, seed rot, and water mold. The rice disease photo galleries provide a series of pictures of common diseases accompanying short descriptions. The Louisiana plant pathology series are numbered AgCenter publications formatted as pdf documents. The rice disease identification and management series provides descriptions, epidemiology, and control options for each rice disease present in Louisiana. Rice fungicide links are provided as an additional resource.

The structure of the revised rice insects page (www.lsuagcenter.com/riceinsects) is similar to the rice diseases page. The new rice insects home page provides access to the following sections: rice insect presentations, rice insect photo galleries, Online rice pest identification guide, Louisiana rice insects blog postings, demonstration tests, rice field notes, meetings (oral and poster presentations), insecticide links, and numbered publications. These links provide information about the most common insects found in rice. The online identification guide (www.lsuagcenter.com/ricepestguide) represents the first website-based delivery method of rice pest identification through an online interactive key. The guide was built within the LSU AgCenter content management system, using a dichotomous key combined with pictures of typical symptoms of pest injury. The demonstration test section includes summaries of the rice water weevil demonstration tests conducted from 2008 to 2011. The purpose of these demonstrations was to evaluate the use of currently available insecticides to control rice water weevils. The Louisiana rice insects blog and rice field notes include field observations made during the production season.

An advantage of information delivery through websites is that it is adaptable and can be easily updated with minimal expense. The structure of these pages will continue to be revised and updated based on user feedback. Users have the ability to rate the webpages and directly email webpage author(s) for additional information.

Precision Aerial Application for Site-specific Rice Crop Management

Lan, Y. and Hoffmann, W.C.

Precision agriculture includes different technologies that allow agricultural professional to use information management tools to optimize agriculture production. The new technologies allow aerial application applicators to improve application accuracy and efficiency, which saves time and money for the farmer and the pilot. The USDA-ARS-Aerial Application Technology group has an active research component in precision application. This presentation will discuss the various research components and how they will ultimately fit into a complete precision application package. Since aerial applicators are flying over numerous fields between spray missions, these aircraft can be fitted with multispectral cameras that can detect crop diseases, water stress, and other crop conditions. Research is underway to convert these images into application maps (i.e. shape files) without a lot of effort or special knowledge from the pilot/operator, which could then be a new service to a customer. These application maps could then be easily uploaded into the spray system computer to make variable-rate aerial application of cotton growth regulators, defoliants, and insecticides. The goal of these research projects is to demonstrate that precision agriculture technology has the potential to benefit the industry by saving operators and farmers' time and money.

Preliminary Studies on Management of Seed-borne Inoculum of *Burkholderia glumae* in Rice Seed

Wamishe, Y., Cartwright, R., Belmar, S., and Kelsey, C.

Bacterial panicle blight (BPB) of rice is thought to be primarily seed-borne and can cause up to 60% yield loss under favorable environmental conditions resulting in failure of seed development and grain-filling. BPB of rice is caused by more than one species of bacteria and *Burkholderia glumae* has been considered the major causal agent. During seed planting, the bacteria can be carried back to the field. To reduce the inoculum density for BPB disease by removing "light-weight" kernels, seeds were separated using ammonium sulphate solution. Then, the seeds were grouped as sinkers (plump with normal color seeds) and floaters (chaff, and light-weight discolored seeds). These groups of seeds were tested for the presence of *B. glumae* on semi-selective medium, CCNT. *B. glumae* was recovered from the chaff, discolored, and "light-weight" seeds, and plump and healthy-looking seeds. Floater seeds germinated relatively very poor indicating the good looking and well germinating sinker seeds as possible carriers of the bacteria back in to the field and cycle the bacteria in plant tissues. The floater seeds decay in the soil and may contribute to bacterial population in the soil.

A few chemical and non-chemical seed treatments also were evaluated against the BPB pathogens. Results were erratic when using naturally infected seeds but more consistent using artificially infected seeds. The chemicals that were effective under low inoculum density appeared less effective when inoculum density increased. Among the non-chemical and chemicals tested hot-water treatment and Oxolinic acid (Starner) appeared to hold up in both situations, respectively. These results are preliminary and we plan to repeat the experiments thoroughly with known inoculum densities.

Discovering the Epidemiology of Bacterial Panicle Blight in Rice

Sayler, R.J. and Wamishe, Y.

Bacterial panicle blight (BPB) has become one of the most important diseases of rice in the southern United States in the last few years. This disease is caused most frequently by *Burkholderia glumae* and occasionally by *B. gladioli*. Rice panicles are most susceptible to infection during flowering, although the pathogen is thought to live epiphytically on the plants before heading. The severity of the disease appears to increase when prolonged high temperatures occur during heading. Seeds from six Clearfield rice varieties that have different heading dates were assessed for the frequency of kernel infection. Two batches of seeds were tested; the first batch consisted of parental seeds that were used for planting and the second batch was their progeny seed obtained after harvest. The infection rate in the harvested seeds ranged between 2 to 8 percent. The earliest maturing line, Clearfield 111, had an infection rate of 3%, suggesting that it may have escaped infection. In contrast, the infection rate in the parental seeds lots used for planting was extremely low, with only one cfu being detected among all seeds tested. These preliminary results suggest that rate of disease spread could be a function of the frequency of infection in planting seed and cultivar heading date. The level of genetic resistance among these Clearfield cultivars may also be an important factor explaining the differences in harvested seed infection rates. We also used PCR based detection of *B. glumae* in stink bugs to determine what fraction of these insects harbor the pathogen's DNA. Samples of the stink bugs were collected from rice fields at Rice Research and Extension Center in Stuttgart before the appearance of BPB, when symptoms first became evident, and later in the season. PCR positives occurred in only three of 20 stinkbugs collected later in the season, suggesting this insect is not a major vector of the disease.

Inoculum Production for Sheath Blight and Blast Virulence Tests

Belmar, S.B., Kelsey, C.D., and Lee, F.N.

Genetic resistance to rice sheath blight, *Rhizoctonia solani,* and rice blast, *Pyricularia grisea,* is routinely determined by artificially inoculating plants. A laboratory production system was developed to provide quality dry inoculum in about 2 to 3 weeks, which is stable for at least 9 months when stored at 25ºC and moderate relative humidity (<70%). Moreover, the shelf life of *P. grisea* inoculum is significantly extended if thoroughly dried and stored under vacuum at 16ºC.

Inoculum production utilized a seed media of commercial ryegrass and yellow cracked corn (corn chops), 30.5 x 61 cm (12 x 24 in) autoclave bags, and a concentric metal-cotton stopper assembly. The process for sheath blight begins with the moistening of ryegrass with water (12:1) and autoclaved immediately. For blast, the ryegrass is moistened with water (9:1) and held in an enclosed container for 3 to 4 hours in a warm greenhouse environment. Corn chops are soaked in water (1:1) for 30 min, then autoclaved on liquid cycle (121ºC, 103 kPa, 50 min) and allowed to cool overnight. The next day, corn chops are crumbled apart and blended with ryegrass in the ratio of 3 L ryegrass to 4 L corn for *R. solani* and 18 L ryegrass to 3 L corn for *P. grisea*. Autoclave bags are 40% filled with the seed media, capped with a stopper assembly and autoclaved on two different cycles for sheath blight: liquid cycle (121ºC, 103 kPa, 50 min) and solid cycle (121ºC, 103 kPa, 60 min). A 12 hr rest period is needed between cycles. For blast, a solid cycle and then a liquid cycle are utilized. The alternate liquid and solid cycles allow for adequate media sterilization to produce high quality inoculum while balancing the media moisture content to favor growth of the pathogen and not contaminates.

Cooled autoclaved bags are inoculated using 4 to 6 petri plates of active agar cultures introduced aseptically through the stopper assembly. After the cotton stopper is replaced, seed media are carefully kneaded immediately and for the next 2 days to distribute the fungus, eliminate clumping, and encourage aeration. Bags are incubated individually in a culture room at 25ºC under continuous florescent light. After 5 to 8 days, colonized inoculum is aseptically transferred to new paper bags at 40% fill. Bags are folded and stapled and placed on a metal wire rack at 25ºC with an air gap around the bag to enhance drying. Bags are turned and gently kneaded daily to encourage drying for approximately 2 weeks. Bags are transferred to storage boxes until needed.

Application of inoculum for the field is direct whereas greenhouse application is indirect. For sheath blight, a single field application is typically made when plants are at the panicle initiation stage. Blast inoculum is typically applied in the field at least twice by sprinkling the material over plants at the 4- to 5-leaf stage to establish a leaf blast infection. Further applications are made at the late boot stage to establish a panicle blast infection. In greenhouse tests, dried inoculum of individual *P. grisea* races is placed on agar plates and incubated at 25ºC with continuous florescent light to promote spore production in 5 to 8 days. Spores are washed from the plates to produce a concentration of approximately 20,000 spores per ml and sprayed on 4- to 5-leaf rice seedlings grown in the greenhouse.

Genotypic and Phenotypic Diversity of *Pyricularia oryzae* among Isolates Recovered from Conventional and Hybrid Rice Cultivars

Zhai, L., Rotich, F., Cartwright, R.D., Lee, F.N., Feng, C., Jia, Y., and Correll, J.C.

Rice blast, caused by *Pyricularia oryzae*, is one of the most economically important diseases of rice worldwide, including Arkansas. Rice blast has been severe the past few years on conventional cultivars and, more recently, has been observed on hybrid rice cultivars. The acreage of hybrid rice cultivars has been steadily increasing in recent years in Arkansas. The first objective of the current research was to examine the genotypic and phenotypic variation in the *P. oryzae* population in Arkansas during the 2009, 2010, and 2011 growing seasons and compare isolates from conventional cultivars with those from hybrids. Earlier studies of the pathogen focused on pathogenic/virulence variability, while more recent studies have utilized genetic and molecular markers to characterize population diversity. A total of 904 isolates were recovered from symptomatic rice cultivars in Arkansas and were examined for their genotypic and phenotypic diversity. The isolates were evaluated for vegetative compatibility, MGR586 DNA fingerprint diversity, SSR marker diversity, and virulence on a set of 40 commercial cultivars or advanced breeding lines, as well as hybrid cultivars. Examination of isolates indicated that three of the four known VCGs were present (VCGs US-01, 02, and 04) and that one VCG (US-01) predominated (>50%). These data are consistent with previous observations. The genotypic data indicated that the VCG, MGR586, and SSR markers all demarcated the same four lineages found in the contemporary population. Using SSR markers, MGR586 fingerprint, and virulence tests, the genotypic and phenotypic differences between lineages of *P. oryzae* from Arkansas were observed. Most of the isolates collected from hybrids showed a similar genotype and phenotype as the isolates recovered from conventional cultivars. However, three isolates collected from hybrids had unique MGR586 fingerprints and could not be assigned to one of the known VCGs. One of the three isolates appeared to have a unique virulence phenotype and two of the isolates were not virulent on any of the rice germplasm tested. Population analysis could continue to provide a better understanding of pathogen virulence evolution, assist in screening for disease resistance, and help develop strategies to breed for durable resistance to blast disease.

Molecular-based Tools for Diagnosing Infection of Rice by *Ustilaginoidea virens*

Jecmen, A.C. and TeBeest, D.O.

False smut, caused by *Ustilaginoidea virens,* was first found in a single rice field in Arkansas about 1998. The disease is presently established throughout the rice growing counties in Arkansas and significant losses have been reported. Generally, false smut is considered to be a minor disease but recent epidemics have occurred throughout the world and its emergence in Arkansas suggests conditions or factors limiting the disease may have changed. The disease cycle for false smut on rice has not been completely characterized. It has been reported that the fungus usually invades the ovary at the time of early flowering and that conidia, secondary conidia, and ascospores are all able to infect rice. It has also been reported that periods of rain, high relative humidity, and soils rich in nitrogen favor disease development and severity.

Our laboratory has been investigating how the fungus might infect rice. Our previous studies showed that spores germinated on rice root tissues and penetrated the roots within 24 to 48 hours after germination. Subsequently, nested PCR analyses of seedlings grown in the field and in the greenhouse showed that seedlings grown from infested seeds contained DNA consistent with *U. virens* within 3 weeks after emergence. Further, we found that seedlings were infected when they were grown in pasteurized soils artificially infested with spores of *U. virens*.

Three objectives of our current research were to determine how rapidly seedlings of selected rice cultivars were infected after emergence, to compare the sequences of the amplicons produced after PCR analysis of cultures with sequences derived from infected tissues, and to conduct initial studies on the effect of selected seed treatments on the levels of seedlings infected in field and greenhouse tests. Fungicide studies were conducted in a randomized complete block design with four replications of each treatment in the greenhouse and at two locations in the field.

Results of work conducted for these objectives show that some seedlings are infected by the fungus within 3 days after emergence and that sequences of the amplicons produced from cultures are consistent with sequences produced from plants and that these are consistent with GENBANK accessions. Further, examinations of seedlings grown from treated seeds suggest that fungicide seed treatments may help reduce the incidence of false smut at harvest.

Influence of Rice Genotype on Fungicide Seed Treatment Efficacy

Rothrock, C.S., Winters, S.A., and Sealy, R.L.

Stand establishment problems occur frequently in Arkansas rice fields and are commonly associated with cool soil temperatures (early planting) and saturated soils. The role of soilborne pathogens, especially *Pythium* spp., in these reductions in rice stands has been documented. In 2011, seven trials examined the efficacy of seed treatment chemistries and genotypes on stand establishment. The study included seven genotypes that differed in their cold tolerance and resistance to seedling disease caused by *Pythium* spp. Each genotype had the seed treatments: (1) not treated or treated with the seed treatments; (2) Allegiance (metalaxyl), (3) Allegiance + Cruiser (thiamethoxam) or (4) Allegiance + Cruiser + Dynasty (azoxystrobin). Three planting date trials were located at the Rice Research and Extension Center at Stuttgart and Pine Tree Experiment Station at Colt and one trial was located at the Northeast Research and Extension Center at Keiser, Arkansas. Planting dates varied to provide a range of planting environments. For the trials, a significant genotype by seed treatment response was frequently found for relative stand improvement over seed not treated and subsequent analysis for each trial was conducted by genotype. A seed treatment response was found for one or more genotypes for five of seven trials. Plant stand for Kaybonnet was increased for each of the five trials having a response. The cultivar Templeton responded to fungicides in one of these five trials. The genotypes PI560243, PI560247, PI560281, RV0701124, and STG05F5-03-088, which have demonstrated some resistance to *Pythium* spp., did not respond to fungicide seed treatment, except PI560243 and RV0701124, which had a fungicide stand improvement for one of the five trials. For the trials and genotypes with a stand improvement, the fungicide Allegiance provided similar control to the combination fungicide treatment Allegiance and Dynasty, except for two of eight comparisons. A Cruiser response was not observed compared with Allegiance alone. The fungicide metalaxyl has activity only against Oomycetes, indicating that *Pythium* spp. are the primary seedling pathogens causing stand losses of rice in Arkansas. Stand improvement from fungicides was greater for earlier planting dates compared with the final planting date for a location. Several genotypes did not have a response to fungicides, suggesting greater resistance to Pythium seed and root rot than cultivars grown currently.

Fungicide Seed Treatment for Managing Rice Seedling Diseases

Zhou, X.G.

Seedling diseases are one of the major rice diseases in Texas and other rice-producing states. Seedling diseases are caused by various soilborne and seed-borne fungi, including *Rhizoctonia solani*, *Sclerotium rolfsii*, *Fusarium* spp., and *Pythium* spp. Infection by these pathogens causes irregular, thin stands, and weakened plants. Seedling diseases are typically more severe in early plantings when the soil is cold. Severe seedling diseases may result in the need to replant. Seed treatment with fungicides can be an effective tool to manage seedling diseases. The objective of this study was to evaluate the efficacy of different fungicide seed treatments for seedling disease control and yield increase under different environments.

A total of six field trials were conducted at two locations in Texas over two years. Three trials (two in 2010 and one in 2011) were conducted at Beaumont and three (one in 2010 and two in 2011) at Eagle Lake. The soil was clay at the Beaumont test field and sandy at the Eagle Lake field. Both fields had been cropped with rice for many years and had a history of seedling diseases. The following products were included in these trials: CruiserMaxx containing Maxim 4FS (fludioxonil), Dynasty (azoxystrobin), Apron XL (mefenoxam) and Cruiser 5FS (thiamethoxam) of Syngenta; Allegiance LS (metalaxyl), Trilex 2000 (trifloxystrobin and metalaxyl), and the experimental products BCS-AA10279-5-1, BYF14182, L1875-A, and PTZ of Bayer CropScience; and the experimental products V-10226, V-10230, V-10260, V-10320, and V-10321, each containing Nipsit INSIDE (clothianidin) of Valent. Prior to planting, seeds of rice variety Cocodrie were treated with CruiserMaxx at the full recommended rate or 1/2 the full rate, or with other seed treatment products individually or in combination. Untreated seeds served as the control. Stands and growth vigor of seedlings were assessed at 3 to 4 weeks after emergence. Rice grain yield was determined at maturity.

Reduced plant stands, which resulted from seedling diseases, were moderate to high in untreated control plots in the trials. Seed treatments with CruiserMaxx at the full rate and half rate increased stands by up to 57%, depending on the test location and year. CruiserMaxx at the full rate increased grain yield by up to 22%. Both seed treatments also improved growth vigor and percent head milling quality. However, CruiserMaxx at half rate was not effective in increasing yield. All other seed treatments had similar effects on increasing stands, improving growth vigor, and increasing yield as did the seed treatment with CruiserMaxx at the full rate. The results of these trials indicated that fungicide seed treatment can be an effective tool to control seedling diseases and increase yield under Texas environments.

Disease Reaction of Rice Varieties in the Ratoon Crop in Texas

Zhou, X.G. and Liu, G.

Ratoon rice is the second crop made from the regrowth following main-crop harvest. Ratoon cropping is an important production practice to maximize seasonal yields and increase economic returns in southwest Louisiana and Texas. Texas has more than 50% of the total main crop ratooned. Diseases are among the major factors affecting ratoon crop potential. The climate conditions for ratoon cropping are different from those for main cropping. Inoculum density of pathogens is often built up following main crop. The reactions of rice varieties in the ratoon crop thus may be different from the reactions in the main crop. However, there has been essentially no research in this area to support ratoon crop production. The objective of this study was to evaluate the disease reactions of rice varieties in the ratoon crop under Texas conditions.

More than 39 varieties and elite lines were evaluated at Beaumont, Texas, in 2010 and 2011 to determine their reactions to sheath blight (*Rhizoctonia solani*), narrow brown leaf spot (*Cercospora janseana*), and bacterial panicle blight (*Burkholderia glumae* or *B. gladioli*) in the main and ratoon crops. *R. solani* was introduced into field plots at the panicle differentiation stage of main crop by inoculation. Narrow brown leaf spot developed from natural infection. *B. glumae* was introduced into field plots at the heading stage of main crop by spray inoculation. Plots were cut using a plot combine at the end of main crop for ratoon crop production. Sheath blight, narrow brown leaf spot, and bacterial panicle blight were rated near maturity using a scale of 0 to 9, where 0 represents no symptoms and 9 represents most severe in symptoms. Lodging due to the damage caused by sheath blight from the main crop also was determined for the ratoon crop.

The results of 2-year trials demonstrated that the disease reactions of varieties in the ratoon crop were different from those in the main crop. In the main crop, sheath blight and bacterial panicle blight were observed on all cultivars and lines evaluated with the disease ratings ranging from 2 to 9. In contrast, there were no or traces of sheath blight and bacterial panicle blight in all cultivars and lines except Francis that had minor infection of both diseases (2.7 or less in disease rating). Narrow brown leaf spot tended to be more severe in the ratoon crop than in the main crop although variations in narrow brown leaf spot severity among varieties in the ratoon crop were similar to the variations among these varieties in the main crop. The impact of lodging caused by the damage of sheath blight from the main crop was significant on the ratoon crop. Lodging was numerically highest on Sierra, Tennessee, RU080318, and RU0903184, and least on Jupiter, Rondo, Templeton, Wells, and RU0703184. There was a positive, linear relationship ($R2 = 0.58$, $P > 0.0001$) between the severity of sheath bight on the main crop and lodging on the ratoon crop.

Field Evaluation of Disease Resistance in Rice Varieties Grown under Texas Environments

Zhou, X.G. and Tabien, R.E.

The development and use of improved disease resistance rice varieties remain of foremost importance to rice producers. Field evaluation of disease resistance under local environments is essential toward this effort. Sheath blight, caused by *Rhizoctonia solani*, and narrow brown leaf spot, caused by *Cercospora janseana*, are the two major diseases in Texas, causing significant losses of yield and milling quality annually. Bacterial panicle blight, caused by *Burkholderia glumae* or *B. gladioli*, has increased its importance in recent years. In 2010, a severe outbreak of bacterial panicle blight occurred throughout the Texas Rice Belt, a clear reminder of how devastating this disease can be. In this study, we evaluated new and existing varieties, potential releases, and Texas elite breeding lines for resistance to these three diseases in two different environmental conditions of Texas.

More than 48 varieties and elite lines were evaluated in seven trials located at Beaumont and Eagle Lake in Texas over the past three years (2009, 2010, and 2011). The Beaumont test site has clay soil and high humidity, while Eagle Lake has sandy soil and a relatively dry environment. Sheath blight was introduced into field plots by inoculation. Narrow brown leaf spot developed from natural infection. Bacterial panicle blight developed from either natural infection or bacterial inoculum sprayed on panicles at the heading stage. Sheath blight, narrow brown leaf spot, and bacterial panicle blight were rated near maturity using a scale of 0 to 9, where 0 represents no symptoms and 9 represents most severe in symptoms.

In summary, no cultivars and lines had immune reactions or high levels of resistance to sheath blight or bacterial panicle blight. All but several cultivars and lines were rated susceptible or very susceptible to sheath blight, with disease ratings ranging from 5 to 9. The cultivars showing moderate levels of sheath blight resistance included Jasmine 85, Milagro Filipino, Templeton, Rondo, and XL723 (hybrid). Bacterial panicle blight was severe or very severe on the majority of the cultivars and lines evaluated. The cultivars Jupiter, RU0703144, and XL723 had the lowest ratings, showing partial resistance to bacterial panicle blight. Majority of the cultivars, including Cocodrie, CL111, CL151, Jazzman, Presidio, Sabine, and Sierra, were susceptible or very susceptible to narrow brown leaf spot. Jasmine 85, Milagro Filipino, Rondo, XL723, XL 744, CL XL729, CL XL730, and CL XL745 showed resistance to narrow brown leaf spot. For more information on the disease reaction of rice varieties in Texas, visit the Disease Management chapter in the 2011 Texas Rice Production Guidelines located online at http://beaumont.tamu.edu/eLibrary/Bulletins/2011_Rice_Production_Guidelines.pdf.

Efficacy Comparison of Fungicides for Sheath Blight Control and Yield Increase in Rice

Zhou, X.G. and Liu, G.

Fungicides are frequently essential for effective management of sheath blight caused by *Rhizoctonia solani*. Sheath blight is one of the most important diseases in rice in Texas and other rice-producing areas of the world. Selection and application of an effective fungicide are the key to reducing control costs and maximizing production return. Farmers are in need of efficacy data of new and currently available fungicides. QuiltXcel is a new formulation of azoxystrobin and propiconazole, containing two times more azoxystrobin than Quilt. QuiltXcel received Section 3 registration from the EPA in 2009. The objective of this study was to evaluate the efficacy of QuiltXcel and other commonly-used fungicides for control of sheath blight in rice.

A field trial was conducted at Eagle Lake, TX, in 2010 and 2011. There were seven treatments: 1) Stratego (1.4 L/ha), 2) Tilt (0.69 L/ha), 3) Quadris (0.69 L/ha) plus Tilt (0.35 L/ha), 4) Quadris (0.69 L/ha), 5) Quilt (1.6 L/ha), 6) QuiltXcel (1.2 L/ha), and 7) untreated control. Treatments were arranged in a randomized complete block design with four replications. Plots consisted of seven 4.8-m rows and spaced 0.18 m between rows. *R. solani* was inoculated into plots at panicle differentiation (PD). Two weeks after inoculation, plots were sprayed with fungicides. Sheath blight severity was rated near maturity using a scale of 0 to 9, where 0 represents no symptoms and 9 represents most severe. Grain yield and milling quality were determined.

In general, the results were similar in both years evaluated. All fungicide treatments significantly reduced disease severity compared with the untreated control. Stratego, Tilt, Quadris plus Tilt, Quadris, Quilt, and QuiltXcel were equally effective in reducing sheath blight. All fungicide treatments significantly increased grain yield compared with the untreated control. All fungicides also equally improved percent head rice in 2010 but did not in 2011. Total rice milling quality was not significantly improved by any fungicide treatment.

No-till Cover Crops Increase Straighthead in Organically Managed Rice

Zhou, X.G. and McClung, A.M.

The market demand for organically produced rice has driven the steady increase in acreage of organic rice in the U.S., with Texas and California having the most acreage. Organic production is frequently associated with the use of crop residues such as legume cover crops to supply nitrogen and maintain soil productivity. Tillage plays a role in the process of converting crop residues to N and other elements in forms available to plants. In this study, we evaluated the effects of cover crops and tillage on disease severity and yield potential in more than 20 rice cultivars over two years.

Two organic field trials with legume cover crops were established in 2010 and 2011 at Beaumont, TX. One trial was tilled while the other was not tilled prior to seeding of rice each year. For the first trial, Durana white clover was planted in the fall, plowed down in the subsequent spring, followed by tillage and water-seeding of the cultivars. For the second trial, Durana white clover was planted then mowed prior to planting of rice. The cultivars were direct-seeded using a no-till drill into the mowed clover. Straighthead was monitored throughout each of the cropping seasons and rated near maturity using a scale of 0 to 9, where 0 represents no symptoms and 9 represents most severe. Grain yield also was determined near maturity of each variety.

In 2010, straighthead occurred in all 20 cultivars evaluated in the no-tilled plots. However, significant differences in disease severity were observed in these cultivars with the ratings ranging from 1.0 to 7.8. Cocodrie and its derived lines, RU0703144 and RU0703190, had the most severe symptoms (7.8, 6.7, and 5.8 in disease rating, respectively) whereas GP 2, Presidio, Rondo, Tesanai 2, and Wells all had the lowest level of straighthead (1.0 in disease rating). All other cultivars, including Bengal, Charleston Gold, Cybonnet, Jasmine 85, Jazzman, JES, Jupiter, and Sierra, had intermediate levels of straighthead. In contrast, no symptoms of straighthead were observed in any of the cultivars in the plots using conventional tillage. Tesanai 2, GP2, and Rondo produced yields that ranked among the highest in both no-till and tilled trials. In 2011, results similar to 2010 were observed on 21 cultivars evaluated.

The results of this study clearly demonstrate that no-till cover crops increase the severity of straighthead. Straighthead may be directly related to decomposition of organic residues in flooded (anaerobic) soils. Straighthead is most likely to occur in no-tilled organic production systems involved with the direct seeding of rice into a cover crop. To prevent straighthead, resistant or tolerant cultivars should be used and the rice crop should not be directly planted into no-tilled fields with an abundance of decaying crop residues. Additional research is needed to determine the optimum timing of termination of cover crops to enhance soil nutrient quality, improve rice yield, and decrease susceptibility to diseases.

Efficacy of Biocontrol Agents for Managing Organic Rice Diseases

Zhou, X.G. and McClung, A.M.

Organic rice production has significantly increased in Texas over the last decade with acreage reaching over 16,000 acres in 2007, 2008, and 2009. This is driven by the increased market demand for organic rice and the access to large tracts of fallow land in Texas that have been used for cattle grazing and are certifiable for organic rice production. Due to prohibition of the use of synthetic pesticides in organic rice, control of pests, including diseases, is a particular challenge. Sheath blight caused by *Rhizoctonia solani* and narrow brown leaf spot caused by *Cercospora janseana* are among the major diseases affecting organic rice production. The purpose of this study was to evaluate the efficacy of commercially available biocontrol products and other biocontrol agents for management of these diseases in organic rice.

An experiment was established in 2010 and 2011 in a field under organic management for many years at Beaumont, TX. Each year, Durana white clover and Tam 90 ryegrass were planted in the fall and mowed in the subsequent spring. Rice (cv. Sierra) was drill seeded. Plots were inoculated with the sheath blight pathogen at the time of panicle differentiation. Narrow brown leaf spot developed from natural inoculum. In 2010, there were three biofungicides evaluated. Plots were sprayed with Serenade Max (*Bacillus subtilis* strain QST713, 14.6% active ingredient), Serenade ASO (*B. subtilis* strain QST713, 1.34% a.i.), Ballad Plus (*B. pumilus* strain QST2808, 1.38%

a.i.), or left untreated as the control. In 2011, four additional biocontrol agents were included: 1) *B. subtilis* Strain MBI-600; 2) *B. subtilis* Strain 99-101; 3) *B. subtilis* Strain EXTN-1; and 4) Thermo MAG, a mixture of *B. subtilis* (25%), *B. megaterium* (25%), *B. amyloliquefaciens* (25%), and *B. licheniformis* (25%). The *Bacillus* Strains MBI-600, 99-101 and EXTN-1 are plant growth-promoting rhizobacteria (PGPR) that have been demonstrated to have growth promoting effects on other crops. Severity of sheath blight and narrow brown leaf spot was rated near rice maturity on a scale of 0 to 9, where 0 represents no symptoms, and 9 represents severe symptoms and damage. Plots were harvested and grain yield adjusted to 12% grain moisture.

In 2010, sheath blight developed slowly following inoculation, resulting in low levels of the disease at maturity. All the biofungicide treatments Serenade Max, Serenade ASO and Ballad Plus did not significantly ($P \geq 0.05$) reduce sheath blight compared with the untreated control. Narrow brown leaf spot became severe toward rice maturity. Serenade Max reduced narrow brown leaf spot while Serenade ASO and Ballad Plus did not. Among the three biofungicides evaluated, only Serenade Max significantly increased yield. In 2011, sheath blight was severe. Sheath blight was significantly lower in plots applied with Serenade Max, Serenade ASO, and MBI-600 than in the untreated control plots. The treatments Serenade Max, MBI-600, EXTN-1, and Thermo MAG had a significantly lower level of narrow brown leaf spot compared with the untreated control. Among seven biocontrol agents evaluated, Serenade Max and Serenade ASO equally increased yield by 20%. The results of this study indicate that use of some biocontrol agents such as Serenade Max can reduce the damage caused by sheath blight and narrow brown leaf spot in organic rice. Serenade Max and Serenade ASO are commercially available biopesticides certified for organic production of rice and other crops.

Abstracts of Papers on Weed Control and Growth Regulation
Panel Chair: Robert Scott

Overview of Rice Weed Management in Louisiana

Webster, E.P., Fish, J.C., Fickett, N.D., and Thevis, E.L.

Several weed management research projects were conducted in Louisiana in 2011. The research was conducted at the LSU Agricultural Center Rice Research Station near Crowley, Louisiana. Other studies were conducted on producer fields located in south Louisiana.

A strip trial was conducted at the LSU AgCenter Rice Research Station evaluating clomazone as a postemergence herbicide. Clomazone was applied at 0.67 kg ai/ha with and without a crop oil concentrate at 1% v/v. Clomazone controlled one- to two-leaf Indian jointvetch (*Aeschynomene indica* L.) and most grasses with less than three leaves. Visual observations indicated that crop injury was reduced with a postemergence application of clomazone compared with a preemergence application. This project will continue to evaluate clomazone as a postemergence herbicide and in mixtures with herbicides with postemergence activity.

A study was established to evaluate the interaction of halosulfuron plus thifensulfuron at 39 and 78 g ai/ha (Permit Plus at 0.75 and 1.5 oz/A) or halosulfuron at 53 and 105 g ai/ha (Permit at 1.0 and 2.0 oz/A) when applied 24 hours after a malathion application at 1 kg ai/ha (Malathion 57 EC at 1.5 pt/A). The study was conducted on a producer location near Lake Charles, Louisiana, planted with medium-grain 'CL 261' rice. The initial application of malathion was applied to rice in the late boot stage on July 18, 2011, and the Permit and Permit Plus applications were made 24 hours later. At 14 DAT, panicle emergence was 60% with the nontreated. Panicle emergence was 40 to 50% with Permit and Permit Plus regardless of rate evaluated; however, following a malathion application, panicle emergence was reduced to approximately 30% when rice was treated with Permit and 10% with Permit Plus. At 22 DAT, the nontreated had panicle emergence of 98% compared with 75 and 40% with rice treated with Permit Plus at 39 and 78 g ai/ha (0.75 and 1.5 oz/A), respectively.

At harvest maturity, plant height was reduce in rice treated with Permit Plus at 78 g ai/ha (1.5 oz/A) following malathion compared with all other treatments. The nontreated rice had a yield of 6922 kg/ha (6,180 lb/A). All rice treated with Permit, with or without malathion, or Permit Plus, without malathion, had yields similar to the nontreated rice. However, Permit Plus at 39 and 78 g ai/ha (0.75 and 1.5 oz/A) following malathion reduce rice yield compared with the nontreated. This research indicates caution should be taken when applying Permit Plus as a salvage treatment and Permit Plus in combination with a malathion application should be avoided.

Survey of Weed Management Practices and Needs in Arkansas and Mississippi Rice

Norsworthy, J.K., Scott, R.C., Smith, K.L., Bond, J.

Rice consultants in Arkansas and Mississippi were sent a direct-mail survey in fall of 2011 with questions concerning weed management on their scouted acres. The goal of the survey was to document the extent of use of Clearfield rice, the weeds perceived to be most troublesome in rice, the level of adoption of resistance management strategies, and areas of research focus that would improve weed management in rice. To date, 42 valid surveys (39 from Arkansas and 3 from Mississippi) have been returned, accounting for 1,058,148 ha (428,400 A) of scouted rice. In 2011, 64% of the hectares (acres) were planted to Clearfield rice, and this technology has been used continually for the past 5 years on 11% of the rice acreage. Of the acres planted to Clearfield rice, 42% of these hectares (acres) were treated solely with an ALS-inhibiting herbicide in 2011. The consultants listed the development of new herbicide modes of action as being the important research need in rice (21% of responses) followed by control of Palmer amaranth on rice levees in the absence of 2,4-D (11%) and improved control options for herbicide-resistant barnyardgrass (9%). The top five weeds in order of importance were 1) barnyardgrass, 2) sprangletop, 3) red rice, 4) northern jointvetch, and 5) Palmer amaranth. Consultants were asked to rate the importance of 11 practices for best management of resistant weeds on a scale of 1 to 5, 1 = not important and 5 = very important. Proper herbicide timing, starting clean at planting, and using multiple effective herbicide modes of action against the most resistant prone weeds were the three highest ranking practices. Consultants were also given an opportunity to rate their concern with a predetermined list of research and educational topics. The topics of most concern to the consultants were 1) control of herbicide-resistant weeds, 2) strategies to reduce the occurrence and spread of herbicide-resistant weeds, and 3) development of herbicide-resistant rice which was comparable with economical weed control options.

Utilization of Saflufenacil in Rice Weed Control Programs

Bond, J.A. and Webster, E.P.

Saflufenacil (Sharpen) is a protoporphyrinogen oxidase (PPOase) herbicide labeled for fallow, preplant, and preemergence application in a variety of small grain crops. A preplant label for rice was approved in 2011; however, applications are restricted to 15 days prior to planting. Previous research indicated that saflufenacil effectively controls many broadleaf weeds common in rice. Research was conducted at the Mississippi State University Delta Research and Extension Center in Stoneville and the Louisiana State University Agricultural Center Rice Research Station near Crowley to evaluate saflufenacil as a component of weed control programs in Clearfield rice.

The study was designed as a randomized complete block with four replications. All plots received the equivalent of two applications of imazethapyr (Newpath; 71 g ai/ha) at early-postemergence (EPOST; two- to three-leaf rice) followed by late-postemergence (LPOST; four-leaf to one-tiller rice). Saflufenacil (50 g ai/ha) or carfentrazone (Aim; 35 g ai/ha) were mixed with imazethapyr (71 g/ha) in the EPOST or LPOST applications. For comparison, a prepackaged mixture of saflufenacil plus imazethapyr (Optill; 50 + 71 g/ha) was applied EPOST or LPOST. Additionally, the prepackaged mixture of saflufenacil plus imazethapyr (50 + 71 g/ha) was applied EPOST or LPOST in a program with a prepackaged mixture of quinclorac plus imazethapyr (Clearpath; 280 + 71 g ai/ha). All treatments included crop oil concentrate at 1% v/v. A nontreated control was included for comparison. Visual estimates of rice injury and hemp sesbania (*Sesbania herbacea*), Palmer amaranth (*Amaranthus palmeri*), and volunteer soybean (*Glycine max*) control were recorded 14 days after the last application at Stoneville while estimates of rice injury, barnyardgrass (*Echinochloa crus-galli*), alligatorweed (*Alternanthera philoxeroides*), Indian jointvetch (*Aeschynomene indica*), and eclipta (*Eclipta prostrata*) control were recorded at Crowley. At maturity, plots were harvested and rice grain yields were adjusted to 12% moisture content. All data were subjected to ANOVA and means were separated using Duncan's multiple range test.

No rice injury was observed 14 days after the last application at Stoneville. However, rice injury was variable and ranged from 3 to 20% 14 days after the last application at Crowley. Hemp sesbania control was greater when saflufenacil, carfentrazone, or the prepackaged mixture of saflufenacil plus imazethapyr were applied LPOST rather than EPOST. All treatments containing saflufenacil controlled Palmer amaranth and volunteer soybean better than those with carfentrazone. A mixture of saflufenacil plus imazethapyr controlled more volunteer soybean than the prepackaged mixture of the same herbicides. At Crowley, all treatments controlled barnyardgrass, Indian jointvetch, and eclipta at least 89% 14 days after the last application. No treatments controlled alligatorweed >60% at the same evaluation. Rice yields were variable at both sites, and there was no trend to the influence of treatments on rice yields.

Carfentrazone is commonly used in mixtures with imazethapyr in Clearfield rice. Data from the current study suggest that saflufenacil is as effective as carfentrazone when mixed with imazethapyr for control of hemp sesbania, alligatorweed, Indian jointvetch, and eclipta. Furthermore, treatments containing saflufenacil controlled Palmer amaranth and volunteer soybean better than those with carfentrazone. With the exception of volunteer soybean, the prepackaged mixture of saflufenacil plus imazethapyr provided similar barnyardgrass and broadleaf weed control to mixtures of the same herbicides. Where hemp sesbania is problematic, herbicide applications containing saflufenacil should be applied EPOST rather than LPOST.

League's First Year in the Majors, Rookie Year Stats - How Did It Go?

Carey, F., Odle, B., and Pawlak, J.

League® Herbicide, with active ingredient imazosulfuron, received registration for use in rice for the 2011 use season. League is formulated as a 75% water dispersible granular and can be applied preemergence at 292 to 467 ml/ha (4 to 6.4 oz/A), postemergence at 234 to 292 ml/ha (3.2 to 4 oz/A), or in a sequential program with 234 ml/ha (3.2 oz/A) applied preemergence followed by a postemergence application at 234 ml/ha (3.2 oz/A). The maximum amount of League that can be applied in a single season is 467 ml/ha (6.4 oz/A). League offers preemergence, as well as postemergence, control of tough rice weeds, including yellow nutsedge (*Cyperus esculentus*), Texasweed (*Caperonia palustris*), Northern Jointvetch (*Aeschynomene virginica*), and Indian Jointvetch (*Aeschynomene indicica*), as well as many other sedge and aquatic weeds. Commercial use of League in 2011 was positive with all label claims being met with preemergence applications, postemergence applications, and sequential applications.

Confirmation of ALS-Resistant Rice Flatsedge (*Cyperus iria L.*) in Midsouth Rice

Lewis, A.L., Norsworthy, J.K., Johnson, D.B., Starkey, C.E., Riar, D.S., and Bond, J.

Rice flatsedge is becoming detrimental to the Midsouth rice crop. In 2010, the recommended field rate application of halosulfuron (52 g ai ha^{-1}) failed to control rice flatsedge in rice fields of Arkansas and Mississippi. Halosulfuron resistance in Arkansas (AR1) and Mississippi (MS1) biotypes was confirmed in a greenhouse study conducted at the University of Arkansas in Fayetteville. A dose response study was conducted to characterize the level of resistance to halosulfuron in both Arkansas and Mississippi rice flatsedge biotypes. The experiment was arranged as a randomized complete block design with 20 replications. Treatments included nine rates of halosulfuron, including the recommended field application rate and rates above and below the field application rate. Susceptible biotypes were sprayed with 1/128, 1/64, 1/32, 1/16, 1/8, 1/4, 1/2, 1, and 2 times, and the resistant biotypes were sprayed with 1/4, 1/2, 1, 2, 4, 8, 16, 32, and 64 times the recommended field application rate of halosulfuron. Plant mortality data were then subjected to probit analysis to find the dose required to kill 50% of the plants (LD_{50}). The LD_{50} value for susceptible biotype was 9.84 g ha^{-1}. Both resistant rice flatsedge biotypes were >340 times more resistant to halosulfuron compared with the susceptible biotype.

Potential for Use of Methiozolin in Dry-Seeded Rice

Devkota, P., Norsworthy, J.K., and Scott, R.C.

Weeds are major constraints for profitable rice production because of their potential in reducing rice quantity and quality. At present, weeds are even more problematic due to evolution of resistance to available herbicides. In Arkansas, barnyardgrass has evolved resistance to four herbicide modes of action commonly used in rice. Therefore, it is essential to investigate new herbicide modes of action for effective barnyardgrass management. Methiozolin is a new herbicide being evaluated in rice and turf. Greenhouse and field studies were conducted to evaluate the effectiveness of methiozolin for weed control in dry-seeded rice. In the greenhouse experiment, methiozolin was applied PRE at 200 and 1000 g ai/ha and EPOST at similar rates. PRE-applied methiozolin provided 92 and 98% control of barnyardgrass at 2 weeks after treatment; however, the EPOST-applied methiozolin was ineffective in controlling barnyardgrass. There was no rice injury from both methiozolin rates and application timings. For the field experiment, methiozolin was applied PRE and EPOST at 200, 500, and 1000 g ai/ha to evaluate barnyardgrass, broadleaf signalgrass, and hemp sesbania control. Rice showed tolerance to all the methiozolin rates in respect to the application timings. Methiozolin at the lower two rates did not provide optimum weed control. When applied PRE at 1000 g ai/ha, methiozolin controlled barnyardgrass >90% at 2 weeks after treatment; however, it failed to control broadleaf signalgrass and hemp sesbania. At the later weeks, it did not provide effective control of any of the evaluated weed species. When applied EPOST, methiozolin at all rates failed to provide effective weed control. In conclusion, PRE- and EPOST-applied methiozolin is not an effective weed control option for weed control in dry-seeded rice.

Herbicide-Resistant Barnyardgrass (*Echinochloa crus-galli*) Challenges in Rice

Meier, J.M., Smith, K.L., Bullington, J.A., and Doherty, R.C.

Rice producers are dependent upon herbicides for control of weeds in rice, especially barnyardgrass. However, repeated use of the same herbicide, or herbicides with the same mode of action, has led to the selection and buildup of herbicide-resistant barnyardgrass populations. In Arkansas, barnyardgrass has developed resistance to propanil, quinclorac, clomazone, penoxsulam, and imazethapyr. Some biotypes have even developed cross-resistance to propanil and quinclorac. Trials were conducted in 2010 and 2011 at the Southeast Research and Extension Center, near Rohwer, AR, to examine barnyardgrass control with various herbicide combinations that excluded different modes of action to simulate resistance. Barnyardgrass control 2 weeks after permanent flood was near 100% with all herbicide combinations. Even though two applications of imazethapyr provided 90 to 100% control of barnyardgrass, the addition of another herbicide such as clomazone can assist with control and reduce the potential for resistance. By rotating herbicides with different modes of action, producers can still effectively control barnyardgrass as exhibiting resistance to only one or two modes of action; however, resistance to multiple modes of action can create exceptional challenges in absence of introduction of new modes of action into this market.

Evaluation of Clearfield® Production System Label Changes on Clearfield® Hybrid Rice

Wallace, D.M., McNeely, V.M., and Hamm, C.E.

BASF® recently changed its Clearfield® Production System to allow Beyond® to be applied at the 4- leaf stage to panicle initiation on Clearfield® hybrids. The label changes allow producers the flexibility to apply Beyond instead of Newpath® at the second application timing. Experiments were conducted in Arkansas, Missouri, Texas, and Louisiana to evaluate the use of Beyond at this second application timing on Clearfield hybrid rice.

The experiments were planted in four states to insure a wide range of environmental conditions and varying soil types for the experiments. The Texas location was planted on April 4 at Eagle Lake, TX. The Louisiana location was planted on March 28 at Eunice, LA. The Arkansas location was planted on April 19 at Harrisburg, AR. The Missouri location was planted on May 31 at Broseley, MO. The experiments ranged from a clay soil at Eagle Lake, TX, to a sandy loam at Broseley, MO. The experiments consisted of 1X and 2X rates in the Clearfield Production System utilizing Newpath applied at the 1- to 2-leaf stage and either Newpath or Beyond at the 4- to 5-leaf stage. All applications were made with a CO_2 backpack sprayer at 15 l/ha. Crop oil concentrate was used at 1% v/v with each treatment.

The data from all four locations showed that regardless of application rate or product at the second timing there was no significant difference in yield among treatments. Newpath or Beyond resulted in very similar yields when applied at the 4- to 5-leaf stage at the varying rates. Yields varied by locations with Louisiana and Arkansas having the highest overall yields. The Missouri location had the lowest yields of all the locations due to its late planting date. The yield data showed that the two newest hybrids had the highest overall yield. The two new hybrids showed approximately an 8% increase in yield over CLXL745. The 1X and 2X application rates of Newpath and Beyond showed very little plant response at any of the locations. The Missouri location on the sandy loam soil did exhibit some plant response from the applications. Plants exhibited stunting and slow growth approximately 2 weeks after application for 7 to 10 days. Plant response was brief and plants quickly recovered from symptoms. No effect on yield was apparent in the Missouri data from the brief plant response. The data concludes that producers can choose between Newpath or Beyond at the second application timing in the Clearfield Production System with no differences in plant response or yield with RiceTec, Inc. hybrids. The label change will give producers more flexibility in choosing what product to use in the Clearfield Production System.

A Digital Photography and Analysis System for Estimation of Root and Shoot Development in Rice Weed Suppression Studies in the Field

Gealy, D.R. and Pinson, S.R.M.

Rice germplasm with an inherent ability to suppress weeds can potentially improve the economics and sustainability of weed control in rice. We devised a simple, rapid, and inexpensive digital imaging system to quantify several shoot and root growth characteristics in field-grown rice plants that have been associated with weed suppression potential. One possible use for the system will be to analyze large numbers of field-grown plants as would be required for the study of genetic mapping populations or other large plant populations. In order to field-test the system, we evaluated selected lines from a Lemont X Teqing ("Teqing into Lemont" or "TIL") mapping population in which the lines differed in weed suppression activity and growth habit. Up to 13 siblines were grown in drill-seeded plots in Stuttgart, AR, in 2009, 2010, and 2011, and replicated four times. Four rice plants were randomly sub-sampled from each plot 7 to 10 days after establishment of the permanent flood when plants were approximately 60 cm tall. Roots were removed from the plots by maintaining them intact in a large plug of soil to minimize damage. They were then immersed in water and rinsed to remove soil, and the entire intact plant was laid on a printed background grid and photographed on a platform at the field site using a digital camera (Canon Power Shot 3G; 4.0 mega pixels; 7.2-28.8 mm zoom lens). Photographs were taken using a fixed camera mount under a rigid frame enclosed in opaque white sheets to prevent interference from shadows and glare. The background grid was white with calibrated black lines projecting upwardly and downwardly at several fixed angles from the point at which the base of the plant shoot was placed. Lengths and growth angles of shoots (stems + leaves) and roots, and tiller numbers could be visually estimated directly from the photographs. Areas of roots and shoots were estimated from the digital photographs using commercial software (Adobe Photoshop Elements ver. 9). By single-clicking the mouse within the "brown-colored" root area or the "green-colored" shoot area, the software provided a total pixel count (relative area) for both roots and shoots. Several standardized squares of known area (100 cm^2; colored red) were printed near the edges at the top, middle, and bottom of the background grid where they were unobstructed by plant tissues, so that pixel counts could be accurately converted to true areas (cm^2). Preliminary analyses showed that digital area estimates for both roots and shoots usually correlated with tissue dry weights. We presented a digital imaging system for rapid estimation of plant root and shoot growth, and tillering patterns of rice lines using inexpensive software. Potential advantages of the system are that numerous plant parameters from field-grown plants can be estimated rapidly, and that the digital photographic images can be analyzed indoors under more comfortable conditions, and at a later time, which helps space out the work load during the busy season. The system appears to be readily adaptable for similar analyses of barnyardgrass plants or other weeds from rice fields. Plant-to-plant variability within plots may reduce the effectiveness of the system, requiring multiple subsamples for best results.

Weed Management in Rice with Sharpen® and Facet® L Herbicides

Rhodes, A., Madison, M.S., and Braun, J.

Two new herbicides will assist weed management programs in rice. Saflufenacil is a new herbicide in the chemical class, pyrimidinadione, for burndown weed control in rice. It will be marketed by BASF as Sharpen® herbicide. Saflufenacil applied at 70 and 140 ml/ha (1 to 2 oz/A) up to 15 days prior to planting rice provided burndown control of broadleaf weeds with some residual into early rice growth and development. Saflufenacil efficacy was evaluated for control of Palmer amaranth (Amaranthus palmeri), horseweed (Conyza canadensi), and morningglories (Ipomoea spp.). Saflufenacil was also found to be effective for control of Texasweed (Caperonia palustris).

Quinclorac is important herbicide chemistry for southern growers to control broadleaf and grass weeds in rice. Greenhouse and field trials were conducted to compare the relative differences in either uptake and/or weed control between two quinclorac formulations; dry flowable (DF) and soluble liquid (SL). Greenhouse 'wash-off' trials resulted in increased uptake (4 HAT) of quinclorac and control of large crabgrass *(Digitaria sanguinalis)* when applied as SL at an equivalent rate (.56 kg ai/ha; 0.5 lb ai/A) of DF. Since 2006, field trials across mid-southern locations resulted in improved residual and foliar efficacy of barnyardgrass *(Echinochloa crus-gali* L.*)* broadleaf signalgrass *(Brachiaria platyphylla)* and hemp sesbania *(Sesbania exaltata)*. Averaged across years and locations, barnyardgrass control was 88% with the SL versus 86% with the DF when applied EPOST (2.54 to 5.08 cm; 1- to 2-inch weed height). However, greater average broadleaf signalgrass control (93%) was recorded with the SL over the DF (85%). EPOST applications for hemp sesbania control resulted in an average 92% (SL) and 89% (DF) control. Unconventional LPOST (25.4 cm; 10-inch grass height) applications (.56 kg ai eq/ha; 0.5 lb ai eq/A) resulted in 12% greater barnyardgrass control with the SL (53%) over the DF (45%). When applied at rates less than commercially acceptable (<.56 kg ai eq/ha; <0.5 lb ai eq/A), the SL (45%) formulation provided 17% greater large crabgrass control over the DF (28%) indicating the SL formulation resulted in greater uptake of quinclorac than the DF. Quinclorac is currently registered for use as an herbicide in rice and marketed by BASF as Facet® 75 DF herbicide. The new formulation of quinclorac from BASF will be marketed as Facet® L herbicide.

RiceBeaux Mixed with Command for Controlling Propanil-Resistant Barnyardgrass (*Echinochloa crus-galli*)

Starkey, C.E., Norsworthy, J.K., and Johnson, D.B.

Barnyardgrass is the most troublesome weed in Arkansas rice (*Oryza sativa*). Propanil-resistant barnyardgrass in Arkansas has become a major problem for producers. Thiobencarb is labeled as a delayed preemergence option for control of barnyardgrass, including that resistant to propanil. A study was conducted in 2010 at Stuttgart, AR, on a silt loam soil to evaluate control of both propanil-resistant and -susceptible barnyardgrass using thiobencarb + propanil at various timings. Propanil at 3.36 kg ai/ha + thiobencarb at 3.36 kg ai/ha (mixture sold as RiceBeaux) was applied alone and in combination with clomazone (Command) at 0.337 kg ai/ha at 1, 2, 3, and 4 weeks after planting (WAP). Weekly visual ratings were conducted for rice injury and weed control. At 2 WAP, rice showed 25 and 32% injury from propanil + thiobencarb and propanil + thiobencarb + clomazone, respectively. Control of propanil-resistant and -susceptible barnyardgrass with thiobencarb + propanil applied 2 WAP was 88 and 100%, respectively. The addition of clomazone to thiobencarb + propanil treatment applied at 1 to 2 WAP controlled barnyardgrass 96 to 100%. As the size of barnyardgrass increased to 6 to 8 in (4 WAP application), control was reduced to 5 to 34%.

Indian Jointvetch and Hemp Sesbania Postemergence Control in Rice

Fickett, N.D., Webster, E.P., Fish, J.C., and Thevis E.L.

Three studies were established in 2011 to evaluate several herbicides with postemergence activity for controlling Indian jointvetch (*Aeschynomene indica* L.) and hemp sesbania [*Sesbania exaltata* (Raf.) Cory] at the Louisiana State University Agricultural Center Rice Research Station near Crowley. Each study evaluated a single timing: early-postemergence (EPOST), mid-postemergence (MPOST), or late-postemergence (LPOST).

The experimental design for all three studies was a randomized complete block with four replications. Clomazone at 0.34 kg ai/ha was applied preemergence to all treatments including the nontreated to control grasses. The treatments were propanil at 3.4 kg ai/ha, halosulfuron at 39 g ai/ha, halosulfuron plus thifensulfuron at 44 g ai/ha, bensulfuron at 42 g ai/ha, orthosulfamuron at 70 g ai/ha, penoxsulam at 35 g ai/ha, quinclorac at 0.45 kg ai/ha, triclopyr at 0.28 kg ai/ha, carfentrazone at 18 g ai/ha, bispyribac at 28 g ai/ha, imazosulfuron at 0.16 kg ai/ha, saflufenacil at 50 g ai/ha, and quinclorac plus carfentrazone at 0.44 kg ai/ha. A crop oil concentrate was added to all herbicides except propanil and carfentrazone, at 1% v/v. A nontreated was added for comparison. Visual ratings were evaluated at 21 and 63 days after treatment (DAT) for the EPOST and the LPOST studies and at 28 and 56 DAT for the MPOST study. Data were analyzed using an analysis of variances, which was followed by Tukey's test at α=0.05 to determine mean differences.

EPOST study. At application, Indian jointvetch was 1- to 8 cm tall, in the cotyledon to 4-leaf stage, and had a population of 25 to 30/m^2. The EPOST study had low populations of hemp sesbania and no data were collected. At 21 DAT, Indian jointvetch control was 90 to 98% with bispyribac, halosulfuron, halosulfuron plus thifensulfuron, orthosulfamuron, penoxsulam, imazosulfuron, saflufenacil, and quinclorac plus carfentrazone. All other herbicides evaluated controlled Indian jointvetch less than 90%. Similar results were observed at 63 DAT. Little to no herbicide injury occurred and no differences were observed for rice plant height. Rice yield was 9,790 kg/ha from rice treated with halosulfuron plus thifensulfuron. Rice treated with all other herbicides except halosulfuron, propanil, and bispyribac had reduced yield.

MPOST study. At application, Indian jointvetch and hemp sesbania were 8 to 13 cm tall with four to six leaves, and a population of 5 to 7/m^2. At 28 DAT, all herbicides controlled hemp sesbania 90 to 98%, except carfentrazone with less than 50% control. This lack of control was due to lack of coverage on hemp sesbania. At 56 DAT, hemp sesbania control dropped below 90% when treated with propanil and triclopyr. Indian jointvetch control was 92 to 98% at both evaluation dates when treated with all herbicides, except propanil (78 and 83%), bensulfuron (40 and 50%), and carfentrazone (0%). Little to no injury or height differences were observed during the duration of the study. Rice treated with halosulfuron plus thifensulfuron yielded 9,350 kg/ha. Rice treated with bensulfuron, quinclorac, saflufenacil, and the nontreated had reduced yield. The nontreated rice had a yield of 7,490 kg/ha, indicating low weed pressure and lack of weed competition in the study.

LPOST study. At application, Indian jointvetch and hemp sesbania were 10 to 13 cm with five to seven leaves, and populations from 3 to 7/m^2. At 21 DAT, all herbicides evaluated controlled hemp sesbania 94 to 98%, except bensulfuron (45%), carfentrazone (13%) and imazosulfuron (89%). At 63 DAT, the only herbicides that controlled hemp sesbania less than 90% were bensulfuron (35%), penoxsulam (83%), triclopyr (84%) and carfentrazone (0%). The reduced control from penoxsulam and triclopyr at the late rating was due to regrowth. Similar to the EPOST and MPOST studies propanil, bensulfuron and carfentrazone failed to control Indian jointvetch above 80%. Yellow nutsedge (*Cyperus esculentus* L.) infested the LPOST study, and the only herbicides that controlled yellow nutsedge above 90% for both evaluations were halosulfuron plus thifensulfuron (98 and 92%) and imazosulfuron (92 and 95%). Little to no injury occurred during the duration of the study. Some height differences occurred due to season long hemp sesbania, Indian jointvetch, and yellow nutsedge competition. Rice treated with halosulfuron plus thifensulfuron yielded 9,400 kg/ha, and no yield difference occurred in rice treated with orthosulfamuron, bispyribac, imazosulfuron, and quinclorac plus carfentrazone.

This research indicates several herbicides can be used to control hemp sesbania and Indian jointvetch. However, it is apparent based on control, injury, and yield that halosulfuron plus thifensulfuron was the most consistent herbicide in the three studies.

Herbicide Mixtures for Increased Red Rice Control with Newpath

Fish, J.C., Webster, E.P., Bond, J.A., Fickett, N.D., and Thevis, E.L.

Producers commonly apply two or more herbicides in a single application to improve the spectrum of weed control, reduce production costs, and/or prevent the development of herbicide resistance in weed populations. Studies were established at the LSU AgCenter Rice Research Station and the Mississippi State University Delta Research and Extension Center to evaluate several herbicide mixtures and their impact on several weed species. Previous data indicate a potential for synergism between RiceBeaux, a pre-packaged mix of propanil and thiobencarb, and Newpath when mixed for control of red rice (*Oryza sativa* L.) and other weed species.

Two studies were established to evaluate the potential synergism between RiceBeaux and Newpath or Beyond, and the components in RiceBeaux, propanil and thiobencarb, with Newpath or Beyond. RiceShot was used for propanil and Bolero was used for thiobencarb. The experimental design was a randomized complete block with four replications in an augmented two-factor factorial arrangement of treatments. A nontreated was added for comparison. In the first study, factor A consisted of Newpath at 0 and 280 ml/ha (0 and 4 oz/A). Factor B consisted of no mixture herbicide, RiceBeaux at 2.24 and 4.48 l/ha (2 and 4 pt/A), RiceShot at 1.68 and 3.36 l/ha (1.5 and 3 pt/A), and Bolero at 0.84 and 1.68 l/ha (0.75 and 1.5 pt/A). The rates of RiceShot and Bolero are equivalent to the rates found in the pre-packaged mixture of RiceBeaux. In the second study, Beyond at 0 and 350 ml/ha (0 and 5 oz/A) was substituted for Newpath.

In Louisiana at 21 DAT, the single application of Newpath controlled red rice and barnyardgrass [*Echinochloa crus-galli* (L.) P. Beauv.] 90 and 84%, respectively. The single applications of RiceBeaux, propanil, and thiobencarb resulted in less than 10% control of red rice and less than 30% control of barnyardgrass at 21 DAT. However, RiceBeaux at 4.48 l/ha (4 pt/A) plus Newpath applied as a mixture controlled red rice and barnyardgrass 96 and

98%, respectively. Similar results were observed with Beyond. At 49 DAT, the single application of Newpath controlled red rice and barnyardgrass 92 and 78%, respectively. Single applications of RiceBeaux, propanil, and thiobencarb failed to control red rice and barnyardgrass above 50%. The addition of RiceBeaux at 2.24 and 4.48 l/ha (2 and 4 pt/A) with Newpath controlled red rice and barnyardgrass 91 to 97%. Similar results were observed with Beyond. Little to no injury was observed for the duration of this study. Rice treated with the high rate of RiceBeaux plus Newpath yielded 8,501 kg/ha (7,590 lb/A). However, no differences occurred with the single application of Newpath or when mixed with RiceBeaux, propanil, or thiobencarb.

In Mississippi, the same studies were conducted on two research areas: one research area infested with red rice and Amazon sprangletop [*Leptochloa panicoides* (J. Presl) Hitchc.] and the other research area infested with barnyardgrass and browntop millet [*Panicum ramosum* (L.) Staph]. At 7 DAT, the single application of Newpath controlled barnyardgrass and browntop millet 74 and 66%, respectively. Single applications of RiceBeaux, propanil, and thiobencarb failed to control red rice and barnyardgrass above 10%. The mixture of RiceBeaux at 4.48 l/ha (4 pt/A) plus Newpath controlled barnyardgrass and browntop millet 91 and 94%, respectively; however, the addition of RiceShot with Newpath had similar control. At 14 DAT, all herbicide mixtures controlled barnyardgrass 84 to 90%. The addition of RiceBeaux and RiceShot at either rate with Newpath controlled browntop millet 89 to 95%. Rice injury was less than 15% across both rating dates. No yields were obtained at these locations.

These studies show a potential of synergism when RiceBeaux is mixed with Newpath compared with propanil or thiobencarb. A slight trend occurred with the pre-packaged mixture of RiceBeaux, propanil plus thiobencarb, compared with each individual product mixed with Newpath. This indicates the pre-packaged mixture is more consistent. With widespread outcrossing and herbicide resistance, it is beneficial to producers to have an effective weed management program.

ALS-Resistant Barnyardgrass: An Update

Riar, D.S., Norsworthy, J., Srivastava, V., Bond, J.A., Bararpour, M.T., Wilson, M.J., and Scott, R.

Barnyardgrass is the most important weed of rice in Arkansas. Recently, putative acetolactate synthase (ALS)-resistant barnyardgrass biotypes have been collected from Arkansas (AR1 and AR2) and Mississippi (MS1). A study was conducted to confirm resistance, characterize response to other ALS herbicides, and determine the resistance mechanism of these barnyardgrass biotypes. Difference in control was observed when these biotypes, along with a known susceptible biotype, were screened in the greenhouse with field rate applications of bispyribac-sodium, imazamox, imazethapyr, and penoxsulam at 37 (0.033 lb ai A^{-1}), 35 (0.031 lb ai A^{-1}), 70 (0.062 lb ai A^{-1}), and 35 (0.031 lb ai A^{-1}) g ai ha^{-1}, respectively. Control of AR1, AR2, and MS1 was 57, 6, and 83%, respectively, with imazethapyr; 59, 6, and 86%, respectively, with imazamox; 26, 51 and 22%, respectively, with penoxsulam; and 15, 98, and 16%, respectively, with bispyribac-sodium. In contrast, control of the susceptible biotype was $\geq$98% with each herbicide. Dose response studies revealed that AR1, AR2, and MS1 biotypes were 21, 0.89, and 11 times, respectively, more resistant to bispyribac-sodium, >94, >94, and 2.6 times, respectively, more resistant to imazamox; and >15, 8.0, and 1.8 times, respectively, more resistant to penoxsulam compared with susceptible biotypes based on lethal dose to kill 50% of plants (LD_{50}). Addition of malathion at 1000 g ai ha^{-1} (0.89 lb ai/A) to penoxsulam reduced dry weight of all resistant biotypes (40 to 96%) at 21days after treatment (DAT) compared with penoxsulam applied alone. However, addition of malathion to imazamox did not reduce dry weight of resistant biotypes 21 DAT. Although, addition of malathion to bispyribac-sodium increased mortality of resistant biotypes, it did not reduce dry weight significantly. Malathion inhibits the activity of cytochrome P450 monooxygenase, an enzyme known to metabolize various herbicides. Reduction in dry weight after addition of malathion confirms that cytochrome P450 monooxygenase is imparting resistance to penoxsulam; nevertheless, some additional mechanism is involved in imparting resistance to imazamox.

Influence of Rate and Application Timing on Rice Tolerance to Acetochlor

Bararpour, M.T., Norsworthy, J.K., Johnson, D.B., and Starkey, C.

About 3 billion people, nearly half the world's population, depend on rice for survival. Arkansas has been the nation's leading rice-producing state since 1973. Field studies were conducted at Keiser and Stuttgart, Arkansas, in 2011 to evaluate the influence of rate and application timing of acetochlor (Warrant) on rice tolerance. The experiment was designed as a three (application timing) by four (acetochlor rates) factorial on a randomized complete block design. Acetochlor was applied at 0 (untreated check), 420, 840, and 1,254 g ai/ha (0, 0.375, 0.75, and 1.12 lb ai/A) (sub-factor) at spiking, 2-leaf, and 4-leaf stage of rice (main factor).

At Keiser, 4 weeks after emergence there was only 1 and 4% rice injury from 840 and 1,254 g ai/ha (0.75 and 1.12 lb/A) of acetochlor. Plots that received acetochlor at 420 and 840 g ai/ha (0.375 and 0.75 lb/A) provided comparable yield to the untreated check, averaged over timing. However, rice yield was reduced 9% from the highest rate of 1,254 g ai/ha (1.12 lb/A) of acetochlor. At Stuttgart, the effect of timing by rate was significant for rice injury, but not for yield. Rice injury was 51, 69, and 83%; 8, 32, and 35%; and 5, 5, and 3% from the applications of acetochlor at 420, 840, and 1,254 g ai/ha (0.375, 0.75, and 1.12 lb/A) at spiking, 2-leaf, and 4-leaf stage of rice, respectively.

Weed Control and Rice Response to Weak Acid Herbicides as Affected by the pH of the Spray Solution

Camargo, E.R., McKnight, B.M., Senseman, S.A., McCauley, G.N., Bond, J.A., Norsworthy, J.K., and Webster, E.P.

In modern agriculture, a significant portion of the pesticides used for crop protection is weakly acidic or basic. Recently developed and widely used herbicides in rice from the imidazolinone, sulfonylurea, pyrimidinyloxybenzoic acid and sulfonamide chemical family are weak acids. For these compounds, water solubility is pH dependent as it alters the proportion of molecular and ionized species in solution. Therefore, herbicide uptake and biological activity in weeds and in the rice crop could be affected, as solubility and ionic forms of weak acid compounds are variable with the pH of the spray solution. Furthermore, the pH of the water source used for tank-mix preparation can change greatly across regions. Perhaps buffers should be recommended to minimize potential reduction in herbicide availability as long as it does affect crop safety. The objective of this multi-institutional study was to evaluate weed control and rice response to imazethapyr, halosulfuron-methyl, imazosulfuron, bispyribac-sodium, and penoxsulam at varying pH values of the spray mixture.

Field experiments were conducted at the research stations located in Beaumont, TX (Texas A&M University), Pine Tree, AR (University of Arkansas), Crowley, LA (LSU AgCenter), and Stoneville, MS (Mississippi State University). Each herbicide was tested in a separate experiment. The experimental design was a randomized complete block with four replications. Three combinations of buffer solutions were added in the spray solution to generate a pH of 5, 7, and 9. An untreated check was also included in all locations. A treatment using the local water source was used in AR, LA and MS. Similarly, an ammonium sulfate treatment (2.25 kg ha^{-1}) was included in all locations, except in MS. Herbicides were applied at the labeled rate using the recommended surfactant (1% v/v of Agri-Dex® for imazethapyr, imazosulfuron, and penoxsulam; 1.5% v/v of Dyne-A-Pak® for bispyribac-sodium and 0.25% v/v of Induce® for halosulfuron-methyl). All treatments were applied at the 1- to 2-leaf stage of rice. Buffers were created by combining proportions of monopotassium phosphate (KH_2PO_4, 1 M) and sodium hydroxide (NaOH, 1 M). Buffers were added in the spray solution followed by the commercial herbicide formulation and the surfactant.

Rice injury and weed control were estimated visually using a scale of 0 to 100%, where 0 = no rice injury or control and 100 = rice death or total control. Rice grain was harvested in some studies at TX and MS. Visual injury was subjected to arcsine transformation prior to analysis to normalize the data. Data were analyzed among locations to assess interaction with treatments. Results were combined when analysis of variance had demonstrated no interaction between locations and treatments. Means for significant effects were separated using Tukey's test at α=0.05.

Significant effects among treatments for weed control were observed for all herbicides, except bispyribac-sodium. Control of hemp sesbania (*Sesbania exaltata*) was lower at pH 5 in evaluations conducted 2 weeks after treatment (WAT) with halosulfuron-methyl in MS. In the same location, greater control was obtained with pH 7 and 9 at 6 WAT. No differences were observed in TX and LA. Yield was significantly lower in MS when halosulfuron-methyl was applied with a buffered solution at pH 5. Similar trends were observed with the herbicide penoxsulam for control of hemp sesbania. Control was significantly lower for this herbicide at pH 5 in evaluations conducted 2 WAT in TX. In subsequent evaluations (6 WAT), lower control was observed in TX and LA with the pH 5 buffer. No effects of penoxsulam treatments were observed on control of barnyardgrass (*Echinochloa crus-galli*) in results obtained in AR and LA. For imazethapyr, no differences were observed on control of barnyardgrass at AR and LA. However, lower control was obtained with one application of imazethapyr at pH 5 in MS. Once again, lower control of hemp sesbania was observed with pH 5 for imazosulfuron in MS. No injury or minimal injury was observed for the tested herbicides on rice. Overall, more consistent weed control was obtained across locations by buffering the spray solution at pH 7 and 9.

Potential of Carryover of League (imazosulfuron) from Rice to Soybean

Rana, S.S., Norsworthy, J.K., Johnson, D.B., Devkota, P., Starkey, C., and Scott, R.C.

In the southern United States, soybean is often grown in rotation with rice; therefore, herbicides used in rice have the potential to injure soybean *via* carryover. Halosulfuron is the current standard of sulfonylurea herbicides used in rice at a field use rate of 52 g ai ha^{-1} (0.0468 lb ai A^{-1}). On the other hand, imazosulfuron is a new sulfonylurea herbicide that was recently labeled for use in Arkansas rice at a maximum use rate of 336 g ha^{-1} (0.3 lb A^{-1}). Consequently, field trials were conducted under a weed-free environment to evaluate the response of soybean to imazosulfuron and halosulfuron applied PRE (tolerance study) and to determine the potential for imazosulfuron applied to rice to injure soybean grown in rotation the following year (rotation study). The tolerance study was conducted at Fayetteville (pH=5.9) and Marianna (pH=7.9), AR, and the rotation study was conducted at Pine Tree (pH=8.3) and Keiser (pH=7.1), AR. Imazosulfuron and halosulfuron were applied PRE at 1/256, 1/128, 1/64, 1/32, 1/16, 1/8, and 1/4 times (X) their respective labeled rates for the tolerance study. For rotation study, imazosulfuron rates were 112, 224, 336, 448, and 672 g ha^{-1}. Soybean was not injured by PRE-applied imazosulfuron and halosulfuron regardless of herbicide rate, and yielded comparable with non-treated check. Soybean injury increased with the increasing imazosulfuron, applied to rice the previous year, rate. Soybean injury at Keiser was ≤3%; whereas at Pine Tree, soybean injury was ≤13%. Soybean injury was higher at Pine Tree than Keiser because Pine Tree has higher soil pH that increased imazosulfuron activity. However, soybean recovered from the injury over time. In both experiments and at both locations, stand count (plants/m^2) at 5 WAP, plant height at 5 WAP and at the end of growing season, and yield were comparable with the non-treated check. Results of both tolerance and rotation study indicate that imazosulfuron can injure soybean *via* carryover at high pH soils (≥8.0), however, soybean can recover from the injury over time to yield comparable with non-treated check.

Rice Performance Following Fall Residual Herbicide Applications

Shinkle, S.A., Bond, J.A., and Eubank, T.W.

Glyphosate-resistant (GR) Italian ryegrass (*Lolium perenne* ssp. *multiflorium*) was first documented in field crops in Washington County, Mississippi, in 2005. Thirteen counties in Mississippi now contain populations of GR Italian ryegrass. Fields with GR Italian ryegrass not controlled at burndown will have significant plant residue at planting. Residue will impede planting practices, contribute to competition between crop seedlings and established GR Italian ryegrass, and hinder herbicide programs due to inadequate coverage. Research at the Delta Research and Extension Center in Stoneville, MS, has demonstrated that residual herbicides applied in the fall offer the best opportunity for controlling GR Italian ryegrass. Clomazone (Command), pyroxasulfone (Zidua), *S*-metolachlor (Dual Magnum), and trifluralin (Treflan) applied in the fall are the most effective fall residual herbicides for GR Italian ryegrass control. Problematically, pyroxasulfone, *S*-metolachlor, and trifluralin are not labeled for fall application prior to planting rice. Therefore, research was initiated at Stoneville, MS, in 2010-11 to determine the rice response to residual herbicides applied in the fall prior to planting.

The study was designed as a randomized complete block with four replications and was repeated in space. Residual herbicides were applied at one-half, one, and two times (0.5, 1, and 2X) the recommended rates for control of GR Italian ryegrass in Mississippi. Clomazone (0.42, 0.84, and 1.68 kg ai/ha), pyroxasulfone (0.082, 0.16, and 0.33 kg ai/ha), *S*-metolachlor (0.72, 1.42, and 2.83 kg ai/ha), and trifluralin (0.84, 1.68, and 3.36 kg ai/ha) were surface-applied in early November 2010. Trifluralin treatments were incorporated with two passes in opposite directions with a tandem disk. A control that received no fall residual herbicide treatment was included for comparison. Plots were left undisturbed until rice was planted on May 16, 2011. Rice was managed throughout the growing season to optimize yield. Visual estimates of rice injury were recorded 7, 14, 21, and 28 days after rice emergence (DAE). Rice seedling density was determined at 14 DAE, and rice height was recorded at weekly intervals from emergence until flooding. The number of days to 50% heading was recorded as an indication of rice maturity. Plots were harvested and rice grain yields were adjusted to 12% moisture content. All data were subjected to ANOVA and means were separated using Duncan's multiple range test.

All rates of pyroxasulfone, *S*-metolachlor, and trifluralin reduced rice seedling density compared with the control. Pyroxasulfone, *S*-metolachlor, and trifluralin applied at 1X rates reduced rice seedling density 19 to 24%. Rice injury was visible 14 DAE for all herbicides and rates except clomazone. Pyroxasulfone injured rice more than other herbicides regardless of rate. Pyroxasulfone and *S*-metolachlor applied at 2X rates reduced rice height 21 DAE compared with the control. All treatments except 0.5X rate of *S*-metolachlor delayed maturity compared with the control. Pyroxasulfone and *S*-metolachlor applied at 2X rates delayed maturity 5 days. Yields were not affected by clomazone or trifluralin. However, yields following other fall residual herbicide treatments varied across experiments. *S*-metolachlor applied at a 2X rate reduced yield in one of two experiments while the 2X rate of pyroxasulfone reduced yield in both experiments.

The rice response to fall residual herbicide treatments was variable. Pyroxasulfone, *S*-metolachlor, and trifluralin applied at 1X rates negatively influenced rice growth and development, but yield was not affected. Yield differences between the two experiments demonstrate the need for further evaluation of fall herbicide treatments in rice. Only clomazone should be utilized as a fall residual herbicide treatment targeting GR Italian ryegrass prior to planting rice.

Evolution of ALS-Resistant Barnyardgrass in Rice: Management Implications

Bagavathiannan, M.V., Norsworthy, J.K., Smith, K.L. and Neve, P.

Barnyardgrass is the most troublesome weed in Midsouth rice production fields. Imidazolinone-resistant (Clearfield™) rice has been gaining popularity among rice growers because this system allows for effective grass weed control, including the control of propanil- and quinclorac-resistant barnyardgrass, which are the most prevalent herbicide-resistance problems in Midsouth rice. In 2010, about 60% of the rice fields in Arkansas were planted to imidazolinone-resistant rice cultivars. With the widespread adoption of this system, which favored multiple and frequent applications of imidazolinone herbicides, the risk of barnyardgrass evolving resistance to acetolactate synthase (ALS)-inhibiting herbicides has been increasing. A barnyardgrass population with cross-resistance to ALS-inhibiting herbicides has recently been confirmed in Arkansas. A widespread occurrence of resistance would have a devastating impact on rice production in this region. Such a situation would limit the options available for growers to achieve effective weed control in rice. As such, proactive measures are important to mitigate the evolution of herbicide resistance and preserve the long-term utility of available herbicides. Herbicide resistance simulation models have been successfully utilized to understand resistance evolution in weed communities and establish best management practices for resistance mitigation/management. A simulation model has been developed using the STELLA® modeling environment to predict the evolution of ALS-resistant barnyardgrass in Arkansas rice. The model incorporates the biology of the species, genetics of resistance (mode of inheritance, dominance, and fitness), and the response of the species to various management interventions. The model was parameterized using field collected data and information from published literature. Preliminary results of the model show that there is about 80% probability for barnyardgrass evolving resistance to ALS-inhibiting herbicides within 8 years of continuous Clearfield™ rice, under existing weed management programs common to this region. A number of weed management scenarios, integrating chemical and non-chemical approaches, were simulated using the model and suitable best management programs were identified for resistance mitigation and management.

Permit Plus: An Improved Permit

Johnson, D.B., Norsworthy, J.K., Scott, R.C., Starkey, C.E., Bararpour, M.T., and Majure, K.

Halosulfuron (Permit) has historically been used for control of several annual broadleaf weeds and yellow nutsedge in row crops. Permit Plus, a pre-packaged mix of halosulfuron and thifensulfuron, has recently been registered in field corn, sulfonylurea-tolerant soybean (STS), rice, and fallow ground for control of broadleaf weeds and yellow nutsedge. Over the past several years, University of Arkansas Weed Scientists have conducted both field and greenhouse studies with the objective of these studies being to evaluate the efficacy of Permit Plus vs. Permit on grass and broadleaf weed commonly found in Arkansas crops. Crop tolerance of non-STS soybean, Clearfield, and conventional rice was also evaluated in these studies. Weed control in these studies was visually rated as excellent (85-100%), good (70-84%), fair (55-69%), or poor (<55%). Crop tolerance was assessed as excellent (0-5%), good (6-21%), fair (21-35%), or poor (>35%). Treatments included both preemergence (PRE) and postemergence (POST) applications of Permit at 1 oz/A and Permit Plus at 840 g ai/ha (0.75 oz/A). Permit Plus applied PRE improved control on susceptible barnyardgrass and large crabgrass from poor to fair and control of propanil-resistant barnyardgrass from fair to good while POST applications of both herbicides were equally as effective on all grasses. Permit and Permit Plus showed equal effectiveness on all of the broadleaf species when applied PRE. However, POST applications of Permit Plus improved control of pitted morningglory, Pennsylvania smartweed, common dayflower, ducksalad, and smellmelon. Rice displayed excellent tolerance to both herbicides. Soybean tolerance was poor for both herbicides, regardless of application timing. These results show that Permit Plus can improve control of some of the most problematic weeds in Arkansas crop production.

Effects of High Night Temperature and Invinsa on Rice Morphology, Phenology, and Physiology

Mohammed, A.R. and Tarpley, L.

High night temperature (HNT) resulting from global warming is one of the environmental stresses that can trigger ethylene production, resulting in plant senescence and decreased yields. The ethylene perception inhibitor, 1-methylcyclopropene (1-MCP), is a plant growth regulator structurally similar to ethylene, which tightly binds to the ethylene receptor in plants, thereby competitively blocking the effects of ethylene. The HNT has been shown to decrease rice (*Oryza sativa* L.) yields; however, the processes through which it decreases yield are not fully established.

The objectives of this study were to determine which plant processes were involved in reduction of yield due to HNT and to determine if application of 1-MCP can negate the effects of HNT. Plants were subjected to ambient night temperature (ANT) (25^{o}C) or HNT (30^{o}C) through the use of continuously, precisely controlled infrared heaters, starting from 2000 h until 0600 h, 30 days after emergence (DAE). Plants were treated with 1-MCP 30 DAE. Net photosynthesis (P_n) of the penultimate leaves from three plants in each treatment was measured between 1000 h and 1200 h using a LI-6400 portable photosynthetic system (LI-COR Inc., Lincoln, Nebraska, USA) at 40 DAE. Respiration rates were measured on the penultimate leaves between 2400 h and 0200 h using a LI-6400 at 40 DAE. Membrane stability was determined at 40 DAE and pollen germination was determined *in vitro*. Spikelet fertility was defined as the ratio of filled grains to total number of grains in the panicle. Grain length and width of brown (dehulled) rice were determined using a Winseedle, which uses image analysis of scanned color images of the grain to calculate these parameters. Grain nitrogen concentration was measured using a FP-528 Nitrogen/Protein analyzer.

The HNT did not affect leaf photosynthetic rate (P_N); however, HNT increased respiration rate (R_S; 20%), relative injury to the membrane (28%), internal CO_2 concentration, transpiration rate (12%), spikelet abortion and grain fissures, and decreased pollen germination (34%), spikelet fertility (21%), grain width (2%), volume (2%) and surface area (1%) and plant yield (10%). The 1-MCP-treated plants grown under HNT showed decreased R_S (5%) and relative injury to the membrane (10%) and increased pollen germination (186%) and plant yield (4%), compared with untreated plants grown under HNT. Reduced respiration rate and membrane injury, along with higher pollen germination as a result of 1-MCP application increased rice yields under HNT.

We appreciate the funding provided by AgroFresh Inc., Philadelphia, PA, USA, in support of this project.

Imazosulfuron: A New Herbicide for Rice

Riar, D.S., Norsworthy, J.K., and Scott, R.C.

Imazosulfuron is a new herbicide developed by Valent® USA. In 2009 and 2010, research was conducted at Stuttgart, AR, to evaluate effect of imazosulfuron tank-mix on weed control efficacy of commonly used POST-applied rice herbicides, and influence of imazosulfuron rate and application timing on weed control in drill-seeded rice. Additionally during same years, research was conducted at Keiser and Stuttgart, AR, to evaluate imazosulfuron-containing herbicide programs in drill-seeded rice. Weed species evaluated included barnyardgrass, broadleaf signalgrass, hemp sesbania, and yellow nutsedge. Imazosulfuron applied at 224 and 336 g ai ha^{-1} during PRE, early-POST (EPOST), or preflood (PREFLD) controlled all weeds similarly. Imazosulfuron applied EPOST or PREFLD controlled hemp sesbania and yellow nutsedge $\geq$93% both years at 5 and 7 wk after planting (WAP), except in 2009 when hemp sesbania control was $\leq$79% at 7 WAP. In 2010, because of inadequate rainfall, hemp sesbania and yellow nutsedge control with PRE-applied imazosulfuron was $\leq$29% at 5 and 7 WAP. Imazosulfuron in tank-mix had no interaction with acifluorfen, bispyribac, carfentrazone, halosulfuron, penoxsulam, propanil, quinclorac, triclopyr, or 2,4-D to influence hemp sesbania and barnyardgrass control. However, imazosulfuron in tank-mix antagonized fenoxaprop and cyhalofop to reduce barnyardgrass control up to 36%. Imazosulfuron plus clomazone PRE followed by (fb) quinclorac plus propanil EPOST and imazosulfuron plus quinclorac EPOST fb thiobencarb plus propanil PREFLD programs controlled hemp sesbania and barnyardgrass (in at least two site years), and yellow nutsedge and broadleaf signalgrass (in at least one site year) greater than or equal to clomazone plus quinclorac PRE fb propanil plus halosulfuron PRELD (standard program). No rice injury was observed with any herbicide program. Rice yield with all imazosulfuron-containing herbicide programs (6,630 to 8,130 kg ha^{-1}) was similar to the standard herbicide program (7,240 kg ha^{-1}). Imazosulfuron should not be mixed with fenoxaprop and cyhalofop, nevertheless, in mixture with clomazone, propanil, or quinclorac, imazosulfuron can be incorporated into herbicide programs of Midsouth rice production for the control of broadleaf weeds and sedges.

Should there be Concerns with Off-target Movement of League (imazosulfuron) from Rice to Soybean?

Rana, S.S., Norsworthy, J.K., Johnson, D.B., Devkota, P., and Scott, R.C.

League is a new sulfonylurea herbicide recently labeled in rice. Soybean is prone to drift of herbicides from rice fields in the southern U.S. because the two crops are often grown in close proximity. Therefore, a field trial was conducted at Fayetteville, Arkansas, to determine the sensitivity of soybean (cv. AG 4703) to drift rates of imazosulfuron. Imazosulfuron was labeled for use in Arkansas rice at a maximum use rate of 336 g ai ha^{-1} (0.3 lb A^{-1}). Soybean was treated at the VC, V2, V6, and R2 growth stages with 1/256, 1/128, 1/64, 1/32, 1/16, 1/8, and 1/4 times (X) the maximum labeled rate of imazosulfuron. Soybean was injured regardless of herbicide rate or application timing. Injury to soybean plants from imazosulfuron was in the form of stunting and purple veins. At 3 wk after treatment, imazosulfuron at 84 g ha^{-1} (1/4X rate) caused 96, 86, 70, and 65% injury when applied at the VC, V2, V6, and R2 growth stages, respectively. However, soybean treated with imazosulfuron at early growth stages recovered from injury over time. At 13 weeks after VC growth stage, injury from the 1/4X rate of imazosulfuron applied at the VC, V2, and V6 growth stages of soybean was 17, 21, and 67%, respectively. However, soybean recovery at the R2 growth stage occurred only for the lowest four (1/256, 1/128, 1/64, and 1/32X) application rates. Imazosulfuron applied at 1/4X rate resulted in significant delays in days to maturity and reduced yield compared with the non-treated check. Imazosulfuron applied at 1/4X rate to soybean delayed maturity by 9, 10, 13, and 14 d and reduced yield by 40, 49, 74, and 89% at the VC, V2, V6, and R2 growth stages, respectively. Results of this research indicate that imazosulfuron can severely injure soybean regardless of the growth stage at which drift occurs; however, soybean injured by imazosulfuron at early growth stages (VC and V2) have a better chance of recovery compared with later growth stages (V6 and R2).

Evaluation of Carryover of GAT Soybean Herbicides to Conventional and Clearfield Rice

Johnson, D.B, Norsworthy, J.K., and Edmund, R.

Rice and soybean are commonly grown in rotation in Arkansas, so herbicides used in soybean could potentially carryover and cause injury to rice. GAT (glyphosate/ALS-resistant) soybean are currently being considered for registration to provide growers with more weed control options in soybean. However, the potential of carryover to rice from herbicides that will be used in GAT soybean production systems is a concern. Experiments were conducted at the University of Arkansas Pine Tree Branch Station in the summer of 2010 and 2011, with the objective being to evaluate carryover of two ALS-herbicides, Classic (chlorimuron) and Resolve (rimsulfuron), to Clearfield and conventional rice. All treatments were applied preemergence in the summer of 2010 to AG 5605 soybean, a Roundup Ready/sulfonylurea-resistant soybean cultivar. Treatments in this study consisted of Classic at 35 and 70 g ai/ha (0.5 and 1 oz ai/A), Resolve at 17.5, 35, and 70 g ai/ha (0.25, 0.5, and 1 oz ai/A), and combinations of both herbicides at 35 and 70 g ai/ha (0.5 and 1 oz ai/A) respectively. In the summer of 2011, Clearfield (CL-171) and conventional (Wells) rice were planted and crop injury was visually assessed weekly throughout the growing season. Stand counts for each variety were taken at emergence and yield was determined at maturity. Injury to Clearfield rice was minimal throughout the growing season (<3%). Emergence and yield were also comparable with the untreated check. All treatments resulted in ≥32% to Wells rice 2 weeks after emergence (WAE). Injury was reduced to ≤10% at 6 WAE with all treatments except treatments containing combinations of Classic and Resolve which resulted in 20 to 21% injury. Emergence in treated plots was <13 plants/row ft which was significantly less than that of the untreated check. Reduced emergence also resulted in a reduction of yield in treated plots (<140 bu/A) compared with the untreated check (175 bu/A). Therefore, rotations from GAT soybean into conventional rice can result in significant crop injury and yield reduction.

Abstracts of Posters on Weed Control and Growth Regulation
Panel Chair: Robert Scott

Glyphosate for Rice Seedhead Suppression in Rice Produced for Crawfish

Thevis, E.L., Webster, E.P., Fish, J.C., Fickett, N.D., McClain, W.R., and Sonnier, J.J.

Crawfish producers would prefer rice to stay in the vegetative stage in order to provide forage for a longer period of time into the winter. However, when rice is allowed to head, the plant matures and foliage desiccates. Based on herbicide drift research conducted at the LSU AgCenter, it was observed that rice maturity would delay or not advance into the reproductive stage when treated with drift rates of glyphosate. The result was a rice plant remaining in the vegetative state. With this in mind, a study was conducted at the LSU AgCenter Rice Research Station near Crowley, Louisiana, in 2011 to evaluate the effects of glyphosate on 'Jupiter' rice. The study was repeated in 2011.

The experimental design was a randomized complete block with four replications in an augmented two-factor factorial arrangement of treatments. A nontreated was added for comparison. Factor A consisted of application timings at two different growth stages: early boot and boot split. Factor B consisted of herbicide rate. Glyphosate in the formulation of Honcho Plus was applied at rates of 53, 105, 160, and 210 g ae/ha (2, 4, 6, and 8 fluid oz/A). Each application was made with a CO_2-pressurized backpack sprayer calibrated to deliver a constant carrier volume of 101 l/ha (9 gal/A) (GPA). The reduced GPA was based on previous research conducted at the LSU AgCenter, indicating that lower spray volume results in higher activity of glyphosate when applied at reduced rates. Two plant heights were taken: overall plant canopy height and height from the ground to the tip of the extended panicle. Percent rice panicle emergence, rough rice yield, 100 count seed weights, and percent seed germination were determined. Injury was visually assessed and did not exceed 15%.

Averaged across timings, rice treated with higher rates of glyphosate had reduced canopy plant heights and reduced plant height to the extended panicle. Canopy height was lower in rice treated with 210 g/ha (8 oz/A) of glyphosate applied at early boot compared with rice treated with 53 g/ha (2 oz/A) of glyphosate applied at the same stage. Rice treated with 105, 160, and 210 g/ha (4, 6, or 8 oz/A) of glyphosate at early boot had a reduced plant height to the extended panicle than those treated with any rate at boot split. There were no rice height differences when treated at boot split regardless of rate.

At 4 days after the boot split application, rice panicle emergence was reduced when rice was treated with 105, 160, and 210 g/ha (4, 6, and 8 oz/A) of glyphosate at the early boot timing. However, rice panicle emergence was not reduced with any of the rates evaluated at boot split timing. Similar results were observed at 28 days after the boot split timing.

Averaged across timings, yield of rice treated with 53 g/ha (2 oz/A) of glyphosate was higher than rice treated with all other rates evaluated. Rice treated with 105 g/ha (4 oz/A) of glyphosate also had a higher yield than rice treated with either 160 or 210 g/ha (6 or 8 oz/A).

Percent germination of rice seed collected was 80% when rice was treated with 53 g/ha (2 oz/A), and the rice treated with 210 g/ha (8 oz/A) at the early boot timing had a reduced seed germination of 37%. However, no other differences occurred regardless of rate or timing.

This research indicates that 160 or 210 g/ha (6 to 8 oz/A) of glyphosate applied to rice in the early boot stage would help prevent rice from maturing. These rates reduced panicle emergence, resulted in little to no reduction in canopy height, little to no crop injury, rice yield was less than 20% of the nontreated, and visual observation indicated the rice remained in the vegetative state. This would provide crawfish with an extended period of available forage.

Tolerance of Midsouth Rice Varieties to Imazosulfuron

Devkota, P., Norsworthy, J.K., Webster, E., and Scott, R.C.

Imazosulfuron is a newly developed herbicide with the trade name League. PRE- or POST-applied imazosulfuron is effective for several broadleaf weeds and sedges in drill- and water-seeded rice. Before imazosulfuron is widely used in rice production, however, the tolerance of Midsouth rice varieties to imazosulfuron has to be evaluated. Research was conducted in summer 2011 at Stuttgart, AR, and Crowley, LA, to evaluate the tolerance of rice varieties to the imazosulfuron. Imazosulfuron was applied PRE at 337 and 674 g ai/ha in different rice varieties: Caffey, Jupiter, Jazzman, Taggert, Cheniere, CL142, CL151, and CL261. In addition, PRE-applied halosulfuron at 53 g ai/ha and a non-treated control for each variety were included for comparison. Visual ratings were taken for rice injury, height, and plant stand at 4 WAT. At the end of the season, rice plots were harvested and yields were calculated in ton/ha. In Arkansas, there was no rice injury from imazosulfuron. For plant height and stand, imazosulfuron rates did not differ from halosulfuron and non-treated control. Furthermore, rice yields were similar to imazosulfuron and halosulfuron. These varieties yielded >7.9 ton/ha of rice. However, at Louisiana, there was significant injury from imazosulfuron among the rice varieties. Imazosulfuron at 337 and 674 g ai/ha injured rice 47 and 21%, respectively; whereas, halosulfuron injured rice by 10% compared with the non-treated control. Similarly, plant height and stand were reduced by imazosulfuron. Imazosulfuron at 337 and 674 g ai/ha reduced plant height 25 and 68%, respectively, and plant stand 13 and 23%, respectively, compared with the non-treated control. Halosulfuron reduced plant height and stand 13 and 2%, respectively. However, there were no differences in rice yield from these treatments. The rice yield from these varieties was >7 ton/ha. In conclusion, in Arkansas, there was no injury to the rice varieties from imazosulfuron; however, at Louisiana, imazosulfuron injured the rice, although yield was not reduced.

Effects of Ultraviolet-B and Plant Growth Regulators on Rice Morphology, Phenology and Physiology

Mohammed, A.R. and Tarpley, L.

The impact of climatic change on crop production is a major global concern. One of the climatic factors, ultraviolet-B radiation (UVB; 280-320 nm), which is increasing as a result of depletion of the global stratospheric ozone layer, can alter crop productivity. The plant growth regulators (PGR) [α-tocopherols (vitamin E), glycinebetaine (GB), and salicylic acid (SA)] play an important role in inducing stress-tolerance in many plant species. Plants pre-treated with vitamin E, GB, or SA, the PGRs used in this study, showed induced stress-tolerance and protection against oxidative damage caused by the abiotic stresses. The α-tocopherol is one of the most effective single-oxygen quenchers and is a strong antioxidant, whereas GB enhances tolerance to several stresses by protecting certain enzymes (e.g., RUBISCO and citrate synthase) involved in carbon fixation. Salicylic acid plays an essential role in stress-tolerance in plants by preventing oxidative damage to the membranes and by detoxifying superoxide radicals. Despite the importance of these PGRs in stress tolerance, little is known about the response of rice UVB-tolerance to these PGRs (vitamin E, GB and SA).

The objective of these studies was to determine the effects of elevated UVB radiation and PGRs on rice growth, development, and physiology. Plants received no natural UVB radiation due to the UV-absorption characteristics of the greenhouse glass; hence UVB was artificially supplied by supplemental UV-B lighting. Plants were grown in soil collected from research plots and exposed to UVB radiation of 5 (ambient) or 10 (high) kJ m^{-2} d^{-1} for 105 days. The PGRs were applied 20 days after emergence (DAE). The α-tocopherol was applied at the rate of 58 μ mol per plant (i.e., 580 mM); GB was applied at the rate of 182.3 μ mole per plant (i.e., 1.823 M), and SA at the rate 0.1 μ mol per plant (i.e., 1 mM).

Across the treatments, elevated UVB radiation decreased yield by 15%. Decrease in yield was due to decreased photosynthetic rate and spikelet fertility. Application of salicylic acid increased yield by 26 and 29% under ambient and elevated UVB radiation, respectively. In addition, application of vitamin E increased yield by 26% under ambient UVB radiation.

Hybrid Rice Response to Apogee, a Plant Growth Retardant, in Clay Soil

Tarpley, L. and Mohammed, A.R.

Plant growth retardants provide a management option to decrease lodging risk. The reduction in lodging risk, partially due to a decrease in plant height, also allows more flexibility in the amount and timing of nitrogen (N) fertility. In some situations, increased N fertility can promote increased yield. For example, Palisade (Syngenta; trinexapac-ethyl), a plant growth retardant, in combination with an increased N rate, decreased plant height and increased yield (by an average of about 780 kg/ha) of the hybrids XL723 and Clearfield XL729 in several studies conducted on clay soil at Beaumont, Texas, and in west Mississippi. On a lighter soil (silty loam at Eagle Lake, Texas) with increased available soil N, the combination of Palisade treatment and increased N rate was ineffective in increasing yield, presumably because of the relatively high soil N availability. In this study, Apogee (BASF; prohexadione; registered for use on apple in the United States and on rice in Japan), a plant growth retardant, was evaluated for potential to decrease plant height (and presumably the risk of lodging) and increase yield of the hybrid rice, XL723, grown in clay soil with high N rate.

The study was conducted at the Texas AgriLife Research and Extension Center at Beaumont in 2011 on clay soil. All of the replicated plots of RiceTec hybrid XL723 were provided 224 kg/ha N (as 56 planting; 90 pre-permanent flood; 78 panicle differentiation [PD]). The Apogee was applied to half of the plots at random at a rate of 10 g active ingredient/ha at 14 d post-PD.

The effect of N rate on hybrid yield in interaction with Apogee treatment was not evaluated in this study. Apogee shortened final plant height by 13 cm ($P < 0.05$). Apogee increased crop grain yield by 225 kg/ha ($P < 0.05$) to 12,000 kg/ha. The grain moisture percentage at harvest was not affected by the Apogee treatment. No lodging was present in the study.

Apogee appears to have the potential to provide for high yields of XL723, and probably other hybrid rice cultivars, grown on soils with limited N availability, such as the clay soils present in many rice fields in east Texas, to the extent that it decreased plant height (a risk factor for lodging) and increased yield above an already acceptable level with high N rate.

Barnyardgrass (*Echinochloa crus-galli*) Resistance to Herbicides in Arkansas

Starkey, C.E., Burgos, N.R., Norsworthy, J.K., and Devore, J.D.

Decades of herbicide use in Arkansas rice (*Oryza sativa*) has resulted in evolution of herbicide-resistant barnyardgrass. This study was conducted to determine the spatial distribution of herbicide-resistant barnyardgrass in Arkansas rice. A total of 81 barnyardgrass samples were randomly collected from rice fields in 2010 from 25 of Arkansas' top rice producing counties. GPS coordinates were collected at each sampling location. All samples were grown to the 3- to 4-leaf stage in pots in a greenhouse with approximately 25 plants per pot replicated twice with two runs for a total of 100 plants targeted. Every population was treated with five different herbicides in separate runs. The following herbicides were used at the 1x labeled field rate: quinclorac, propanil, imazethapyr, fenoxaprop, and glyphosate. Visual control ratings and live dead counts were recorded. Any sample that had less than 70% control was considered to be resistant. Of the 81 samples collected, 3.7 and 16.1% were found to be quinclorac- and propanil- resistant, respectively. Of the samples collected, 7.4% were resistant to both quinclorac and propanil. Resistance to glyphosate, fenoxaprop, and imazethapyr was not found in the samples collected. The samples that were collected showed no spatial pattern of resistance in Arkansas; however, the resistant samples do provide an overview of the magnitude of herbicide-resistant barnyardgrass in Arkansas.

Fertility-based Herbicide Injury Recovery from Clomazone Herbicide in Hybrid Rice (*Oryza sativa*)

McKnight, B.M., Senseman, S.A., and McCauley, G.N.

Field studies were conducted near Eagle Lake and Ganado, TX, to assess fertility-based herbicide injury remediation from clomazone. Yield data, visual injury ratings, and plant tissue samples were collected throughout the study. Chlorophyll extraction procedures were utilized in the laboratory to develop a standard curve of clomazone injury and assess any remediation from added fertilizers.

Influence of Rate and Application Timing on Rice Tolerance to Pyroxasulfone

Bararpour, M.T., Norsworthy, J.K., Johnson, D.B., and Starkey, C.

Rice, wheat, and corn are the three leading food crops in the world. Human consumption accounts for 85% of total production for rice, compared with 72% for wheat and 19% for corn. Arkansas has been the nation's leading rice-producing state since 1973. Field studies were conducted at Keiser and Stuttgart, Arkansas, in 2011 to evaluate the influence of rate and application timing of pyroxasulfone (Zidua) on rice tolerance. The experiment was designed as a three (application timing) by four (pyroxasulfone rates) factorial arrangement in a randomized complete block design. Pyroxasulfone was applied at 0 (untreated check), 0.050, 0.075, and 0.090 kg ai/ha (0.045, 0.067, and 0.08 lb ai/A) (sub-factor) at spiking, 2-leaf, and 4-leaf stage of rice (main factor).

At Keiser, 4 weeks after emergence, the effect of timing by rate was significant for rice injury. Rice injury was 8, 16, and 29%; 0, 3, and 3%; and 3, 16, and 21% from low to high rates of pyroxasulfone applications at spiking, 2-leaf, and 4-leaf stage of rice, respectively. Rice yield was not affected by application timings (averaged over rate) or rates (averaged over timing). At Stuttgart, the effect of timing by rate was significant for rice injury and rice yield. Rice injury was 75, 81, and 76%; 69, 74, and 76%; and 31, 29, and 6% from the applications of pyroxasulfone at 0.050, 0.075, and 0.090 kg/ha (0.045, 0.067, and 0.08 lb/A) at spiking, 2-leaf rice, and 4-leaf stage of rice, respectively. Rice yield was reduced 53, 89, and 72%; 47, 61, and 79%; and 16, 22, and 32% from low to high rate of pyroxasulfone applications at spiking, 2-leaf, and 4-leaf rice.

Rotational Options for Reducing Red Rice (*Oryza sativa*) in Clearfield Rice Production Systems

Davis, B.M., Scott, R.C., and Dickson, J.W.

Weedy rice or "red rice" has been one of the most troublesome weeds to control in rice production history. Until the release of imidazolinone-tolerant rice in 2002, there was no selective herbicide that would control red rice in rice. In 2006, Arkansas producers planted 81,200 hectares of Clearfield rice. More recent in 2009, 42% of all the rice planted in Arkansas was in the Clearfield technology. The Clearfield technology has enjoyed rapid adoption by rice producers with severe infestations of red rice. The imidazolinone herbicides provide excellent control of red rice and other weeds. However, the continual use and lack of rotation have led to the discovery of Imidazolinone-resistant red rice in 2006. In fact, red rice has become resistant to imazethapyr by both traditional selection and out-crossing. Also, in 2006, a survey by Norsworthy et al. reported that 56% of the growers were using the Clearfield technology. They also reported red rice to be the second most problematic weed in rice (2007).

Crop rotation and other management practices have also been discussed and implemented in the effort to control red rice. One other technology released in 1996 was the Roundup Ready system that allowed for over the top applications of glyphosate onto soybean. Glyphosate is very effective at controlling red rice, so crop rotation to Roundup Ready soybean has been an effective management tool. Recently, the release of Liberty Link Soybean in 2009 has provided growers another tool for red rice control in some rotations. This technology allows for the over the top application of Ignite (glufosinate) onto soybean. Both herbicides have provided effective reduction of red rice in field trials.

A study was established in 2010 to evaluate continuous use of the Clearfield system versus various rotational schemes including: delayed planting, Roundup Ready soybean, Liberty Link soybean, and fallow. This test was established in an area known to have a very diverse red rice and volunteer hybrid rice population. Data collected from 2010 and 2011 indicate that continuous use of the Clearfield system does result in an increasing red rice problem. This test will continue into 2012 and results from 16 different rotational systems will be evaluated.

Evaluation of Residual Herbicide Options for Barnyardgrass Control in Rice

Bagavathiannan, M.V., Norsworthy, J.K., Starkey, C., Johnson, D.B., and Scott, R.C.

Herbicide-resistant barnyardgrass has been a serious concern in Arkansas rice fields. Soil active residual herbicides are known to be invaluable in herbicide-resistance management. Residual herbicides must be an integral component of effective resistance management programs because they introduce mode of action diversity within herbicide programs, and with high efficacy, they reduce the probability of new resistant mutants from occurring as a result of reduced weed population size. Incorporation of residual herbicides in weed management programs is particularly critical for herbicide-resistant crop production systems because these systems favor repeated application of limited herbicide modes of action. In the Clearfield™ rice system in Arkansas, fields typically receive about three applications of ALS-inhibiting herbicides within a growing season, exerting enormous selection pressure on weeds. As such, there is a critical need to identify suitable residual herbicides and integrate them in existing weed management programs to prevent herbicide resistance issues from evolving. Knowledge of the length of residual control provided by various herbicides is vital in devising appropriate management strategies. An experiment was carried out during the summer of 2010 at Stuttgart, AR, to evaluate the residual activity of various herbicides, including quinclorac (Facet®), clomazone (Command® 3ME), thiobencarb (Bolero®), pendimethalin (Prowl® H20), and imazethapyr (Newpath®), for barnyardgrass control.

The experiment was laid out in a completely randomized block design with four replications. The application rates for various herbicides were as follows: Facet® at 0.37 and 0.75 kg/ha (0.33 and 0.67 lb/A), Command® 3ME at 1.12 and 2.24 l/ha (0.8 and 1.6 pt/A), Bolero® at 5.60 l/ha (4 pt/A), Prowl® H20 at 2.94 l/ha (2.1 pt/A), and Newpath® at 280 and 420 ml/ha (4 and 6 fl oz/A). The experiment also included non-treated check plots. Prior to the initiation of study, the experimental plot was over-seeded with barnyardgrass. Herbicide treatments were carried out using a CO_2 pressurized-backpack sprayer calibrated to deliver 93.5 l/ha, and no herbicide was applied to non-treated plots. The rice crop was managed according to standard rice production practices for Arkansas. Evaluations for barnyardgrass control were carried out at 3, 4, and 5 weeks after herbicide treatments (WAT). At 3 WAT, Command® at 1.12 and 2.24 l/ha (0.8 and 1.6 pt/A), Facet® at 0.37 and 0.75 kg/ha (0.33 and 0.67 lb/A), and Newpath® at 420 ml/ha (6 fl oz/A) were comparable for barnyardgrass control (≥95%). At 4 WAT, all herbicides except Bolero® and Prowl® H20 provided comparable barnyardgrass control (≥90%). At 5 WAT, Command® (both rates) and Facet® at 0.75 kg/ha (0.67 lb/A) provided excellent control for barnyardgrass (≥96%). Application of Command® at 2.24 l/ha (1.6 pt/A) resulted in total barnyardgrass control. As such, the longevity of residual control for barnyardgrass was greater for Command® and Facet®. Thus, the findings indicate that Command® 3 ME and Facet® are valuable herbicides for inclusion in weed management programs for barnyardgrass. The findings will be useful for parameterizing the herbicide resistance simulation models for barnyardgrass in rice, which is currently being developed by our research group.

Abstracts of Papers on Rice Culture
Panel Chair: Nathan Slaton

Rice Irrigation in the Mid-South: Where Do We Head From Here?

Massey, J.H.

According to the 2010 USA Rice Federation's *Environmental Indicators* report, the volume of irrigation water required to produce a 45 kg (100 lb) of rice in the U.S. declined by about 40% between 1982 and 2008. Energy use declined by about 53% over the same time period. Producers in Mississippi did their part in these reductions by precision-leveling rice fields beginning in the 1980s. Use of straight-levees increased water savings by about 15% over that of contour levee systems. In the 1990s, Mississippi producers began using multiple (side) inlet irrigation and zero-grade (level basin) systems that increased water savings by approximately 30 and 50% over that of contour levees, respectively. Currently, over 70% of the rice land in Mississippi has been precision-leveled. More than any other group, rice producers have made steady progress in reducing water inputs while increasing yields.

However, a closer inspection of the Rice Federation's report reveals that most of these water savings occurred in the 1980s and 1990s as the savings reached a plateau in the 2000s. Similarly, average water use in Mississippi rice production has remained at approximately 8124 ±1015 m^3 ha^{-1} (36 ± 4 acre-inches $acre^{-1}$) for the past nine years. Adoption of the highly efficient zero-grade systems in Mississippi remains at approximately 5% of rice hectares. The limited adoption of this system can be attributed to the issue of water-logging of rotational crops. Growing continuous rice to address the water-logging issue has its own disadvantages (e.g., increased potential for pest resistance) and doesn't allow the producer to benefit from yield gains associated with the 2:1 soybean-rice rotation common to the Delta.

There are pros and cons associated with any irrigation system. Sprinkler-irrigated rice may have a fit for certain growers but most do not expect it, or zero-grade irrigation, to become the method used to grow the majority of rice in the Midsouth. Early flood termination reduces water use, but can be risky as producers cannot know how hot and dry the end of the growing season will be. On-farm reservoir and tailwater recovery systems represent an outstanding means to reduce water and energy use, but current installation costs are estimated to be approximately \$3700 ha^{-1} (~\$1500 $acre^{-1}$). Similarly, irrigation pump-control systems offer the convenience of remote pump shut-off and system monitoring along with potential water and energy savings. However, these devices are still largely under development and their current cost may prohibit widespread adoption in the short term. Moreover, current efforts to develop drought-tolerant rice are mainly directed towards rain-fed production settings common to developing countries, not the Midsouth USA.

So what water-conserving option exists that is available to the majority of Midsouth USA rice producers today? Multiple (side) inlet irrigation has a proven track record as an economical means to conserve water and energy and is the most readily-available option applicable to the majority of rice hectares in the Midsouth. However, the adoption rate of this system is estimated to be at only 20% of the rice hectares in Mississippi. Multiple-inlet irrigation is known to reduce water use by about 15% and has many other benefits such as reduced cold-water rice and improved nitrogen management. As important, it serves as a platform upon which additional water-savings, often approaching those of zero-grade systems, can be attained with no additional input costs.

This presentation will highlight findings from nine years of on-farm research and demonstration. On average, cooperating Mississippi rice producers that have combined straight-levees with multiple-inlet irrigation distribution and intermittent flood management have used approximately 5586 m^3 ha^{-1} (22 acre-in $acre^{-1}$) irrigation water versus 5078 m^3 ha^{-1} (20 acre-in $acre^{-1}$) used by zero-grade. To date, there has been no significant rice yield or milling quality differences observed between intermittently- and continuously-flooded plots. Increased rainfall capture and reduced over-pumping associated with intermittent flooding and the ability of rice to thrive in a non-continuously-flooded environment help to explain these results.

Evaluation of Seeding Rate, Fertilization, and Fungicide Application for 'CL151' Production

Corbin, J.L., Walker, T.W., Fitts, P.W., Harrell, D.L., and Bottoms, S.L.

‘CL151’ has become a popular cultivar for southern USA rice production and accounted for approximately 25% of the planted hectarage when averaged over 2010 and 2011. In addition to providing red rice control because of its tolerance to Newpath® and Beyond® herbicides, CL151 has shown excellent yield potential. CL151 produced 20% greater yields compared with the once popular ‘CL131’ averaged over multi-location variety trials in Mississippi during 2009-2011. One negative characteristic of CL151 is that it is very susceptible to lodging. Lodging can create many problems for harvest, including decreased harvest efficiency, reduced grain quality, and the potential for reduced yield. The objective of this study was to evaluate seeding rate, fertilization, and fungicide application practices aimed at minimizing lodging potential for CL151.

Study 1 was conducted on a Sharkey clay (Chromic Epiaquerts) soil in 2010 at the Delta Research and Extension Center (DREC), Stoneville, MS. A trial consisting of a factorial combination of seed rates (161, 323, and 483 seeds m^{-2}) and nitrogen (N) fertilization schemes (101 kg N ha^{-1} to 252 kg N ha^{-1} with various preflood, midseason, and heading splits) for a total of 30 treatments was conducted. Study 2 was conducted in 2011 at the DREC on a Sharkey clay soil and on a Dundee silt loam (Typic Endoaqualfs) in Shaw, MS. Treatments consisted of a factorial combination of N rate, K rate, and fungicide timing. Nitrogen and K rates were 112 and 224 kg N ha^{-1} and 67 and 134 kg K_2O ha^{-1}, respectively. Azoxystrobin was applied at the rate of 0.2 kg ha^{-1} at either panicle differentiation (PD) or boot. Response variables for Study 1 and Study 2 included grain yield, percent of plot lodged, and lodging severity score (1-5 rating where 1 is erect and 5 is flat on ground). Data were subjected to tests of fixed effects using PROC MIXED in SAS. Means were separated using LSMEANS at a 95% confidence interval.

In Study 1, grain yield was affected by the main effects of seed rate and N application scheme. Pooled across N application scheme, grain yields were greater for seed rates of 323 (9801 kg ha^{-1}) and 483 (9848 kg ha^{-1}) seeds m^{-2} compared with 161 seeds m^{-2} (9356 kg ha^{-1}). The N management scheme affected rice grain yield in a quadratic manner. In general, grain yield was greatest when N was applied at 151 to 202 kg N ha^{-1} prior to flooding. An interaction among seed rate and N management scheme was present for percent of plot lodged and lodging severity. Lodging did not occur for any combination of seed rate and N management scheme where <202 kg N ha^{-1} were applied by midseason. The percent of plot lodged and severity increased with increasing seed rate when 202 and 252 kg N ha^{-1} were applied preflood. Percent of plot lodged and severity was 6.7% (0.3), 20% (2.0), and 50% (3.3) for 161, 323, and 483 seeds m^{-2}, respectively, when 202 kg N ha^{-1} were applied preflood. Likewise, when 252 kg N ha^{-1} were applied preflood, percent of plot lodging and score was 35% (2.7), 73% (4.0), and 83% (4.3).

In Study 2, grain yield, percent of plot lodged, nor lodging severity were affected by interactions of main effects for either soil type. For the Dundee silt loam, 112 kg N ha^{-1} pooled over K rate and fungicide timing resulted in 5% less grain yield compared with 224 kg N ha^{-1}. However, 53% of the plots that received 224 kg N ha^{-1} lodged whereas no lodging occurred when 112 kg N ha^{-1} were applied. The severity of lodging score at 224 kg N ha^{-1} was 4. For the Sharkey clay soil, results were similar; however, the yield loss when 112 kg N ha^{-1} were applied was 15%. Lodging occurred on an average of 10% of the individual plots and the severity score rated 2 when 224 kg N ha^{-1} were applied. A fungicide application at PD or Boot increased rice grain yield by 6% compared with none being applied.

In summary, N rate appears to be the largest factor in managing CL151 for lodging. If excessive N rates are used, higher seed rates can make lodging more severe. Up to 95% of the maximum yield potential (Ymax) can be achieved with N while minimizing lodging; however, lodging is expected when N fertilization exceeds 95% of Ymax.

Effect of Seeding Rate on RiceTec Hybrid Rice Yield and Milling Quality

Simpson, G.D., McNeely, V.M., and Hamm, C.E.

Field studies have been conducted from 2004 to 2011 in Arkansas, Louisiana, Mississippi, Texas, and Missouri in multiple locations using RiceTec commercial hybrid rice seed. The purpose of these tests has been to observe the effect of seeding rate on emergence and resulting plant populations on yield and milling yield of RiceTec hybrid rice in an on-farm setting. In every test, RiceTec hybrid rice seed was compared side by side with locally recommended varieties. Seeding rate treatments of 494,200, 988,400, 1,482,600, and 1,976,800 seeds ha^{-1} were directly compared using a randomized strip plot design or randomized complete block design depending on the local field conditions. RiceTec hybrid genotypes included in the tests were XL723, Clearfield XL729, and Clearfield XL745. Variety checks were CL161, CL151, Wells, and Cheniere depending on the location and year. At each location, tests were harvested using a 'Wintersteiger Delta plot combine' with 'Harvest Master' digital plot weigh system. Grain samples were collected at harvest and milled immediately after air drying. In individual location tests and in combined analysis over locations and years, grain yields and milling yields from seeding rates of 988,400 seeds to 1,482,600 seeds ha^{-1} were not significantly different. To achieve an acceptable rice plant stand the theme should be good seed to soil contact with the correct seeding rate. The top risk factors are improper planting date, poor seedbed preparation, poor planter adjustment/maintenance, and poor surface drainage. If these risks are avoided, the probability of acceptable stand establishment will be greatly increased.

Independent of seeding rate, USDA standard grain quality grades are routinely achieved commercially using RiceTec hybrid rice seed if the common risk factors that reduce rice milling yield are avoided. The most common issue with rice grade and milling scores are 'fissuring,' 'rewetting,' or 'checking.' 'Rice fissuring' has been documented through the years as rice that has dried below a certain moisture level in the field then rewetted by rainfall, dew, or humidity forming micro-fissures within the kernel that reduce the kernel strength leading to breakage when the rice grain is milled using commercial friction methods. Questions have been raised for years around what affect if any the large amount of tillers hybrids produce has on milling. Results from side-by-side field tests indicate that the reduced seeding rates and corresponding increased tillering of RiceTec hybrids does not affect milling yields. Actions that minimize the risk of rice checking are timely harvest, proper combine adjustment, well managed storage, and drying after harvest.

In conclusion, individual location tests and in combined analysis, grain yields and milling yields from seeding rates of 988,400 to 1,482,600 seeds ha^{-1} were not significantly different. Even at plant populations below 11 plants m^{-2} RiceTec hybrid rice seed offers significant economic advantage over commercial varieties.

Seeding Date Effects on Grain Yield Stability

Golden, B.R., Walker, T.W., and Linscombe, S.D.

Seeding date is an important consideration for southern USA rice production. Studies conducted in Arkansas and Louisiana determined that relative yield potential was described by a quadratic function and that maximum yield potential could be achieved over a broad planting window in both states. Specifically, in Louisiana, planting could occur between 16 Feb - 28 March without experiencing significant yield loss. Similarly, in Arkansas, planting 29 March – 26 April resulted in maximum yield potential. Recently, the effects of climate change have been more pronounced. Record high day and nighttime temperatures have been experienced throughout the growing seasons in 2010 and 2011. Heat unit accumulation throughout the season has contributed to more rapid growth and development through the season. Furthermore, record heat during periods of anthesis and grain fill have contributed to panicle sterility due to biotic and abiotic factors. The objective of this research was to quantify planting date influence on relative rice grain yield potential and compare the optimum planting window in recent years to those reported a decade ago.

Experiments were conducted at the Rice Research Station in Crowley, LA, and at the Delta Research and Extension Center, in Stoneville, MS. Several modern, in-bred cultivars were planted in LA and MS in 2009 – 2011. In LA, planting dates ranged from mid-February to early July, whereas in MS, planting began in late March and concluded in early June. Planting dates were typically spaced approximately 2 wk apart. Small plot procedures were employed and managed according to state recommendations to ensure highly productive environments and minimize variability except for that of planting date. Replicated plots were harvested with plot combines and grain yield was adjusted to 12% moisture content. Rice grain yields from all cultivars (8-10) were averaged within rep. All yields were transformed to % relative rice grain yield (RY) by assigning the highest average yield for each rep within each planting date a value of 100%. Subsequently, other yields were divided by the highest yield and multiplied by 100. The experiment was analyzed as a randomized complete block with treatments defined by states (2) and years (3). Each year and state combination contained at minimum of five planting dates. Relative rice grain yields were initially regressed on planting date allowing for linear, quadratic, and intercept coefficients to depend on state and year. The most complex nonsignificant ($P > 0.05$) model terms were removed sequentially, and the model was refit until a satisfactory final model was obtained. Least-square means were used to compare the relative rice grain yields among states and years at various levels of planting date. Statistical analysis was conducted using PROC GLM in SAS version 9.2.

Planting date substantially impacted relative grain yields in Louisiana. Maximum (95% RY or greater) yields were achieved in LA over varying planting windows from 2009 – 2011. Rice planted before 21 Mar 2009 achieved 95% or greater RY; however, in 2010, only 93% RY was achieved when planted on 21 Mar. The same planting date in 2011 for LA resulted in 82% RY. In each of the years in LA, the highest RY were achieved at the earliest planting dates. Relative rice grain yield declined linearly over time for Louisiana experiments. The rate of loss per day was 0.4, 0.8, and 0.6%, respectively, for 2009, 2010, and 2011. In 2010 and 2011, RY were 29 and 37% when rice was planted June 9; however, in 2009, the same planting date resulted in 65% RY. Planting date affected RY in Mississippi also. In 2009, ≥ 95% RY could be achieved at any planting date prior to early June. In all three years, ≥ 95% RY was achieved when rice was planted by April 5. The planting window for optimum RY in 2010 and 2011 was shorter, relative to 2009. By late April, RY dropped to 81 and 87%, respectively, for 2010 and 2011. By June 9 for 2010 and 2011, RY were 60 and 76%. Similar to Louisiana, RY typically decreased in a linear manner in Mississippi. Relative yields decreased by 0.1, 0.5, and 0.3% per day for 2009, 2010, and 2011, respectively.

The planting window for achieving high RY has changed substantially compared with a decade ago. In LA, 95% RY could be achieved if planting occurred by April 9; however, these current data suggest that in two of the three studies, rice had to have been planted by March 20 to achieve ≥95% RY. In 2011, a March 20 planting resulted in only 82% RY in Louisiana. In Arkansas, the optimum planting date for 100% RY was April 12 a decade ago. In the similar latitude of Mississippi, except for 2009, rice had to be planted by April 5 to achieve 95% RY whereas 100% RY was achieved by planting March 24. Excessive heat at anthesis and grain fill certainly impacted rice grain yield in 2010 and 2011. These data also suggest in years with mild temperatures, such as was experienced in 2009, rice has a broad planting window. If climate change is indeed occurring, it is imperative to continue to investigate the optimum planting window and inform producers so that rice has the best chance for high grain yield potential. Furthermore, cultivar tolerance to heat is something that should be given its due attention in coming years.

Nitrogen Soil Testing for Rice Grown on Clayey Soils: Development of N-STAR Correlation and Fertilizer Calibration Curves

Fulford, A.M., Norman, R.J., Roberts, T.L., Slaton, N.A., Wilson, Jr., C.E., and Rogers, C.W.

The efficient management of nitrogen (N) fertilizer sources continues to be an elusive goal sought after by researchers in an attempt to develop sustainable recommendations for agricultural production. In order to improve fertilizer rate recommendations, an accurate, reliable, and reproducible method for the estimation of N derived from soil over the growing season must be identified. Soil organic-N (SON) associated with the soil organic matter (SOM) fraction is thought to be a more consistent indicator of plant available N because SON is subjected to fewer loss mechanisms prior to mineralization than is inorganic-N and therefore can provide an estimate of N fertility. Two chemical soil test methods that quantify plant available-N in an attempt to estimate SON mineralization are diffusion (DIF) and direct steam distillation (DSD) of alkaline hydrolyzable-N (AH-N). These soil test methods have been used to distinguish between fields of high or low native N fertility and have been developed for the identification of yield maximizing N fertilizer rates. The objective of this study was to evaluate the application of both DIF and DSD on clayey soils used for rice (*Oryza sativa*) production in Arkansas. The development of correlation and fertilizer calibration curves will be the basis for the assessment of either soil test method to accurately reflect the concentration of plant available N across an array of field conditions.

Grain yield and growth of rice in response to incremental N fertilization were evaluated using 11 site-years of small-plot field trials on clayey soils from across the state of Arkansas. At each location, urea (460 g N kg^{-1})-N fertilizer was broadcast applied using a two-way split application at the 4- to 5-leaf growth stage of rice and total N fertilizer rates of 0, 101, 135, 168, 202, and 236 kg N ha^{-1} were arranged as a randomized complete block with four blocks. Soil samples were removed in four successive 15-cm increments to a 60-cm depth from each 0 kg N ha^{-1} plot. This sampling protocol allowed individual sampling increments (i.e., 0–15, 15–30, 30–45, and 45–60 cm), as well as depth averaged sampling increments (i.e., 0–30, 0–45, and 0–60 cm), to be evaluated for the development of correlation and fertilizer calibration curves. The quantification of AH-N was determined using either DIF or DSD soil test methods. The DIF or DSD soil test values were correlated to percent relative grain yield (%RGY) and calibrated using the fertilizer rate required to achieve 95% RGY. The overall significance of the correlation and fertilizer calibration curve linear models were determined using regression analysis with alpha=0.05.

Percent relative grain yield was successfully and significantly correlated to either DIF or DSD across all depth averaged soil sample increments. However, the strength of the correlation curve (R^2 = 0.84) indicated that the greatest predictive ability was not obtained until soil was sampled to a 30-cm depth and AH-N quantified using DIF. The strongest correlation (R^2 = 0.70) obtained for DSD analysis was not obtained until soil was sampled to a 45-cm depth. These results indicate that it is necessary to sample deeper than the surface 0 to 15 cm in order to accurately represent the quantity of AH-N available for rice uptake on clayey soils. The fertilizer calibration curve developed using DIF (R^2 = 0.84; $p < 0.0001$) indicated that the 0- to 30-cm soil sample depth can adequately determine the N rate needed to achieve 95% RGY. The DSD fertilizer calibration curve (R^2 = 0.71; $p = 0.0012$) indicated that the 0 to 45 cm depth provided the greatest accuracy for predicting the N rate needed to achieve 95% RGY. These results indicate that either DIF or DSD is promising N soil test methods that can be applied to clayey soils in order to accurately identify yield maximizing N fertilizer rates based on native soil N fertility.

Farm Scale Validation of N-ST*R in Louisiana: Year 1 Results

Harrell, D.L., Gauthier, S.J., Courville, B.A., Fontenot, K.A., Roberts, T.L., and Norman, R.J.

Current nitrogen (N) fertilizer recommendations in commercial drill-seeded, delayed-flood rice production have historically been determined by multi-location variety by N trials established by research scientists in each of the mid-southern USA, rice-producing states. Recommendations for N fertilizer rates derived from these trials are published in production handbooks on a state-by-state basis. Published recommendations are categorized by rice variety and are generally altered slightly by producers based on soil texture, previous crop, and estimated yield potential. This current system generalizes N recommendations and does not take into account the variability that exists between different soils to provide N during the growing season. Recently, a N soil test has been calibrated to provide N fertilizer recommendations for silt loam soils in drill-seeded, delayed-flood rice production systems typical of the mid-southern USA rice-producing region. The N soil test for rice, coined N-ST*R, is a direct steam distillation procedure that provides an estimate of alkaline hydrolyzable-N that has been previously shown to have a high correlation with mineralizable-N from incubation trials. The soil test has shown great promise in small plot trials but has not been evaluated in a large commercial size field basis in Louisiana. The objective of the current study was to validate the ability of the N-ST*R silt loam calibration to provide accurate N rate recommendations on a large-scale basis from soils testing high in N-ST*R extractable N (thus providing low N recommendations) and comparing the grain yields with the producers' typical N fertilization practices.

Four validation trials were initiated in Louisiana on commercial rice fields in Vermilion, Acadia, and Evangeline parishes. Fertilizer N recommendations were determined by the 95 and 100% relative grain yield (RGY) N-ST*R calibrations and were compared with the individual farmers' practice (FP). Fertilizer N source varied by location; however, all fields were flooded within 2 days of application, therefore minimizing volatilization N losses. Four measured subsamples were taken within each treatment block using a commercial combine and were individually weighed with a weigh wagon. A grain sample was then taken from the weigh wagon and analyzed for moisture with a portable moisture meter.

Mean extractable N-ST*R N at the first Vermilion Parish (Zaunbrecher) location was 140 mg kg^{-1} and resulted in N fertilizer recommendations of 50 and 90 kg N ha^{-1} using the 95 and 100% RGY calibration curve, respectively. Mean extractable N at the second Vermilion Parish (Hardee) location was 130 mg kg^{-1} and resulted in N fertilizer recommendations of 73 and 112 kg N ha^{-1} using the 95 and 100% RGY calibration curve, respectively. The Acadia Parish location had a mean N-ST*R value of 150 mg kg^{-1} with resulting fertilizer N recommendations of 28 and 67 kg N ha^{-1} for the 95 and 100% RGY calibrations, respectively. The N-ST*R extractable N at the Evangeline Parish location was 170 kg ha^{-1} with a 95 and 100% RGY recommendation of 0 and 39 N kg ha^{-1}, respectively.

The 100% RGY N-ST*R recommendation achieved yields equivalent or greater than the FP rates used at each of the tested locations. The 95% RGY N-ST*R recommendation was equivalent or better than the FP at three of the four tested locations. The only failure of 95% RGY calibration occurred when no N fertilizer was recommended. The FP rate at the Acadia Parish location (202 kg ha^{-1}) reduced yields by approximately 544 kg ha^{-1} compared with the 100% RGY rate (67 kg N ha^{-1}) even though one-third less N was used. This reduction was due in part to the excessive sheath blight disease pressure that was visually evident in the FP treatment and not in the 100% RGY treatment. Two more years of farm-scale validation trials on silt loam rice soils are planned in Louisiana. Consistent acceptable results from the validation trials may lead to the future adoption of N-ST*R in Louisiana as a best management practice for commercial rice production on silt loam soils.

Effects of Nitrogen and Variety on Rice Production in Texas

Dou, F. and Tarpley, L.

Cultivar choice and associated nitrogen (N) management are critical to rice production. This study focused on the effect of cultivar [hybrid 'Clearfield XL745' (RiceTec, Inc., Alvin, TX) vs. inbred 'Presidio'] and N application on yields and milling quality of the rice main and ratoon crops planted in clay or sandy loam soil in south Texas. A factorial experiment designed with four replications was used for this study. On clay soil, increasing N application rate did not increase main crop (MC) yield of Clearfield XL745, although the highest grain yield was with the greatest N application rate (235 kg N ha^{-1}). For Presidio, however, MC yield responded to increased N application. A similar pattern was also observed on the sandy loam soil. The effect of N splitting on MC yield was only beneficial with Clearfield XL745 on the clay soil. High N application caused severe lodging for Clearfield XL745 on the sandy loam soil. Different N treatments to the main crop had carryover effects on ratoon crop yield. For total crop yield, Clearfield XL745 with 235 kg N ha^{-1} on clay soil had the highest yield (19,030 kg ha^{-1}). The milling quality (whole grain percentage) of MC of Clearfield XL745 was affected by N rate. The whole grain percentage of MC of Clearfield XL745 on sandy soil was 54% and 30% for 135 kg N ha^{-1} and 202 kg N ha^{-1}, respectively. However, a higher milling quality of Clearfield XL745 was associated with the higher N rate on clay soil. For Presidio, the highest whole grain percentages were obtained with moderate N application on clay soil but there was no N effect on milling quality in the sandy loam soil study. The highest whole grain percentage was for the MC of Presidio on clay soil. Our study indicated that appropriate N management and cultivar selection are critical for rice production. Based on results to date, for clay soil, 202 kg N ha^{-1} was recommended for Clearfield XL745 for higher yield and milling quality.

Nitrogen Uptake Efficiency of a Hybrid versus a Pure Line Rice Cultivar

Norman, R.J., Roberts, T.L., Fulford, A.M., Slaton, N.A., Wilson, Jr., C.E,
Frizzell, D.L., Williamson, S.M., and Branson, J.D.

Hybrid rice (*Oryza sativa* L.) hectarage in the United States southern Rice Belt has increased substantially in the last decade. The higher yields obtained with hybrid rice compared with a pure line rice cultivar is the reason for this increase in hectarage. Nitrogen (N) fertilizer rate recommendations for hybrid rice are usually similar to slightly less compared with pure line rice to maximize yield, but the hybrids typically have about a 15-25% greater yield potential compared with pure line rice varieties. This would insinuate that the hybrid rice varieties have a greater N uptake efficiency compared with pure line rice varieties. Consequently, a 2-year study utilizing the isotopic tracer N-15 was conducted to evaluate and compare the N fertilizer uptake efficiency and the native soil N uptake of the RiceTec hybrid CLXL745 and the pure line rice cultivar Francis.

Four microplot field studies were established during the spring of 2009 and 2010 at the Lake Hogue Research Farm (LHRF) on a Hillemann silt loam and at the Pine Tree Research Station (PTRS) on a Calhoun silt loam. The previous crop was soybean (*Glycine max* (L.) Merr.) at both locations across both years. The rice cultivars chosen to evaluate and compare were the pure line rice cultivar Francis and the RiceTec hybrid CLXL745. Plots were nine rows wide (18 cm row spacing) by 2.5 m in length. In each of the N response studies, urea was applied by hand in a single preflood application when the rice reached the 5-leaf stage; immediately prior to flooding (i.e., preflood) onto a dry soil surface. The following fertilizer N rates were labeled with 2 atom % ^{15}N and applied at each location: 0, 34, 68, 101, 134, and 168 kg N ha^{-1}, in a randomized complete block design with four replications. Following preflood N application, a 10-cm deep flood was established within 2 days and maintained until maturity. Above-ground biomass was harvested at 50% heading from the two center rows of each plot. All plant material was dried at 60˚C to a constant weight, weighed, and ground to pass through a 1 mm sieve, and a subsample was taken for N analysis. Total N and atom % ^{15}N were determined by the UC Davis Stable Isotope Facility (Davis, CA), using an elemental analyzer interfaced to a continuous flow isotope ratio mass spectrometer (Europa, Sercon, Ltd., Cheshire, UK). The experimental design was a factorial arrangement with cultivar (2) and preflood N rate (6) arranged in a randomized complete block with four replications. Statistical analysis was performed on total N uptake, soil N uptake, and fertilizer N use efficiency (FNUE) using JMP 9.0. Mean separations were determined using Fisher's protected least significant difference.

The location x cultivar x N rate interaction for N uptake by rice was not significant (P=0.109), but there were two-way interactions between N rate x location (P=0.0004) and cultivar x N rate (P=0.002). Total N uptake by the rice was greater at LHRF compared with the PTRS when 0 and 34 kg N ha^{-1} were applied, indicating the native soil N was greater at LHRF. However, when the N rate was increased to 67 kg N ha^{-1} or higher, the total N uptake by the rice was similar for both locations. No three-way interaction (P=0.653) was present for fertilizer N uptake efficiency (FNUE), however, there were two-way interactions between N rate x location (P=0.0001) and cultivar x location (P=0.034). The FNUE of the rice ranged from 69.7 to 87.8% and generally increased as N rate increased at both locations. Fertilizer N uptake efficiency was greater at the LHRF compared with at the PTRS at N rates of 34, 67, and 101 kg N ha^{-1} and no different at N rates of 134 and 168 kg N ha^{-1}. The hybrid CLXL745 had a greater FNUE compared with the pure line cultivar Francis at both locations. Francis had a greater FNUE at LHRF than at the PTRS while the hybrid CLXL745 had a similar FNUE at both locations. For uptake of soil N, there existed only a two-way interaction between N rate x location (P=0.003) and a main effect of cultivar (P=0.001). Uptake of soil N by the rice was not significantly different between locations at all N rates except when no N or 34 kg N ha^{-1} were applied. When averaged over location and N rate, the hybrid CLXL745 had a soil N uptake of 60.5 kg N ha^{-1}, which was significantly higher than the soil N uptake of 51.7 kg N ha^{-1} measured for Francis.

Evaluation of N Source on Mitigating Nitrification/Denitrification Loss in Rice

Fitts, P.W., Walker, T.W., Corbin, J.L., Krutz, L.J., Golden, B.R., and Varco, J.J.

Nitrogen application and its appropriate management are critical to achieve economically optimum grain yields. The dynamic nature of N and the flooded soil environment pose challenges to N management. Ideally, a N fertilizer could be applied in a window from planting to preflood with the N being converted to or remain in the ammonium form until after a permanent flood is established. However, ammonium is subject to nitrification and nitrate is not stable under anaerobic conditions. Therefore, the common practice has been to apply an ammoniacal form of N and establish a flood as soon as possible, e.g., <7 days. Depending on the field size and irrigation capacity, some fields may go unflooded for >10 days after N application. Minimal studies have been performed examining nitrification and subsequent denitrification loss of applied N in delayed-flood rice. Therefore, it is not known to what extent agronomic N use efficiency can be affected when nitrification/denitrification occurs. Furthermore, few studies have examined the ability of commercially available products to stabilize N in the ammonium form. To this end, laboratory incubations were conducted to measure the nitrification potential of several soils commonly used for rice production. Preliminary findings led to further investigation in the field where the efficacy of the nitrification inhibitor (NI) dicyandiamide (DCD), and a sulfur-polymer-coated urea product were evaluated.

A laboratory incubation study was conducted in 2010 and 2011. A completely randomized design was used with 1 fertilizer source (urea), 7 soils, and 6 sample timings. A non-fertilized control was included. All treatments were conducted in triplicate. The soils included 2 Sharkey clays (Chromic Epiaquerts), 1 Tunica clay (Vertic Epiaquert), 1 Dundee silty clay loam (Typic Endoaqualf), 1 Dundee silt loam (Typic Endoaqualf), 1 Forestdale silt loam (Typic Endoaqualf), and 1 Crowley silt loam (Typic Albaqualf). One hundred g of soil (dry weight basis) were added to polypropylene containers and brought to 80% field capacity moisture and placed in an incubation chamber for 14 d. At the conclusion of 14 d, two urea granules were applied below the soil surface and placed in the incubation chamber at 25°C. The soils were extracted at 2, 5, 9, 15, 20, and 26 d after fertilizer application with 500 mL of 1.0 M KCl. Extracts were analyzed on an auto-analyzer to determine NH_4^+ and NO_3^- contents. Recovery was based on % of N applied. Non-linear regression was used to determine the half-life of ammonium for the soils.

A field study was conducted on a Sharkey clay soil in 2011 at the Delta Research and Extension Center in Stoneville, MS. The study evaluated effectiveness of the nitrification inhibitor DCD and a 43% N sulfur-polymer-coated urea product. Fertilizer was applied via urea and the coated N product at two rates (84 and 168 kg N ha^{-1}), and DCD was applied at 5, 10, and 15% N basis. Both products were applied 14 days before permanent flood establishment (dbf), and the DCD was delivered with urea liquor. The controls included N applied at the same rates without DCD at 14 and 1 dbf. An incorporating rainfall event occurred within 1 d after the 14 d application, thus minimizing any potential for volatilization loss. Plots were harvested with a small plot combine and yields adjusted to 12% moisture content. Grain yield data were subjected to analysis of variance and means separated with Fisher's LSD at $\alpha = 0.05$.

Laboratory results indicated that the rate of nitrification potential was greatest in the Sharkey clay soil at Stoneville, MS. In this soil, 37, 79, and 93% of the applied N was recovered as nitrate 2, 9 and 15 d after application, respectively. In the field study, DCD applied at a minimum of 12.5 kg ha^{-1} resulted in grain yields being 12% greater than the urea alone applied 14 dbf. Increasing the DCD rate to 19 kg ha^{-1} resulted in a 16% yield advantage. However, all DCD applications resulted in yields less than the standard 1 dbf application. The sulfur-polymer-coated urea proved to be the best at stabilizing urea from nitrification loss; however, a 5% yield loss still occurred relative to the 1 dbf application at both 84 and 168 kg N ha^{-1}. Research is on-going to address nitrification/ denitrification loss in rice production.

Evaluation of Preflood N Strategies to Maximize Fertilizer Use Efficiency

Walker, T.W., Harrell, D.L., Rogers, C.W., Dillon, K.A., Krutz, L.J., Roberts, T.L., and Norman, R.J.

Nitrogen (N) is typically the most expensive fertilizer input in commercial rice production. Nitrogen fertilizer applications in midsouthern USA drill-seeded, delayed-flood rice production are applied most commonly using 2-split applications with the first two-thirds of fertilizer N being applied just prior to permanent flood establishment and the remaining one-third at midseason. Preflood N fertilizer applications are surface broadcasted and remain on the soil surface until a flood can be established. In many fields, it is common to take up to 10 days or more to establish the initial flood. During that time, urea is susceptible to volatilization loss of N as ammonia. Soil and soil/climatic environments can affect the amount of N that is potentially lost. The amount of products that have entered the market that claim to "stabilize" N has escalated in recent years. Often times, the active ingredients have not been proven in the literature to affect the loss mechanism, i.e., urease inhibition. Therefore, the objective of this research is to evaluate various N "stabilizer" products to determine their effectiveness in minimizing ammonia volatilization loss in midsouthern USA rice production.

Aerobic laboratory incubation studies were conducted in Arkansas and Mississippi to quantify ammonia volatilization of urea with and without N "stabilizer" products. Products included were Agrotain®, Arborite®, Nutrisphere-N®, N-ZONE® (also marketed as STAY-N® and N-STAY®), N-FIXX®, and Upgrade®. The rates were based on labeled recommendations; however, most product rates were in the range of 4.7 to 9.4 L ton^{-1} of urea. Studies in Arkansas were conducted with Dewitt silt loam (Typic Albaqualfs) soils, whereas studies in Mississippi were conducted with Sharkey clay (Chromic Epiaquerts) and Forestdale silt loam (Typic Endoaqualfs) soils. Prior to incubation the volumetric water content of the dried ground, topsoil was adjusted to 20% v/v and 50 g of soil were added to each diffusion chamber. Replicated fertilizer treatments were added to the surface of the soil within the diffusion chambers to equal a rate of 168 kg N ha^{-1} on an area basis. Petri dishes were placed within the diffusion chamber lids and 5 mL of 4% boric acid indicator solution was added. Immediately following fertilizer application, the modified lids containing the petri dishes with boric acid were used to seal the diffusion chambers. Samples were incubated at 25°C within the laboratory. Lids were removed and the petri dishes containing boric acid were replaced with new petri dishes containing boric acid and resealed within 30 seconds on 3- to 4-d increments for a total of 15 to 21 d after application. Following removal from the diffusion chambers, 5 mL of deionized water was added to each petri dish and the sample was titrated to a predetermined endpoint using an autotitrator in Arkansas and to a color change in Mississippi. The volume of acid required to titrate the sample was used to determine the mass of N that volatilized during the sample period. Nitrogen loss was calculated in a cumulative manner and the data were presented graphically over time.

Small-plot field studies were conducted from 2009-2011 at the Rice Research Station in Crowley, LA, and at the Delta Research and Extension Center in Stoneville, MS. Soils were Crowley silt loam (Typic Albaqualfs) and Sharkey clay, respectively. Urea and N "stabilizer" products were applied in three or four application timings prior to permanent flood establishment. Specific timings were 10, 7, 5 or 4, and 1 day prior to flood. The N 'stabilizer' products that were tested include Agrotain, Arborite, and N-ZONE. Products were coated onto urea at labeled rates and applied in a range of 67 to 168 kg N ha^{-1}, depending on the study. Additionally, an in-field, static chamber method was used to estimate ammonia volatilization loss. Ammonia volatilization loss and grain yields were subjected to analysis of variance and means were separated using Fisher's LSD at $\alpha = 0.05$.

Laboratory results indicated that Agrotain, Arborite, and N-FIXX were highly effective in minimizing volatilization loss. These products have N-(n-butyl) thiophosphoric triamide (NBPT) as the active ingredient, which is a proven urease inhibitor. NutriSphere-N, N-ZONE (N-STAY, STAY-N), and Upgrade did not minimize volatilization loss compared with urea alone. Static chamber results were similar in that Arborite and Agrotain were effective in minimizing volatilization loss whereas N-ZONE (N-STAY, STAY-N) were not. Clay soils in Mississippi did not lose more than 10% of N applied as urea to volatilization in laboratory or field studies; however, in laboratory studies in Arkansas and Mississippi for silt loam soils and in field studies in Louisiana, urea, as well as N 'stabilizers' that were not effective, routinely lost 25% or more to ammonia volatilization. In Louisiana, grain yields were reduced by as much as 15% when loss occurred. It is imperative that products be evaluated in a fair and unbiased manner to provide the industry information that is pertinent to N stabilization.

Nitrogen Fertility Management for Mitigating Greenhouse Gas Emissions in California Drill-Seeded Rice Systems

Adviento-Borbe, M.A.A., Pittelkow, C., Abrenilla, C., Hill, J., Six, J., Linquist, B., and Van Kessel, C.

Reducing greenhouse gas (GHG) emissions per ton of grain yield (i.e., yield-scaled Global Warming Potential, GWP) can address both global environmental issues and food security. Fertilizer N application in excess of plant demand will fuel high yield-scaled GWP. Flooding and frequent draining of rice fields lead to conditions favorable for production of GHG: methane (CH_4) and nitrous oxide (N_2O). Under a drained condition, the dominant GHG emitted is N_2O via microbial nitrification while under flooded condition, CH_4, another potent GHG, is largely produced through the process of methanogenesis. To determine the effect of N rates to GHG emissions from rice fields with frequent dry periods, a field study was conducted with different N fertilizer rates.

The GHG experiment was conducted in a grower's field in North Sacramento Valley, CA, in 2010 and 2011. Six N fertilizer N rates ranging from 0 to 200 kg N ha^{-1} were used and arranged in a randomized complete block design with three replicates. Seeds ('Koshihikari') were drilled into the soil at 84 kg seed ha^{-1} (75 lb $acre^{-1}$). The field was flooded for several days and then drained to provide an aerobic environment for seedling emergence. Floodwater was maintained at about 15 cm and a month before harvest the field was drained. After harvest, rice residues were chopped and incorporated in the soil for the winter period. The field remained dry for the fallow period. Greenhouse gas emissions were quantified as rice growth progressed, for each N rate within each N treatment plot, using a vented cylindrical surface chamber, with a 14.7 cm diameter and varying chamber height (15.2-30.5 cm). To determine peak gas fluxes, daily to weekly gas samplings were conducted on periods of relevant emissions, such as flooding, N application, or field drainage, after which samples were obtained once or twice a week throughout the growing season. Gas concentrations were analytically determined using a gas chromatograph, and gas fluxes were calculated according to the change in gas concentration inside the chamber over a 1-hour sampling period. Other ancillary plant variables related to GHG emissions were measured, such as rice grain yields at 14% moisture content.

Daily gas emissions in all N treatments ranged from 0 to 88 g N_2O-N ha^{-1} d^{-1} and -56 to 12,646 g CH_4-C ha^{-1} d^{-1}. Methane emissions increased after about a month of flooding, remained high until around flowering stage, and declined after heading stage. This seasonal trend was observed in all N treatments for both years. Nitrous oxide emissions varied in all N rates and were highly associated with drained events and amount of N applied. For both years, large N_2O emissions were measured during the dry period and at N rates >100 kg N ha^{-1}. After flooding, daily N_2O emissions were low and remained low during the growing period before final dry down prior to harvest. Total CH_4 emissions were similar in all N rate treatments, suggesting no fertilizer N effect on methane production. In contrast, seasonal N_2O emissions were significantly higher at N rates >100 kg N ha^{-1}. Global warming potential in this field was largely affected by both CH_4 and N_2O emissions. In 2010, N_2O accounted for about 45% of total GWP at high N rates. Yield-scaled GWP varied among N rates for both years and showed no clear trend to increasing fertilizer N rates due to combination of high GHG emissions and low yields. However, estimated yield-scaled GWP was reduced on average by 34% in N rate at 100 kg ha^{-1} relative to higher N rates. This N rate is the amount of fertilizer N applied by many rice growers in the state and the recommended N rate for the Koshihikari variety. Our results suggest that GHG can be low in the drill-seeded system if fertilizer N rates do not exceed crop demand and water resources are at optimum.

Methane Emissions from Rice Following Soybean on a Silt Loam Soil in Arkansas

Rogers, C.W., Brye, K.R., Norman, R.J., Roberts, T.L., Gasnier, T., and Fulford, A.M.

Methane (CH_4) is a potent greenhouse gas with a global warming potential approximately 23 times greater than carbon dioxide (CO_2). Rice (*Oryza sativa* L.) production is unique among agricultural crops in its susceptibility to CH_4 emissions. As a semi-aquatic plant, rice is produced under flooded conditions for the majority of the time it is actively growing. Flooding results in soil chemical changes, including the rapid depletion of oxygen in the soil and the sequential reduction of molecules utilized as terminal electron acceptors. Methane emissions in soils occur when the soil is highly anaerobic and highly reduced. Data concerning flux estimates from Arkansas, the state with the largest rice acreage, is currently unavailable. Thus, a study was initiated to investigate CH_4 emissions from Arkansas production practices and a soil that is typical of a large portion of the rice produced in the state.

Research was conducted at the Rice Research and Extension Center near Stuttgart, AR, on a DeWitt silt loam (fine, smectitic, thermic Typic Albaqualf). Rice was planted in small plots in a rice-soybean (*Glycine max* L.) rotation. The cultivar 'Wells' was planted in the study due to its relatively high yield potential and widespread usage in Arkansas. Rice management was conducted based on recommended guidelines. Rice was flooded to a 10-depth at the 4- to 5-leaf stage and remained flooded until drainage for harvest. Fertilized plots received nitrogen (N) in a split application of 118 kg N ha^{-1} preflood followed by a 50 kg N ha^{-1} application at midseason.

Chamber-based enclosures constructed of polyvinyl chloride (PVC) with a diameter of approximately 15 cm and heights of 40, 60, and 100 cm were used to measure CH_4 fluxes from field plots. Collars made of PVC were installed to a depth of 10-cm 1 week prior to initial sampling and remained in place throughout the season. Collars were established in-row and between-row in plots containing rice and in open-water in both fertilized and unfertilized plots. Permanent boardwalks were established to mitigate the possibility of foot-traffic artificially influencing emissions. Chambers were covered with metal reflective tape to minimize temperature changes and a small fan was used to mix the chamber headspace after capping. Four samples were collected from each sampling event at 0, 15, 20, and 45 min after sealing. Samples were collected and analyzed by gas chromatography weekly. Statistical analysis was performed using an analysis of variance in SAS 9.2 with means separated using Fisher's protected least significant difference.

Preliminary data indicate that appreciable CH_4 emissions began around 20 days after flooding (DAF), and peaked 41 DAF for in-row treatments with maximum fluxes of 28 and 27 mg CH_4-C m^2 hr^{-1} for fertilized and unfertilized in-row chambers, respectively. Between-row chambers reached their maximum between 60 and 70 DAF with fertilized and unfertilized treatment fluxes peaking at 14 and 11 mg CH_4-C m^2 hr^{-1}, respectively. Fluxes from all treatments decreased approximately 60 DAF until field drainage at 85 DAF. Of the 12 sampling dates before field drainage, 10 of the 12 had significant differences between chamber locations (i.e. in-row v. between-row). Emissions from Arkansas rice production confirm the influence of the rice plant acting as a conduit for CH_4 production and indicate that between-row and open-water areas produce less, but measurable amounts of CH_4 during the growing season.

Greenhouse Gas Emissions and Yield-Scaled Global Warming Potential of Wet-Seeded Rice in California

Pittelkow, C.M., Adviento-Borbe, M.A.A., Six, J., Hill, J.E., Van Kessel, C., and Linquist, B.A.

Management practices that reduce greenhouse gas (GHG) emissions while maintaining yields are an important option for reducing the global warming potential (GWP) of agriculture. In flooded rice systems, nitrous oxide (N_2O) and methane (CH_4) are important GHGs emitted from the soil. Nitrogen (N) fertilizer is an important factor regulating N_2O emissions, thus proper N management is both critical for optimizing yields and reducing environmental impacts. To identify N management practices that minimize GHG emissions per unit of grain yield produced (i.e. yield-scaled GWP), an on-farm experiment was conducted for two years to quantify N_2O and CH_4 emissions during the rice growing season and winter fallow periods. This work was carried out to test the hypothesis that yield-scaled GHG emissions are minimized when optimal yields are achieved and fertilizer N rates match crop N demand.

The experiment was performed on a clay soil (9% sand, 34% silt, and 57% clay) with a pH of 6.0 and organic C and total N contents of 1.7 and 0.14%, respectively. The N fertilizer trial was arranged in a randomized complete block design with three replications. Fertilizer N in the form of aqua ammonia was applied at five N rates ranging from 0 to 260 kg N ha^{-1}. The field was seeded with a medium-grain Calrose variety at 224 kg ha^{-1} into a permanent flood. Water levels were maintained around 15 cm during the growing season and the field was drained 1 month prior to harvest. Before the field was re-flooded for the winter period, straw residue for corresponding N rates was incorporated to a depth of 15 cm. The GHG emissions for each N rate were determined daily during specific management events (e.g. N application and field drainage periods), and weekly otherwise using a vented, closed chamber technique combined with a gas chromatograph for analysis of N_2O and CH_4 concentrations. Annual GHG emissions and yield-scaled GWP (GWP = cumulative N_2O + CH_4) were assessed with respect to N fertilizer rate, agronomic productivity, and N recovery efficiencies. Data for the second year of this study are currently being processed and will be included in the presentation.

Results indicate that during the growing season, CH_4 emissions were similar across N rates and ranged from 0 to approximately 3000 g CH_4-C ha^{-1} day^{-1}, with the highest fluxes occurring midseason and during the drainage period before harvest. Emissions of CH_4 during the winter were relatively small and across N rates the fallow period accounted for approximately 20% of annual emissions. Low N_2O emissions occurred regardless of N rate when a permanent flood was maintained, with daily emissions remaining < 3.5 g N_2O-N ha^{-1} day^{-1}. On the other hand, during drainage periods N_2O emissions increased, especially for high N rates. Emissions of N_2O during winter represented roughly 50% of annual emissions. On an annual basis, N_2O emissions were significantly higher when 260 kg N ha^{-1} were applied compared with other N rates.

Estimated annual GWP was close to 3,000 kg CO_2 eq ha^{-1} across treatments receiving N fertilizer. From an agronomic standpoint, grain yield increases were not observed at N application rates above 140 kg N ha^{-1}. Therefore, values for yield-scaled GWP decreased from approximately 310 to 220 kg CO_2 eq Mg^{-1} as N rate increased from 0-260 kg N ha^{-1}, although significant differences were not observed. Furthermore, N uptake data indicate that yield-scaled GWP decreased as N recovery efficiency increased. These results support our hypothesis that optimal yields can be obtained at relatively constant yield-scaled GWP values when current N management recommendations are followed and N fertilizer inputs are closely matched with crop N demand.

Long-Term Rice Rotation, Tillage, and Fertility Effects on Near-Surface Chemical Properties in a Silt Loam Soil

Motschenbacher, J.M., Brye, K.R., Anders, M.M., and Gbur, E.E.

A majority of the rice (*Oryza sativa* L.) produced in the United States is produced on alluvial soils in the Mississippi River Valley and adjacent areas in the lower coastal plain of Louisiana and Texas or in the Sacramento River Valley of California. Of the roughly 1.1 million ha of rice planted and 8.5 million Mg of rice grain produced in the United States annually, over 44% of the total rice area (484,000 ha) and over 42% of the total grain production (3.6 million Mg) occurs in the Mississippi River Delta region of eastern Arkansas. Rice is considered the number one cash-crop in Arkansas, so ensuring the sustainability of rice production systems is vital to protecting the economic livelihood of the state. One of the key factors to accomplishing viable food-production systems is through the continual management and maintenance of proper soil fertility. Therefore, a study was conducted to evaluate the long-term effects of rice-based crop rotations [with corn (*Zea mays* L.), soybean (*Glycine max* L.), and winter wheat (*Triticum aestivum* L.)], tillage [conventional and no-tillage (NT)], and fertility (optimal and sub-optimal) treatments after 11 years (1999-2010) of consistent management on chemical properties (Mehlich-3 extractable nutrients, pH, and electrical conductivity) in the top 10 cm of a silt loam soil. The field study was conducted at the Rice Research and Extension Center near Stuttgart, Arkansas. Results showed that soil electrical conductivity increased drastically over time and extractable phosphorous, potassium, manganese, and iron concentrations generally increased for all tillage-fertility-rotation combinations. However, extractable sulfur primarily decreased for all treatment combinations, and the NT rotations with winter wheat showed a decrease in copper concentrations. The organic matter, total N, and total carbon concentrations generally increased under NT, particularly in rotations with winter wheat. Understanding the decadal effects of rice-based crop rotations and the associated management practices will give insight to the longer-term sustainability of these systems so that they remain highly productive without detrimental effects to the environment and the soil resource.

The Right Way to Grow Rice: 4R Nutrient Stewardship

Phillips, S.B. and Harrell, D.L.

Agricultural production strategies that best combine the expectations of various stakeholder groups can be called "best management practices." The International Plant Nutrition Institute works in many countries to develop and disseminate fertilizer best management practices (FBMPs). Fertilizer use BMPs can be aptly described as the application of "4R Nutrient Stewardship." The 4R concept is simple—apply the right source of nutrient, at the right rate, at the right time, and in the right place—but the implementation is knowledge-intensive and site-specific. These four "rights" are all necessary for sustainable management of plant nutrition: management that increases the sustainability of the plant system to which it is applied. Sustainability consists of economic, social, and environmental dimensions and all three dimensions need to be included in the assessment of any nutrient management practice to determine whether or not it is "right."

The four "rights" are interconnected. They must work in synchrony with each other and with the surrounding environment of plant, soil, climate, and management. For most systems in which plants are managed to provide food, feed, fiber, fuel, and aesthetic benefits, soils are the medium in which the plants grow. Soil fertility is a basic need for plants to grow productively. Although fertility is vital to productivity, not all fertile soils are productive soils. Poor drainage, drought, insects, diseases, and other factors can limit productivity, even when fertility is adequate. To fully understand soil fertility, we must know other factors which support…or limit…productivity.

This presentation will provide a foundation for the implementation of improved nutrient management for rice based on the principles of the 4Rs. The 4Rs are not a recipe or a guidebook…4R nutrient management is site specific. Established scientific principles guide the development of practices determining right source, rate, time, and place. The principles are the same globally, but how they are put into practice will be dictated by the goals of the farmer, available resources, the cropping system, soil conditions, climatic conditions, and other factors that influence any management decision.

Agronomic Potential of Southern Rice Cultivars under Organic Management

McClung, A.M., Zhou, X-G., and Dou, F.

Organic rice production is expanding in the United States as a result of increasing market demand. Although acreage of conventional produced rice has declined in Texas over the last 20 years, organic rice production has increased to almost 10% of the Texas rice acreage. Organic growers in Texas have relied upon using land that has been fallow for a number of years and can be certified as organic. However, because there is little information available regarding organic rice production methods, yields are highly erratic. In addition, even though there are a wide variety of organic fertilizer amendments available to farmers, there is little known about their efficacy in a rice production system and their economic impact on the crop. Moreover, the organic rice market utilizes not only conventional market classes of rice but also specialty rice cultivars suited for the aromatic, flour, and pet food markets. We conducted a set of studies to determine the impact of organic fertilizer amendments on rice yield, potential yield, and to identify rice cultivars that are best suited for organic production. For the variety study, 16 cultivars were evaluated over 3 years in a replicated yield trial. Cultivars were evaluated under both conventional management and organic management at Beaumont, TX. For over 2 years, the variety Presidio was evaluated using four rates of seven organic fertilizer products. Yield, agronomic traits, and milling data were collected in all studies. Results will be presented that will demonstrate the best performing rice cultivar under organic management and selection of the best combination of organic fertilizer amendment and rate that achieves the highest yield potential. In addition, the impact of other production factors, such as cover crops, seeding rate, and seeding method on yield, will be discussed.

Canopy Air Temperatures in a Texas Rice Field

Tarpley, L., Mohammed, A.R., Holgate, L.C., Yoshimoto, M., Fukuoka, M., and Hasegawa, T.

Rice crop yield is reduced when periods of excessive heat coincide with reproductive development. Such periods occur in the Gulf Coast rice-growing region and elsewhere in the southern United States; these are predicted to increase in frequency as part of global climate change. The temperature conditions of primary interest are those that the panicles are subjected to at critical stages of development; however, most predictions of crop response to temperature are based on weather-station data, which typically differ from in-field conditions due to canopy influences on the microclimate.

Under the leadership of the National Institute of Agro-Environmental Sciences of Japan, an international network was established in 2010 to monitor the canopy environment of rice paddies throughout sites in Asia using common measurement practices. In addition, a site at Beaumont, TX, USA, was included. The canopy temperatures and relative humidity of all sites were monitored during reproductive development using a stand-alone, force-ventilated measurement system developed for this purpose.

Although the above-canopy daily maximum air temperature did not differ greatly among sites, the relative humidity and daily minimum air temperature varied greatly. In areas of low relative humidity, the temperature in the canopy was typically lower than that above the canopy. These results were not unexpected because relative humidity has a strong influence on evapotranspiration cooling. At two of the sites, China and Texas, the relative humidity above the canopy exceeded 75%, and the air temperature in the canopy was close to (China) or exceeded (Texas) the above-canopy temperature. Looking across all the sites, the magnitude of the temperature difference above and in the canopy did not always coincide with the relative humidity difference. Under conditions of high canopy relative humidity, along with high irradiance and/or low wind speed, the panicle temperature in the canopy could possibly exceed the air temperature inside the canopy. Across the sites, the daily mean air temperature at the nearby weather station typically exceeded that above the canopy, which in turn exceeded that in the canopy. However, the magnitude of these differences varied among sites. For example, in the Philippines, the difference between the weather station and in-canopy daily mean air temperatures was 2.4°C, whereas in Texas the difference was 0.8°C. The direct application of weather station data in heat-stress studies will result in errors, especially in comparisons among sites. Findings from this international monitoring network will contribute to quantitative understanding of the factors affecting the temperatures in rice canopies, which will assist in predicting rice crop response to high temperature.

Rice Production under Limited Water Conditions

Anders, M.M., Brooks, S., and Kerr, S.

In a 3-year study that compared four rice varieties/hybrids (Bengal, CL161, CLXL745, XL753, and/or XL723) and four irrigation treatments (flood, row-water, flood-row watered, and row-watered-flood) and two nitrogen levels (120 or 216 kg ha^{-1}), we found significant differences between varieties and irrigation treatments in each of the three years. Grain yields were greatest, regardless of variety, in the flood and row-flood treatments. The lowest grain yields were with Bengal and CL161 in the row-watered treatment. Irrigation treatments that were changed (row-flood; flood-row) during the growing season showed that grain yields were reduced more when plants were stressed during their reproductive growth stage (flood-row). There were no significant differences found between nitrogen treatments. In a study beginning in 2011, two hybrids (CLXL745 and XL723) and six irrigation treatments [flood, row (40%), row (60%), intermittent (40%), intermittent (60%), and row (40%)-flood] were compared. Percentage values following nonflooded irrigation treatments indicate the percent of soil field capacity moisture content at the time each irrigation treatment was applied. Irrigation water use ranged from 0.37 ha m (43 acre inches) in the flooded treatment to 0.17 ha m (13 acre inches) in the intermittent (40%) treatment. Grain yields for the flood, intermittent (40%), intermittent (60%), and intermittent (40%)-flood irrigation treatments were similar.

Fungicides and Insecticides in Irrigated Rice: Residues in Grains and the Water Irrigation

Teló, G.M., Marchesan, E., Zanella, R., Oliveira, M.L., Ferreira, R.B., Coelho, L.L., and Roso, R.

The increasing world population along with the reduction of rural contingency is reflected in rapid changes in production systems in order to produce food in sufficient quantities to meet the basic needs of the population. In this context, the use of pesticides is a management practice used to ensure agricultural productivity. The application of fungicides in rice has been intensified in recent years due to higher incidence of diseases, in the same way the use of insecticides has also increased due to different types of pests that affect the crop, especially in the time closest to harvest. Due to these pesticides reaching the grain directly, fungicide and insecticide residue analysis is essential in rice grains. Another important fact relates to these applications done directly on cultures that are cultivated in shallow water, which could lead to water contamination by pesticides. In this sense, the purpose of this study was to analyze fungicide and insecticide residue in irrigated rice grains and in the irrigation water under different forms of processing.

The study was conducted in the growing seasons 2007/08, 2008/09, and 2009/10 at the Federal University of Santa Maria, Brazil, the first part on the field and the second in the laboratory. The sowing of rice was always performed during the month of October, regardless of the year, in plots isolated by a levee with individual irrigation and drainage to avoid contamination of plots. The pesticides were applied at different stages of plant development. Four fungicide applications were done that consisted of the active ingredients propiconazole, difenoconazole, tebuconazole, azoxystrobin, and trifloxystrobin. One application was carried out at stage R2 and two applications at stages R2 + R4. Regarding pesticides, the active ingredients evaluated were cypermethrin, lambda-cyhalothrin, permethrin, and thiamethoxam which were applied at stage R2. For the analysis of waste water 1 L of water was collected from each plot at intervals of 1, 3, 5, 7, 10, 15, 20, 25, 30, 35, and 40 days after the application of pesticides. To analyze the rice grains, they were harvested and separated into nine types of samples: rice bark, polished grain, whole grain, cooked polished grain, cooked whole grain, parboiled polished grain, parboiled whole grain, cooked parboiled polished grain, and cooked parboiled whole grain. The second stage of the study was performed at the Laboratory of Pesticide Residue Analysis (LARP), at the Federal University of Santa Maria, the quantification of residues in irrigation water and rice grains was performed by gas chromatography-mass spectrometry in series (GC-MS/MS) type triple quadrupole. The sample preparation was performed using the QuEChERS method modified.

In irrigation water, there were quantified residues of thiamethoxam, permethrin, azoxystrobin, propiconazole, and tebuconazole in the three years of evaluation. The highest concentrations of pesticides were always observed in the first days after application, although the presence of pesticides was quantified up to 40 days after application. For the fungicides difenoconazole and trifloxystrobin, and the insecticides cypermethrin and lambda-cyhalothrin residues were not quantified in the crop water. Regarding rice grains in the bark, we quantified residues of azoxystrobin and cypermethrin only in the 2007/08 season. For the 2008/09 and 2009/10 seasons, pesticide residues in rice bark were not quantified. In rice grains, raw and cooked under different forms of grain processing, polished or whole grain, were not quantified residues of fungicides or insecticides by the quantification method used. Thus, as an overall evaluation, we can say that in the irrigation water, the pesticides thiamethoxam, permethrin, azoxystrobin, propiconazole, tebuconazole, and cyproconazole were quantified up to 40 days after application. In barkless grains, residues of the pesticides analyzed, regardless if raw or processed grains, were not quantified.

Vermilion Rice Grower Salt Survey

Gauthier, S.J.

Rice production has historically been the largest agricultural commodity grown in Vermilion Parish, Louisiana, with a traditional base of over 30,000 ha (>80,000 ha) planted. Hurricane Rita in 2005 and Hurricane Ike in 2008 elevated salt levels in irrigation canals and storm surge flooded areas. Subsequently, 40% of the rice acreage in Vermilion Parish has not returned to rice production due to substantial infrastructure loss and lingering salt concerns.

About 70% of Vermilion Parish rice growers depend on inexpensive surface water to flood their rice crop. In May 2010, a water survey of 32 irrigation canals around the parish found 25% of the samples had salt levels over the LSU AgCenter 600 ppm recommended tolerance with growers not recognizing any reduction in their expected rice yields.

The LSU AgCenter guidelines profess that the use of 2688 kg ha^{-1} (2400 lb $acre^{-1}$) as NaCl in a growing season to be the maximum allowable level before an expected yield reduction. During the 2011 growing season, water, soil and tissue samples were taken from 14 rice fields in salt prone areas to monitor salt usage levels. A drought during this time period caused rainfall levels to lag 25 to 50 cm behind normal seasonal averages and acerbated grower salt issues. Water, soil and tissue samples documented highly elevated salt levels and found values to be at levels generally perceived to be compatible with zero relative productivity. However, overall, over 60% of these salt-laden fields still produced yields at or above the parish average yield. Rice varieties, soil types and cultural practices were not consistent amongst the sampled fields. More investigation is needed to determine the reason for the perceived salt tolerance and lack of total yield loss.

Rotation, Tillage, and Fertility Treatment Differences in Rice Grain Yield and Soil Carbon under 10 Years of Consistent Management

Anders, M.M., Yeater, K.M., Motschenbacher, J.M., and Kerr, S.

The effects of rotation, tillage, fertility, and variety treatments on rice grain yield were measured over a 10-year period. Mean rice grain yield, pooled over five rotations, two tillage, two fertility, and four varieties was 9,632 kg ha^{-1}. The main effects of fertility and tillage were not significant while there was a significant interaction between tillage and rotation. Rice grain yields for no-tillage were greater than traditional-tillage in the rice-corn-soybean and rice-soybean-corn rotations and less than traditional-tillage in the rice-corn, rice-soybean, and continuous rice rotations. As the frequency of rice in a rotation increased, rice grain yields declined with the lowest grain yield in the no-tillage-continuous rice rotation. Soil carbon measured 5 years following the initiation of this study indicated that soil carbon content increased as the frequency of rice in a rotation increased. These data highlight the need to develop crop management strategies that will improve soil quality and not reduce crop grain yield.

Boosting Profitable Rice Grain Yield with Foliar Potassium Nitrate Sprays

Holwerda, H.T.

Field, fruit and nut crops have shown to respond beneficially in terms of yield and quality to one of more foliar sprays with completely water-soluble crystalline potassium nitrate fertilizer (KNO_3, 13.5% N (as nitrate) and 45% K_2O). Greatest benefits were found under conditions of limited K availability for plant uptake and when localized within-plant demand exceeded the capacity of within-plant nutrient redistribution. Therefore, it was tested if similar positive results could be achieved in cereal grain crops, like rice and wheat.

In China and India, trials in rice were conducted with foliar applications of SQM's commercially branded Ultrasol™ K potassium nitrate and Speedfol™ Rice SP, a completely water-soluble powdery formulation with 13% N (as nitrate), 42% K_2O, 0.2% B and 0.7% Zn.

In China, the trial was conducted in Dandong, Liaoning province on a sandy loam soil, which analysis showed 55.8 ppm available N, 42 ppm exchangeable K, 1.5 ppm B and 0.7 ppm Zn. Treatments consisted of a control (water only), 4.5 kg Ultrasol™ K/spray ha^{-1} and 4.7 kg Speedfol™ Rice SP/spray ha^{-1}. With both fertilizer products, an equal amount of N and K was applied. In total, three sprays were applied at the phenological growth stages of active tillering (BBCH code 2), booting (BBCH code 4) and end of flowering (BBCH code 69). In addition, three different soil-applied K levels of 100% (90 kg K_2O ha^{-1} applied as a basal dressing with 150 kg KCl ha^{-1}), 75% and 50% of the soil test based K recommendation were included in the trial. The statistical design consisted of a randomized complete block design with nine treatments and four replicates, in total 36 plots.

In India, the trial was conducted at the research farm of the Directorate of Rice Research, Rajendranagar, Hyderabad, Andhra Pradesh province on a clay soil, which analysis showed 314 kg available N ha^{-1}, 109 kg available K ha^{-1}, 0.5 ppm B and 8 ppm Zn. The treatments consisted of a control (water only), 9 kg Ultrasol™ K /spray ha^{-1} and 9.5 kg Speedfol™ Rice SP/spray ha^{-1}. With both fertilizer products an equal amount of N and K was applied. In total, three sprays were applied at the phenological growth stages of active tillering (BBCH code 2), booting (BBCH code 4) and flowering (BBCH code 6). In addition, three different soil-applied K levels of 100% (50 kg K_2O ha^{-1} applied as a basal dressing with 83 kg KCl ha^{-1}), 75% and 50% of the soil test based K recommendation were included in the trial. The statistical design consisted of a randomized complete block design with nine treatments and three replicates, in total 27 plots.

In both trials, rice grain yields were significantly increased ($P<0.05$) by 11% and 10% with Ultrasol™ K and 15% and 14% with Speedfol™ Rice SP, in China and India, respectively, compared with the untreated control. Yields were reduced by 4% ($P<0.05$) and 3% for the 75% soil-applied K level treatment (not significant at $P=0.05$) and by 6% and 11% for the 50% soil-applied K level treatment (significant at $P<0.05$), in China and India, respectively, compared with the untreated plot. The greatest yields were obtained in the treatment combination of 100% soil-applied K level and foliar sprays with Ultrasol™ K or Speedfol™ Rice SP. Interestingly, the treatment combination of 50% soil-applied K level and foliar sprays with Ultrasol™ K or Speedfol™ Rice SP resulted in greater yields than 100% soil-applied K level without any foliar treatment. Furthermore, in both trials, a reduction of 25% and 50% of the recommended KCl dose rate as a basal dressing could be compensated for in terms of grain yield and farmers' income with three foliar applications with Ultrasol™ K or Speedfol™ Rice SP during the growing season. Economic analysis showed that foliar spray treatments with Ultrasol™ K and Speedfol™ Rice SP were cost beneficial compared with the untreated control plot for each of the three soil-applied K levels.

Effect of Foliar Potassium Nitrate Applications on Rice Stalk Strength, Lodging, and Grain Yields

Dunn, D.J. and Stevens, W.E.

A 2-year rice experiment was performed in 2010 and 2011 on a Crowley silt loam soil located at the Missouri Rice Research Farm at Qulin, MO. The initial soil test K levels at this location was 46 ppm (92 lb K $acre^{-1}$). All other soil test parameters were found to be adequate for drill-seeded delayed flood rice production in Southeast Missouri. The University of Missouri recommended rates for K was 67.2 kg K_2O ha^{-1}. Research plots were established reflecting 0, 50, 75, or 100% of this K rate with preplant applications of KCl. Subsequently, each plot either did or did not receive in-season foliar KNO_3 applications. Those plots that did were treated three times preflood, internode elongation, and 10% heading. These foliar treatments were applied using a CO_2 back pack sprayer. Each application consisted of 5.15 kg K ha^{-1} as KNO_3. The experimental design was a randomized complete block design with six replications. In this evaluation, rice was cultivated under the standard methods for producing rice in a dry-seeded, delayed-flood production system in Missouri. At season's end, each plot was harvested and grain yield determined. A representative sample of grain was collected from each plot. This sample was used to determine the milling quality and K content of the grain. The K content was combined with yield data to calculate K removal.

The following additional data were collected during the season. Plant tissue samples were collected from each plot before each foliar application and 7 days following to the 10% heading application. These samples represent 0.9 m (3 row feet) of the outside drill row of each plot. They were dried, weighed, ground, and analyzed for K content. From these data, aboveground K uptake was calculated. Following harvest, 30 cm long basal stalk samples were collected from each plot. These samples were evaluated for breaking strength by progressively adding weights to a cup suspended by a string from the stalk. The weight at which each stalk failed was recorded. Two weeks following harvest, soil samples representing a 15-cm depth were collected and analyzed for K content.

Additions of K either as soil applied KCl or foliar applied KNO_3 increased rice grain yields. When averaged for both years, the lowest yielding treatment was the untreated check (5,935 kg ha^{-1}), while the greatest yielding treatment was the 100% recommended rate of KCl + foliar KNO_3 (7,956 kg ha^{-1}). In 2010, lodging was reduced by foliar KNO_3 applications, while in 2011 no lodging was encountered. In both years, stalk strength was increased by foliar KNO_3 applications.

Rice Growth and Yield as Affected by Nitrogen and Potassium Fertilizer Rates

Slaton, N.A., Roberts, T.L., Norman, R.J., DeLong, R.E., and Massey, C.G.

Rice (*Oryza sativa* L.) growth and yield responses to N and K fertilization are each well documented, but less is known about how they interact. Information on the interaction between these two essential nutrients may provide research-based answers regarding their role in lodging and a diagnosis for late-season (i.e., near boot stage) symptoms involving leaf tip chlorosis and necrosis that have been observed in Arkansas for decades. Our research objective was to examine rice growth and yield responses to the application of different combinations of N and K fertilizers on soils with a range of K availability index values.

Trials were conducted during 2010 and 2011 in two established plot areas that had received five annual K rates of 0 to 179 kg K_2O ha^{-1} for nine or more years with the annual K rates serving as main plots. Each annual K rate contained four preflood N rate subplots that received 90 (suboptimal) to 224 (above optimal) kg N ha^{-1}. The five annual K fertilizer rates represent soil having from low to high K availability and fertilization rate. Rice and soybean [*Glycine max* (L.) Merr.] yield differences among annual K fertilizer rates are commonly >1500 and 700 kg grain ha^{-1}, respectively. 'Wells' and 'CL151' rice were drill seeded into the previous year's soybean stubble (no-till) in April 2010 and May 2011, respectively. Aboveground dry matter accumulation was measured at early heading, plant tissue was analyzed for N and K concentrations, and grain yield was measured at maturity. Each trial was a randomized complete block design with eight (2010) or nine (2011) blocks. Analysis of variance was performed using Proc Mixed in SAS v9.1 where N and K rate were considered as fixed effects and site-year was evaluated as a random effect. Differences were interpreted as significant when $p < 0.10$.

Rice dry matter accumulation at early heading was affected only by N rate and annual K rate but not their interaction. Dry matter accumulation, averaged across site-years and annual K rates, was lowest for rice fertilized with 90 and 135 kg N ha^{-1} (10,750 and 11,057 kg ha^{-1}) and increased to maximums of 11,297 to 11,330 kg ha^{-1} for rice fertilized with 180 to 224 kg N ha^{-1}. Likewise, dry matter increased numerically and sometimes significantly as annual K rate, averaged across site-years, and N rates increased. Rice receiving K, regardless of rate, produced 8 to 21% more dry matter than rice receiving no K. For rice receiving K, only rice fertilized with 179 kg K_2O ha^{-1} produced significantly more dry matter than 45 kg K_2O ha^{-1}. Analysis of rice tissue for N and K concentrations is not yet complete for the 2011 trial samples, but will be included in the presentation. Rice yield was affected by the interaction between N rate and annual K rate ($p=0.0020$) with mean yields ranging from 5267 to 7852 kg ha^{-1}. The lowest numerical grain yield was produced by the lowest N rate (90 kg N ha^{-1}) in all annual K rate whole-plots except rice that received 0 kg K_2O ha^{-1} yr^{-1}, which produced the lowest yield with the largest N rate (224 kg N ha^{-1}). The greatest numerical rice yield in each annual K rate was produced when 179 or 224 kg N ha^{-1} was applied. Statistically, within each whole-plot, the N rate that produced the lowest numerical yield was often significantly lower than the three other N rates, which produced similar yields. Significant lodging occurred in 2011 when CL151 was grown. Results clearly showed that lodging was a function of preflood N rate and the application of high rates of K did not reduce lodging. Lodging was worst (46% lodged) in rice that was fertilized with 224 kg N ha^{-1} compared to 90 to 179 kg N/ha (1 to 5% lodged).

Application of above optimal N and/or K fertilizer rates did not allow for greater yield potential than the nominal rate of 90 kg K_2O plus 179 kg N ha^{-1}, which produced statistically maximal yield. When K was severely deficient, rice response to N was limited and high rates of N actually reduced yield presumably due to increased disease incidence and severity. These results highlight the need for soil test methods that can accurately predict the optimal rates of N and K required for maximizing rice grain yield and/or profitability.

Salinity Effect on Germination for Common Rice Varieties during Short-term Incubation

Williamson, S.M., Roberts, T.L., and Norman, R.J.

Soil salinity is a major problem in many of today's rice-producing regions. Accumulation of salts can occur in rice production fields even when best management practices are incorporated due to the poor internal drainage of soils commonly cropped to rice. The soils used for rice production in the United States often have subsurface clay layers that lower water infiltration and prevent leaching of salts from the root-zone. For most rice producers, long-term cropping has led to substantial decreases in soil nutrient levels, and the addition of these nutrients through application of synthetic fertilizers can lead to increased salinity levels prior to establishment of a permanent flood. Poultry litter is an excellent source of nutrients and can have a significant impact on rice vigor and establishment but also contains a significant amount of salt which can injure rice when applied at high rates. Although salt accumulation can be overcome with high quality water sources, the availability of irrigation water for crop production is becoming scarce. Due to the amount of water required to produce direct-seeded, delayed-flood rice, many producers have begun to explore the potential of incorporating furrow- or intermittent-flood irrigation practices. In furrow-irrigated and intermittent-flooded rice, salt accumulation can be exaggerated due to the repeated soil drying and the upward movement of salt to the soil surface due to evaporation. Previous research has identified varying degrees of tolerance to a wide variety of salt concentrations. Not only does rice vary in salinity tolerance at different stages of growth, the cultivar plays an important role as the physiological response of the rice plant can help to overcome moderate levels of salt in both soil and water. Rice cultivars enter the market annually, and with the widespread use of hybrid rice, the number of varieties planted has increased but the average lifespan of a variety has decreased. With the current issues facing the rice industry and the rate at which new rice cultivars enter the market, screening for salt tolerance is becoming an increasingly important issue. This study was developed to quickly screen commonly grown hybrid and pure-line rice cultivars for salinity tolerance at germination.

To assess the relative salt tolerance of modern rice varieties that are commonly planted in the United States, cultivar entries from the University of Arkansas variety by nitrogen trials were selected and screened for salt tolerance based on seedling germination. During 2011, 22 common rice varieties were screened for salt tolerance by placing 10 seeds on filter paper within a polystyrene petri dish. To incorporate a wide range of salinity levels, a total of nine salt solutions were evaluated, with electrical conductivity readings of 0, 2.5, 5, 7.5, 10, 12.5, 17.5, 20, and 25 dS m^{-1} (mmho cm^{-1}). Seeds and filter paper were covered with 5 mL of salt solution, covered, and placed in an incubator set to 30°C to optimize germination. At 7 days, germinated seeds were counted and percent germination was determined. For the basis of this study, germination was defined as elongation of the seedling radicle to greater than 0.5 cm. Data were analyzed based on a full factorial randomized block design with cultivar (22) and salinity level (9) representing the two main factors. Statistical analysis was performed using JMP 9.0 and means were separated using Fisher's protected LSD where appropriate.

Germination percentage was significantly influenced by the interaction of cultivar and salinity level ($P<0.0001$), indicating that some cultivars were more sensitive to increasing salinity levels than others. Traditionally, medium-grain varieties have been thought of as more robust and able to overcome moderate to high salinity levels and are often planted on marginal soils. This study included four medium-grain varieties, three of which ranked within the top five in terms of salt tolerance (Bengal, CL261, and Jupiter). Of all the cultivars screened, CL111, CL261, and CL131 showed the highest mean germination percent, 90.2, 90.2, and 89.1%, respectively, and all Clearfield varieties had significantly higher ($P<0.001$) germination percents, indicating that these cultivars may have some type of genetic predisposition to higher salt tolerance. Pure-line cultivars were traditionally planted on all rice acreage, but the development of hybrid rice has led to a decrease in the number of acres planted to pure lines. Hybrid rice varieties are known for their high yield potential and vigor, but the results of this study suggest that they may not be as tolerant to salinity as some of the commonly grown pure-line cultivars. Within this study there was a wide range of relative salt tolerance, indicating that some cultivars may be better suited for emerging production systems such as furrow or intermittent-flooded rice. With the continuous development of hybrid rice and the equal emergence and turnover in pure-line varieties, salt tolerance screening will play an important role in variety selection as water quality and supply continue to diminish throughout the primary rice-producing regions of the United States.

Response of Two Rice Varieties to Midseason Nitrogen Fertilizer Application Timing

Frizzell, D.L., Norman, R.J., Roberts, T.L., Wilson, Jr., C.E., Slaton, N.A., and Branson, J.D.

A study was initiated in 2010 at the Rice Research and Extension Center (RREC, Stuttgart, AR) to examine the influence of midseason nitrogen (N) application timing on the grain yield of two conventional rice (*Oryza sativa* L.) varieties currently grown in the southern United States. The two conventional rice varieties chosen for the study were the Louisiana long-grain, semidwarf Cheniere and the Arkansas long-grain, standard stature Taggart. A second location at the Pine Tree Research Station (PTRS, Colt, AR) was added in 2011. During 2010, a midseason N rate of 50 kg N ha^{-1} was applied at 12.7-mm internode elongation (IE, ½ inch), 12.7-mm IE + 7 days, or 12.7-mm IE + 14 days to individual plots that had received a preflood N application of either 50 or 100 kg N ha^{-1}. During 2011, preflood N application rates to individual plots were 0, 50, or 100 kg N ha^{-1} followed by a midseason N rate of either 0 or 50 kg N ha^{-1}. During 2011, the midseason N fertilizer treatments were applied earlier in reproductive growth at beginning internode elongation (BIE), BIE + 7 days, or BIE + 14 days.

During 2010, there was no significant three-way interaction between variety x preflood N rate x midseason N application timing for grain yield of rice; however, for rice grain yield there was a two-way interaction between variety x midseason N application timing. Rice grain yield increased for both Cheniere and Taggart when the midseason N application was delayed from 12.7-mm IE until 12.7-mm IE + 7 or 14 days but not when it was delayed from 12.7-mm IE + 7days until 12.7-mm IE + 14 days.

During 2011, there was no significant four-way interaction between variety x preflood N rate x midseason N rate x midseason N application timing for rice grain yield at either location. There was no two-way interaction between variety x midseason N application timing during this study year, but there was a slight trend toward increased rice grain yield as midseason N application was delayed. There was, however, a two-way interaction between preflood N rate x midseason N rates that would indicate a need for midseason N fertilizer, especially following applications of sub-optimal preflood N rates.

The 2-year study indicates that midseason N application timing needs to be reevaluated for the currently grown rice varieties. Recommendations for midseason N application timing between beginning IE and 12.7 mm IE are supported by data that is now almost 20 years old. Rice varieties have changed over the last 20 years and the results from this 2-year study indicate the possibility that the proper midseason N application timing may also have changed. The 2010 results indicate it is better to apply midseason N 7 to 14 days after 12.7 mm IE, and the 2011 results indicate there is a 2-week window of application from 12.7 mm IE to 12.7 mm IE + 14 days.

Influence of Poultry Litter on Inorganic Soil Nitrogen Concentrations and Rice Yield on Silt Loam Soils in Arkansas

Greub, C.E., Roberts, T.L., Slaton, N.A., Norman, R.J., and Fulford, A.M.

Poultry litter is one of the most nutrient rich manures and is applied to a large amount of row crop acres each year in Arkansas. The objective of this research is to quantify changes in NH_4-N and NO_3-N concentrations occurring in the soil following the application of pelletized poultry litter 1 month prior and at rice planting using a 2 *M* KCl extraction. Poultry litter is typically applied to satisfy phosphorus and potassium recommendations; however, a previous study indicated that about 25% of the total nitrogen (TN) applied as poultry litter was recovered by the rice crop. In agriculture, it is important to be able to accurately predict the quantity of soil N that can become available to plants for N fertilization recommendations, which is influenced by a poultry litter application. Depending on time of application and management practice, 15 to 75% of the total-N content of poultry litter is plant available within the first year for summer crops. Most of the N in poultry litter is in the organic form (approximately 75%), with the remaining 25% of the total-N found in poultry litter as inorganic-N, mainly in the form of NH_4-N. It has been reported 30 to 35% of the TN in poultry manure was mineralized in the soil within the first 7 d, and after 2 months approximately 34 to 50% of the total N in poultry manure was mineralized. Previous research indicated that spring applied poultry litter results in a higher yield response when compared with fall applied poultry litter applications.

Two field experiments in 2011 were established to evaluate crop and soil responsiveness to pelletized poultry litter as a fertilizer. The experiment had a full factorial complete randomized block design with two locations, two poultry litter application times, plots with and without rice, and four poultry litter rates. The two locations for this study were the Pine Tree Research Station (PTRS) and the Rohwer Research Station (RRS), both on silt loam soils. The two PL application times were 4-5 weeks and 8-9 weeks prior to flooding. The four poultry litter applications were applied by hand and incorporated at rates of 0, 2240, 4480, and 6720 kg litter ha^{-1} to generate a N response curve and allow quantifiable changes in the soil N status. Soil samples were collected three times from the plots devoid of rice in 2-week intervals prior to flooding, and plots with rice were used to measure total N uptake. Extractable NH_4-N and NO_3-N were measured using a 2 *M* KCl extraction and analyzed using a Segmented Flow Auto Analyzer (San System, Brenda, Netherlands).

Poultry litter application resulted in significant increases in rice yield and were influenced by the two-way interaction of location and poultry litter rate. Rice response to increasing poultry litter rate exhibited a linear relationship at RRS, but exhibited a quadratic response at PTRS. Response curves indicated that rice yield may not have been maximized at RRS following the application of 6720 kg poultry litter ha^{-1}, but at PTRS, application rates above 2240 kg ha^{-1} had no influence on rice yield. Application time also influenced rice yields as poultry litter applied at planting resulted in higher yields than the equivalent rate applied 1 month prior to planting. The highest overall yield of 8400 kg rice ha^{-1} was observed at RRS when 6720 kg poultry litter ha^{-1} were applied at planting. Applying poultry litter at planting resulted in larger numerical concentrations of soil NH_4-N throughout early growth stages of the rice when compared with the 1 month prior application, with larger overall concentrations of NO_3-N in the 1 month prior to planting application. Within the 1 month prior application, the peak concentrations of inorganic-N were identified 2 weeks after planting. However, the peak concentration of NH_4-N for the at planting application occurred 2 weeks after planting, while the peak concentration of NO_3-N occurred 4 weeks after planting. The results of this experiment indicate the need for further research concerning the impact of poultry litter applications on N Soil Test for Rice (N-ST*R) soil test values and the potential for high levels of poultry litter to alter N-ST*R recommendations on silt loam soils.

Using Normalized Difference Vegetation Index to Estimate Rice Grain Yield Potential

Harrell, D.L., Tubana, B.S., Walker, T.W., and Phillips, S.B.

Nitrogen (N) fertilization in mid-southern USA drill-seeded, delayed-flood commercial rice (*Oryza sativa* L.) production systems is generally accomplished by splitting fertilizer applications. The first application generally supplies two-thirds of the estimated crop needs and is applied just prior to flood establishment. The second application occurs at midseason, generally during the brief period between panicle initiation (PI) and panicle differentiation (PD), and the rate is predetermined to supply the remaining one-third of the estimated crop needs and is adjusted up or down by visual assessment by crop producers and/or crop consultants. This predominant system of determining midseason N rates lends itself to the potential for over application of N fertilizer and can lead to subsequent yield reductions from increased disease pressure and lodging. Canopy reflectance sensors with an active light source that utilize normalized difference vegetation index (NDVI) measurements have the potential to improve midseason N fertilizer rate decisions in commercial rice production. Implementing the sensor-based N decision tool in wheat and corn production systems resulted in improved N use efficiency, economic returns, and decreased N loss. The reported benefits of deriving an N recommendation from sensor-based estimates of yield potential in wheat and corn justifies the need to conduct similar research in rice. The objectives of this study were to determine the optimum sensing timing and establish a yield prediction model using NDVI measurements acquired with the GreenSeeker® sensor.

Weekly sensor readings were collected over a 5-week period from multirate N fertilization trials established at six different locations throughout Louisiana and Mississippi from 2008 to 2010. The NDVI readings were collected on a weekly basis for five consecutive weeks starting at PI using a GreenSeeker™ handheld sensor (NTech Industry Inc., Ukiah, CA). Reflectance values in the red (RED, 670±10 nm) and near infrared (NIR 780±10 nm) regions were used to compute NDVI as $(R_{NIR}-R_{RED})/(R_{NIR} + R_{RED})$. Total aboveground biomass samples were collected at PD and 50% heading. Relationships were determined for biomass with grain yield, and for NDVI readings collected at different times with grain yield. The cumulative growing degree days [GGD = ((Tmax + Tmin)/2)-10°C] and the number of days from seeding (DFS) were determined for each sensing. These two variables were used to group and standardize NDVI readings prior to regression analysis.

Categorizing sensing timing by growth stage demonstrated that sensing at the PI and PD timings were superior estimators of rice yield potential compared with sensing timings beyond PD. Similar power function regression equations were established that could explain 36 and 42% of the variation in grain yield at PI and PD, respectively. Sensing post PD reduced yield potential predictability and is not practicable according to current midseason fertilization practices. To improve the predictability of the equations and to account for some of the seasonal variation in growing conditions across all site-years, NDVI values were normalized using cumulative GGD and DFS values at the time of sensing. When sensor timings were categorized by cumulative GDD, the 1501-1700 and 1701-1900 GDD groupings (r^2=0.41 for both) were superior to the 1301-1500 and >2100 GDD groupings (r^2=0.28 and 0.37, respectively). In almost all instances, normalization of NDVI data using DFS (NDVI/DFS) or GDD (NDVI/GDD) did not improve yield potential prediction compared with NDVI alone. However, the of GDD prediction equations are a logical fit for use in rice DD10 (DD50) programs where timing sensitive applications, like midseason N, are estimated using accumulated heat units. The four yield prediction models produced from this study provide producers with sensible model choices, depending on the methodology and sensing window used to stage rice and make midseason N application decisions in midsouthern USA commercial rice production.

Rice Growth, Nutrient Uptake, and Yield on Undisturbed Soils as Affected by Hydra-Hume DG and Fertilization Rate

DeLong, R.E., Slaton, N.A., Roberts, T.L., Norman, R.J., and Massey, C.G.

Humic acid-containing products are being marketed as soil amendments for use in commercial agriculture with little or no research to support or refute manufacturer claims concerning their potential benefits. Our research objective was to evaluate rice (*Oryza sativa* L.) growth, nutrient uptake, and grain yield response to a granular humic acid product marketed under the name of Hydra-Hume DG (Helena Chemical Co., Collierville, TN).

Field trials were established in 2010 and 2011 on soils mapped as Calhoun silt loams at the Pine Tree Research Station, Colt, AR. Rice was drill seeded (100 kg seed ha^{-1}) in nine, 0.19 m wide rows in a 1.7 m wide by 4.9 m long plot. A 10-cm deep flood was established at the 5-leaf growth stage after preflood N was applied. Each experiment was a randomized complete block design with a split-plot treatment structure where the whole plot was the combination of preplant phosphorus (P) and preflood nitrogen (N) fertilizer and the subplot was Hydra-Hume rate. MicroEssentials fertilizer (MESZ, The Mosaic Company, Plymouth, MN, 12-40-0-10S-1Zn) was applied at 0 or 168 kg ha^{-1} as the P fertilizer source in combination with preflood N rates of 0 or 112 kg urea-N ha^{-1} resulting in four main plot fertilizer treatments. Hydra-Hume DG was applied at 0, 1, 5, and 10 times the recommended rate of 45 kg ha^{-1} (1x) within each main plot. Aboveground dry matter accumulation and nutrient uptake were measured at midtillering (all treatments) and early heading (plots receiving 168 kg MESZ preplant and 0 or 112 kg N ha^{-1} applied preflood). Grain yield was measured at maturity. Data were analyzed by site with differences interpreted as significant at the 90% confidence level ($p<0.10$).

Grain yield was not affected by Hydra-Hume rate, the subplot factor, or its interaction with fertilizer rate, the main plot factor, at either site-year. Each year, rice fertilized with 168 kg MESZ and 112 kg N ha^{-1}, averaged across Hydra-Hume rates, produced the greatest yields and was followed by rice fertilized with only 112 kg N ha^{-1} preflood. The grain yields of rice that received no preflood N were the lowest and were not affected by MESZ rate in 2011. Grain yield among the four Hydra-Hume rates, averaged across fertilizer rates, differed by 181 to 197 kg ha^{-1} in 2010 and 2011, respectively, and showed no consistent trend between years. Dry matter accumulation by rice at the midtillering and early boot stages was also affected significantly by fertilizer rate, which showed trends similar to that described for grain yield. The trial conducted in 2010 showed that whole plant P and Zn concentrations and aboveground uptake were affected only by fertilizer rate. In 2011, dry matter was affected only by fertilizer rate, but whole plant P concentration and aboveground P and Zn content at the midtillering stage were affected by the fertilizer by Hydra-Hume rate interaction. Overall, aboveground P and Zn content tended to increase as preflood N, MESZ, and Hydra-Hume rates increased. Within each whole plot, effect of fertilizer rate, tissue P, and Zn concentrations were different among Hydra-Hume rates only when 168 kg MESZ ha^{-1} was applied with 0 (P only) or 112 (Zn and P) kg N ha^{-1}. The trend among Hydra-Hume rates was inconsistent as different Hydra-Hume rates had the lowest and greatest concentrations among fertilizer rates.

Hydra-Hume DG had no measurable benefit on rice dry matter accumulation at two growth stages and grain yield, regardless of the amount of N and P fertilizer applied. There were no consistent benefits of Hydra-Hume rate on aboveground tissue P and Zn concentrations. Based on these results, Hydra-Hume appears to have no short-term (i.e., year of first application) benefits for rice grown on undisturbed silt loam soils. Trials evaluating the same Hydra-Hume rates have also shown no yield benefit for soybean [*Glycine max* (L.) Merr.] in Arkansas.

Comparison of MicroEssentials Fertilizer to Standard Phosphorus Fertilizer Sources

Massey, C.G., Slaton, N.A., Roberts, T.L., Norman, R.J., and DeLong, R.E.

Evaluating new fertilizers and application methods for rice (*Oryza sativa* L.) production is important for providing thorough recommendations to growers and managing increasing fertilization costs. Rice requirement for phosphorus (P) is well documented, but recent price increases of inorganic P may merit new P sources or fertilization strategies that reduce input cost and improve P-use efficiency. Our research objective was to compare the effectiveness of MicroEssentials fertilizer (MESZ, The Mosaic Company, Plymouth, MN) with conventional P fertilization P and Zn sources.

Seven rice trials were established in 2008 (2), 2009 (1), 2010 (2), and 2011 (2) at the Pine Tree Research Station (PTRS) on silt loam soils. Rice was drill seeded and managed using the delayed-flood production system. All trials included six common treatments, including no P with 11 kg Zn ha^{-1} as a granular water-soluble $ZnSO_4$, triple superphosphate (TSP) with no Zn, TSP with 11 kg Zn ha^{-1}, diammonium phosphate (DAP) with 11 kg Zn ha^{-1}, monoammonium phosphate (MAP) with 11 kg Zn ha^{-1}, and MESZ (120 g N, 400 g N, 100 g S and 10 g Zn kg^{-1}). Each P source was applied at a rate of 45 kg P_2O_5 ha^{-1} in 2008, 2009, and 2011, and 67 kg P_2O_5 ha^{-1} in 2010. Preflood nitrogen (N) was broadcast at 145 kg urea-N ha^{-1} to each research area. Whole, aboveground plant samples were taken from a 0.9 m linear section of an inner row from each trial at midtillering for dry matter and tissue nutrient concentration. A small-plot combine was used to harvest for grain yield determination. Harvested grain yield was calculated based on uniform moisture of 120 g H_2O kg^{-1}. Each field trial was a randomized complete block design using four or five replications. A split-plot design was used to analyze dry matter, tissue P and Zn concentration, and grain yield where the whole plot was site-year (fixed) and the subplot was fertilizer treatment (fixed). Site-years were categorized as potentially responsive (<0.20% P) or unresponsive (>0.20% P) to P fertilization based on the mean whole-plant P concentration at the midtillering stage of rice receiving no P. Analysis of variance was performed on these categorized site-years using PROC GLM in SAS v9.1 using Fisher's Protected Least Significant Difference (LSD) method at a significance level of 0.10.

Comparing the three P-responsive sites together, the site by fertilizer treatment interaction was significant only for Zn tissue concentration. The main effects of site-year and P fertilizer significantly affected all rice growth parameters except grain yield and dry matter, respectively. Dry matter at midtillering was numerically greater (4-7%) for P-sources that included N (MAP, DAP, and MESZ) but was not significantly different from rice fertilized with TSP (2495 kg ha^{-1}). Only rice fertilized with MESZ (2674 kg ha^{-1}) produced greater dry matter than rice that received no P (2421 kg ha^{-1}). Phosphorus concentration at midtillering was similar in rice receiving P (0.17-0.18% P), regardless of the P source, and was greater than rice receiving no P (0.15% P). Rice grain yield was significantly greater (8473 kg ha^{-1}) for rice fertilized with P compared with rice receiving no P (7845 kg ha^{-1}) as confirmed by single-degree-of-freedom contrast (p=0.0119). Among P sources, grain yields differed by <7% with MESZ-fertilized rice producing similar yields as rice fertilized with MAP, TSP with Zn, and TSP with no Zn. In general, rice that received 11 kg Zn ha^{-1} contained numerically and sometimes significantly greater Zn concentrations (30 to 33 ppm) than rice that received a lower (1.1 to 1.7 kg Zn ha^{-1}) Zn rate from MESZ (27 ppm) or no Zn (26 ppm).

For the five site-years categorized as unresponsive to P, dry matter, tissue P concentration, and grain yield were not affected by P source or the site-year by P source interaction. Only tissue Zn concentration was affected by the main effect of P source, which showed that rice receiving 11 kg Zn ha^{-1} contained greater Zn concentrations (20 to 21 ppm) than rice receiving 0 to 1.7 kg Zn ha^{-1} (17 ppm). Thus, rice grown on silt loams in Arkansas does not appear to discriminate between P supplied by different sources. The small amount of preplant applied N supplied with MAP, DAP, and MESZ appears to benefit rice dry matter accumulation perhaps by increased root growth or facilitating early season P uptake. Across four years of research, MESZ appears to supply adequate P for optimal rice growth. Additional Zn application may be required in fields fertilized with MESZ because it contains a relatively low amount of Zn when applied at rates that satisfy P fertilizer recommendations, which may be insufficient for rice demand on soils with very low Zn levels and high pH.

Rice Growth and Yield as Affected by Nitrogen and Potassium Fertilizer Rates

Slaton, N.A., Stobaugh, R.B., Roberts, T.L., Norman, R.J., DeLong, R.E., Massey, C.G., and Frizzell, D.L.

Protecting crop root systems from root-damaging pests can be an important component to improving soil and fertilizer nutrient uptake. CruiserMaxx® seed treatment (Syngenta, Wilmington, DE) contains both insecticides and fungicides to aid in rice (*Oryza sativa* L.) stand establishment and prevention of grape colaspis and rice water weevil damage. Corn (*Zea mays* L.) hybrids possessing Bt rootworm resistance have been reported to possess greater yield potential and nutrient uptake than hybrid isolines lacking Bt resistance to rootworm. Although current rice cultivars and hybrids lack a genetic insect control mechanism, proper use of insecticides that control root-feeding pests may also result in increased root mass and improved nutrient uptake. Our research objective was to evaluate rice growth and yield responses to CruiserMaxx and fertilization levels.

Field trials were conducted at two sites during 2011 at the Pine Tree Research Station near Colt, AR, on alkaline soils mapped as Calhoun and Calloway silt loams. 'Wells' rice (23 kg) was hand treated with a 370 mL slurry that included 103.6 mL CruiserMaxx®, 6.5 mL color coat blue, and the ~259.9 mL tap water. CruiserMaxx® is a premixed combination of insecticide and fungicides, including Thiamethoxam (26.4%, insecticide), Fludioxonil (0.28%, insecticide), Azoxystrobin (1.32%, fungicide), Mefenoxam (1.65% fungicide), and other ingredients (70.35%). A second bag of Wells rice from the same seed lot received no seed treatment (0 mL CruiserMaxx). Rice was drill seeded into conventionally tilled seedbeds on 19 April on the Calloway soil and 10 May on the Calhoun soil at a rate of 90 kg seed ha^{-1}. Each plot was nine rows wide (18 cm drill spacing) and 4.1 m long and was separated from adjacent plots by a 60 cm plant-free border. The experimental treatments for this trial included two rates of CruiserMaxx® (0 and 2.1 mL kg^{-1} seed), two rates (0 and 168 kg ha^{-1}) of preplant applied MicroEssentials fertilizer (MESZ, The Mosaic Company, Plymouth, MN; analysis of 120 g N, 175 g P, 100 g S, and 10 g Zn kg^{-1}) and two rates of preflood urea-N (100 and 145 kg urea-N ha^{-1}). The MESZ was broadcast by hand after the final seedbed was prepared but before the rice was drill seeded. The two preflood urea-N rates were used to simulate suboptimal and near optimal N rates, respectively. Urea was broadcast by hand to a dry soil surface on 26 May (Calloway soil) and 15 June (Calhoun soil) and plots were flood irrigated within 48 hours after application. Plant samples were collected from each plot at the midtillering stage on 15 and 27 June and at the early heading stage 26 July and 3 August for the Calloway and Calhoun soils, respectively, to evaluate dry matter accumulation and nutrient uptake. At maturity, grain was harvested with a small plot combine and adjusted to 120 g H_2O kg^{-1}.

Both CruiserMaxx seed treatment and fertilizer rate, but not their interaction, significantly ($p<0.10$) influenced rice grain yield, and dry matter accumulation at midtillering and early heading. Compared with untreated seed, averaged across fertilizer rates and site-years, rice treated with CruiserMaxx increased rice yield by 5% (8,492 kg ha^{-1}), early heading dry matter by 11% (13,664 kg ha^{-1}), and midtillering dry matter by 25% (2,508 kg ha^{-1}). Early-season P and Zn uptake and tissue concentrations were not significantly affected by CruiserMaxx rate, but the p-values for this main effect ranged from 0.1267 to 0.2333, suggesting a strong trend for enhanced nutrient uptake. Early heading tissue analysis is not yet complete but will be reported. Fertilizer rate, the other main effect, also had a significant effect on grain yield, dry matter at midtillering, and early heading, and aboveground P concentration and content. In general, rice growth and yield increased as N and P application rates increased.

These first year results suggest that CruiserMaxx may benefit plant growth, nutrient uptake, and grain yield. However, identifying the mechanism for the measured benefits was beyond the scope of this project. Additional research is needed to determine whether enhanced growth was due to prevention of pest damage, enhanced root growth, or another less obvious mechanism.

A 5-Year Summary of the University of Arkansas Rice Research Verification Program

Runsick, S.K., Mazzanti, R., Wilson, Jr., C.E., and Watkins, K.B.

Rice (*Oryza sativa L.*) production is constantly changing as new varieties are released and new production challenges arise. Producers continue to request the University of Arkansas field test existing technology to determine the profitability of rice production. In 1983, the Arkansas Cooperative Extension Service initiated the Rice Research Verification Program (RRVP). The RRVP is an interdisciplinary effort between growers, county Extension agents, Extension specialists, and researchers. The RRVP is an on-farm demonstration of all the research-based recommendations required to grow rice profitably in Arkansas. The specific objectives of the program are to: 1) verify research-based recommendations for profitable rice production in all rice-producing areas of Arkansas, 2) develop a database for economic analysis of all aspects of rice production, 3) demonstrate that consistently high yields of rice can be produced economically with the use of available technology and inputs, 4) identify specific problems and opportunities in Arkansas rice production for further investigation, 5) promote timely implementation of cultural and management practices among rice growers and 6) provide training and assistance to county agents with limited expertise in rice production.

Each RRVP field and cooperator was selected prior to planting. Cooperators agreed to pay production expenses, provide crop expense data for economic analysis and implement the recommended production practices in a timely manner from seedbed preparation to harvest. The RRVP is funded by the Rice Check-off monies and administered through the Arkansas Rice Research and Promotion Board.

Through the 29 years of the RRVP (1983 – 2011) there have been 358 commercial rice verification fields in 33 rice-producing counties enrolled in the program. The program has been conducted on 8,472 ha (20,936 acres), with an average field size of 23.5 ha (58 acres). The average yield for the Rice Research Verification Program from 2006 – 2010 was 8,789.8 kg ha^{-1} (174.4 bu $acre^{-1}$). The Arkansas state average yield for that same period was 7,771.7 kg ha^{-1} (154.2 bu $acre^{-1}$). Producers enrolled in the program averaged 1,018 kg ha^{-1} (20.2 bu $acre^{-1}$) or 14% more than the Arkansas state average yield. This difference has been observed many times since the program began and can be attributed in part to intensive management practices, and utilization of University of Arkansas recommendations.

Producers enrolled in the program have been able to increase yields and gain valuable knowledge of rice production practices. Producers many times state that the RRVP fields are the highest yielding or most profitable fields on their farms. The trends in yields, management decisions, and impacts will be presented.

RiceTec Hybrid Planting Date Evaluation

Hamm, C.E., Wallace, D.M., and McNeely, V.M.

The RiceTec hybrid planting date evaluation is an experiment designed to analyze grain yield and quality in addition to other physiological differences associated with varying planting timings. The experiment is constructed to compare current commercial and experimental hybrids alongside of available commercial varieties in the rice-growing regions of the Gulf Coast and Midsouth. Currently, the testing range includes one location in each of three states, Texas, Louisiana, and Arkansas. A unique experimental protocol, which is updated annually, is strictly adhered to so as to ensure consistency and precision of all concluded data.

The experimental protocol includes several planting timings for each location that begins March 1 and concludes on June 1. Trial notes for soil temperature, emergence date, stand count, panicle initiation date, 50% heading, plant height, lodging score, grain retention, grain yield at 12.5% moisture, and milling yield are measured for each experiment. Standard cultural practices such as soil preparation, herbicide/fertilizer application, and water management are kept consistent throughout all locations and planting timings. A digital weather station is designated for each location to record temperature, humidity, rain, and wind speed at 1-hour intervals during the experiments. Ratoon crop data are collected when and where applicable. All field studies are planted and harvested with small plot equipment to maximize space usage. The average plot is 1.8 x 4.9 m (6 x 16 ft), seeded at the current recommended rate for hybrids and 67-90 kg ha^{-1} (60-80 lb acre^{-1}) for varieties. Each plot is randomized and replicated four times within a trial so that each line tested can be accurately represented within the test range.

The planting date evaluation continually evolves to include new hybrid and varietal line comparisons as well as conform to herbicide label changes. Actual planting dates are subject to weather related environmental conditions but annually represent early to late planting timings for rice. The primary utility of the hybrid planting date test is as an information gathering tool to aid in the advancement of hybrid rice technology.

Soil Aggregation and Carbon and Nitrogen Dynamics in Rice-Based Cropping Systems

Motschenbacher, J.M., Brye, K.R., Anders, M.M., and Gbur, E.E.

Rice (*Oryza sativa* L.) production in the United States is primarily concentrated in the Mississippi River Delta region of southeastern Missouri, eastern Arkansas and Louisiana, and western Mississippi, and rice-based cropping systems are different from other row crops due to the flood-irrigation scheme used from about one month after planting to a few weeks prior to harvest. The frequent cycling between anaerobic and aerobic conditions can influence the rate of soil organic matter decomposition, which sequentially affects soil water-stable aggregation and carbon (C) and nitrogen (N) sequestration over time. Water-stable aggregation and C and N storage in agriculturally managed soil can also be affected by tillage practices, crop rotation, and fertilization treatments. Understanding agricultural practices that influence soil aggregation is crucial to developing management strategies that will increase soil C and N sequestration at regional and global scales. A study was conducted on a silt-loam soil (fine, smectitic, thermic, Typic Albaqualf) in the Mississippi River Delta region of eastern Arkansas to evaluate the long-term effects of rice-based crop rotations [with corn (*Zea mays* L.), soybean (*Glycine max* L.), and winter wheat (*Triticum aestivum* L.)], tillage [conventional tillage (T) and no-tillage (NT)], and soil depth (0- to 5-cm and 5- to 10-cm) after 10 years of consistent management on soil water-stable aggregation and C and N accumulation within five aggregate-size classes (0.25- to 0.5-mm, 0.5- to 1-mm, 1- to 2-mm, 2- to 4-mm, and > 4 mm). Results showed that the concentration of water-stable aggregates increased as aggregate-size class decreased. There was also a greater concentration of water-stable aggregates under NT at the 0- to 5-cm depth than any other tillage-depth treatment combination for all rotations. Furthermore, the C and N concentrations of equivalent aggregate-size classes were roughly 2.5 times greater in the 0- to 5-cm depth than the 5- to 10-cm depth in all aggregate-size classes sampled. Among cropping systems, rotations with increased frequencies of corn generally had a greater water-stable aggregate C and N content in comparison to other rotations. Soil aggregates play an important role in maintaining soil aeration, water infiltration, soil structural stability, and physical protection for soil organic matter storage, and finding soil management practices that maintain these physical properties of the soil is important in assuring the long-term sustainability of row crop agriculture.

Flooding Impacts on Oxidation/Reduction Potential in Flooded Paddy Soils

Rogers, C.W., Brye, K.R., Norman, R.J., Roberts, T.L., and Fulford, A.M.

Flooding of rice (*Oryza sativa* L.) fields results in a marked change in the underlying soil environment. The floodwater acts as a barrier to oxygen (O_2) diffusion, and highly toxic soils are quickly depleted of O_2, and subsequently, the sequential reduction of chemical compounds occurs. This reduction of chemical compounds is particularly important in the production of the greenhouse gases nitrous oxide (N_2O) and methane (CH_4), both of which require a depleted O_2 status in the soil. Nitrous oxide is released when nitrate (NO_3^-) is reduced by denitrification occurring around 250 mV. A primary pathway of CH_4 production is when carbon dioxide (CO_2) is reduced by the process of methanogenesis, which occurs around -250 mV. The timing at which soils reach a critical redox potential conducive to denitrification and methanogenesis varies between soils and is a function of the availability of reducible compounds, along with other substrates necessary for cellular metabolism. Thus, an understanding of when representative Arkansas soils cropped to rice reach critical redox potentials for denitrification and methanogenesis is useful for estimating key times of production of these greenhouse gases.

A study was conducted in the greenhouse to investigate the changes in soil redox potential that occurred in two Arkansas silt loam soils. A Dewitt silt loam (fine, smectitic, thermic Typic Albaqualf) and a Calloway silt loam (fine, smectitic, thermic Glossaquic Natraudalfs) were collected from the plow layer of a rice-soybean (*Glycine max*) rotation from the Rice Research and Extension Center near Stuttgart, AR, and the Pine Tree Research Station near Colt, AR, respectively. Soils were added to tubs with and without rice, and redox sensors were installed to a depth of 7.5 cm (3 inches) and were used to record soil redox potentials, along with a data sonde to measure floodwater chemical properties.

Soil tests on the two soils indicated that the Dewitt silt loam had a greater initial concentration of available nutrients than the Calloway silt loam. Floodwater temperature was slightly greater in plots without rice present likely due to shading by the rice canopy. In the two soils, redox potential decreased differently when no rice was present. The Dewitt silt loam reached critical redox potentials conducive to denitrification and methanogenesis later after flooding than the Calloway silt loam. However, when rice was present, critical redox potentials for denitrification and methanogenesis were reached between day 20 and 25 and day 45 and 50 after flooding, respectively. Thus, it is clear that in the timeframe of a typical growing season, Arkansas rice soils achieve critical redox potentials necessary for N_2O and CH_4 production.

Cultivar-specific Emissions of Methane and Nitrous Oxide from Wet-seeded Rice Systems

Simmonds, M.B., Linquist, B.A., and Van Kessel, C.

Selection of rice cultivars that exhibit lower emissions of CH_4 and N_2O may prove to be a viable addition to greenhouse gas (GHG) mitigation strategies for rice cropping systems in California, but few studies have investigated this potential. We evaluated the GHG mitigation potential of four commonly grown cultivars (i.e., Koshihikari, Calmati-202, L-206, and M-206) at the Rice Experiment Station in Biggs, California. The experimental design was a randomized complete block with three replications. Gas fluxes were measured biweekly during the majority of the growing season while the field was continuously flooded. During the end-of-season draining event we measured gas flux on a daily basis to capture peaks in emissions as the soil environment changed relatively quickly.

Nitrous oxide emissions were minimal for most of the growing season due to highly reduced soil conditions, while CH_4 emissions were high and very variable within and among treatments. The maximum mean CH_4 fluxes observed during a sampling event for M-206, L-206, CT-202, and Koshihikari were 1,107, 856, 921, and 1,591 g CH_4-C ha^{-1} day^{-1}, respectively. Due to the high variability among chambers within each treatment, further analysis on the seasonal emissions per gas flux chamber is needed to test for differences among cultivars.

Methane and Nitrous Oxide Emissions from Rice Grown under Different Nitrogen Levels

Anders, M.M., McClung, A., Kerr, S., Sells, T., and Hendrix, D.

A study was initiated in 2011 to determine the potential of reducing methane (CH_4) and nitrous oxide (N_2O) emissions from rice fields through better nitrogen (N) management. The hybrid CLXL745 was treated with N rates of 0, 112, 168, and 224 kg N ha^{-1} as a single preflood application. Gas measurements were collected from static chambers adjusted to accommodate plant height. Measurement intervals were adjusted to capture management and weather events that would be expected to impact gas levels. Methane rates were similar for the three highest N treatments while N_2O levels increased as N fertilizer rates increased. Global warming potential, expressed as kg CO_2 equivalents ha^{-1}, were lowest (644) for the 0 N level and highest (1,576) for 168 kg N ha^{-1}. When data were expressed as yield-scaled, there were no differences between treatments. These data suggest that applying N at, or close to, the 112 kg N ha^{-1} would result in minimal greenhouse gas production and acceptable rice grain yield.

Can Southern U.S. Rice Cultivars be used to Mitigate Greenhouse Gas Emissions? A Preliminary Study

McClung, A.M., Anders, M., Adviento-Borbe, A., Bryant, R., Linquist, B., and Van Kessel, C.

Most rice in the world is produced under flooded paddy conditions as a means of producing high stable yields and controlling nonaquatic weeds. However, the anaerobic soil conditions that occur as a result of the flooded fields cause high levels of methane production due to bacterial methanogenesis. Because rice feeds about half of the world's population, the expansive global acreage results in rice contributing 10-20% of global methane emissions. Nitrous oxide is another gas associated with global warming and its presence is, in part, a result of the application of nitrogen-based fertilizers in agriculture. We conducted a replicated study in Stuttgart, AR, during 2011 to determine season-long greenhouse gas emissions as a result of fertilizer application rates and timing using one rice cultivar. In addition, a small exploratory study was conducted to determine the potential that choice of variety may play in mitigating greenhouse gas emissions from rice production fields. The study was conducted adjacent to the fertilizer-rate study and included five public varieties and one hybrid (CLXL751). The varieties included Jupiter, conventional medium-grain variety; Francis and Roy-J, conventional long-grain varieties; and Rondo and Sabine, specialty long-grain varieties. In addition, Francis and Rondo are parents of a mapping population developed by Wengui Yan, which captures indica x japonica genomic interactions. The objective in this preliminary study was to determine if cultivars differed for season-long greenhouse gas emission profiles that could be used as a component in mitigation efforts. In addition, the inclusion of the mapping population parents provided the opportunity of possibly mapping traits and genes associated with greenhouse gas emissions in the future. Each variety was drill seeded in a standard size yield plot. After planting, a static flux vented chamber was placed in each cultivar field plot. Gas samples were collected from within the chambers approximately twice a week throughout the growing season and nitrous oxide and methane emissions were determined. In addition, various plant growth parameters and grain yield were determined. Results will be presented that demonstrate major differences between the methane emissions of the tropical japonica cultivars (Francis, Sabine, and Roy-J) in comparison to Rondo (indica), Jupiter (temperate japonica), and the hybrid. Even though there was a 12-day difference in heading among the six cultivars, the emission profile appeared to be independent of maturity factors.

Abstracts of Papers on Economics and Marketing
Panel Chair: Bradley Watkins

Impacts of Lodged Rice on Milling Yield, Market Price, and Net Returns

Salassi, M.E., Deliberto, M.A., Linscombe, S.D., Wilson, Jr., C.E., Walker, T.H., and McCauley, G.N.

A downed rice crop due to adverse weather prior to harvest can significantly impact the income and expenses associated with the affected area of rice production in a field. Four potential categories of direct economic impact of downed rice on rice net economic returns include: increased harvest cost, rice harvest yield loss, reduced milling yield, and lower rice grade. A research project was initiated in 2010 to determine the impact of lodged rice on milling yield and resulting market price. In 2010, field tests were conducted at the Rice Research Station to simulate downed rice under commercial production conditions. Plots were lodged one week prior to field drainage (rice lodged for 24 days) and one day after field drainage (rice lodged for 12 days). Grain samples were also taken from commercial fields actually lodged in Evangeline Parish. Samples were milled at the Rice Research Station in Crowley, LA. The impact of lodged rice on milling yield and estimated rough rice market price received varied greatly and was primarily dependent on the length of time and conditions under which the rice was lodged. The longer rice is lodged, the greater the reduction in milling yield and market price received. Impacts on estimated rough rice market price ranged from $0.0121 to $0.0730 per kg ($0.55 to $3.31 per hundredweight), based on a $0.3086 per kg ($14 per hundredweight) base market price (55 percent whole kernels; 70 percent broken kernels). Field studies were conducted in 2011 at research stations in Crowley, LA, Stuttgart, AR, Stoneville, MS, and Eagle Lake, TX. Similar results were observed regarding length of time rice was lodged and reduction in milling yield. Drier weather at harvest time resulted in less reduction in milling yield for lodged rice than was observed in 2010.

An Economic Risk Analysis of No-till Management for the Rice-Soybean Rotation System used in Arkansas

Hristovska, T., Watkins, K.B., and Anders, M.M.

Arkansas is the top domestic rice producer, representing approximately half of the total U.S. rice production and rice acres planted. Sediment is one of the major pollutants in rice producing areas of Arkansas, and no-till is often recommended to alleviate this problem. No-till is not fully comprehended by farmers. Traditionally, it is believed that no-till is less profitable due to lower yields offsetting cost savings. No-till has often been compared with conventional practices. However, this paper evaluates the two practices using consistent 11-year data, 2010 is the last year. Crop yields, prices, and stochastic input costs are simulated for a typical rice-soybean rotation using multivariate empirical distributions of the variables. Risk efficiency was estimated using the stochastic efficiency method in SIMETAR. The no-till rice-soybean rotation, which is the most widely used practice, was found to be more profitable than conventional till. Projected net returns for 2011 for the no-till rotation were estimated to be $436 per hectare ($176 per acre), while conventional-till produced net returns of $418 per hectare ($169 per acre). Stochastic fixed expenses were estimated to be lower for no-till than conventional till practices, while variable costs were slightly higher and gross revenues was slightly lower. Both risk neutral and risk adverse farmers would benefit more from no-till than conventional till. However, no-till risk premiums are positive, implying risk-averse rice producers would benefit monetarily from no-till management. Besides being more profitable, no-till is also associated with lower fuel quantity and higher environmental benefits.

Stochastic Analysis of Monetary Benefits to Multiple Inlet Irrigation in Arkansas Rice Production

Watkins, K.B., Hristovska, T., and Anders, M.M.

Irrigation fuel costs represent a significant portion of rice production expenses. Multiple inlet (MI) irrigation represents a water saving alternative to conventional flood irrigation in rice production. Rather than discharging water directly from the well or riser into the first paddy, the riser is connected to a pipe and gates or holes are placed in the pipe for each paddy. Multiple inlet irrigation allows each paddy to be watered concurrently instead of receiving overflow from a higher paddy. By adjusting the gates, the operator can fill all paddies simultaneously. Water savings may be achieved using MI irrigation over conventional irrigation. The field is flooded quicker, and irrigation efficiency is increased through reduced pumping time during the season. Reported MI water savings over conventional flood irrigation ranged from 5 to 44% and averaged 21% based on Arkansas field demonstration data for the period 2000 through 2007. Other benefits of MI include reduced irrigation labor and possible higher grain yields. A positive though non-significant numeric rice yield difference of 3.4% has also been reported for demonstration fields in Arkansas using MI versus conventional irrigation.

This study uses simulation to calculate the range of monetary benefits to MI in rice production for three different pump lift scenarios (stationary relift using a 6 m (20 ft) maximum vertical pipe; standard well 37 m (120 ft) or less deep; and deep well between 37 to 73 m (120 and 240 ft) deep). Rice yields, rice prices, prices for key production inputs (diesel and fertilizer), and water savings from MI relative to conventional flood irrigation are simulated using the simulation model SIMETAR. Stochastic rice net returns above variable and fixed expenses are calculated for each pump lift scenario with and without MI and with and without a rice yield increase in simulated yields of 3.4% for MI irrigation. Stochastic per hectare monetary benefits to MI are calculated as the difference between net returns to rice under MI and net returns to rice under conventional flood irrigation.

The results of this study indicate that monetary benefits to MI depend greatly on pump lift and the presence or absence of a yield increase. Without a yield boost, monetary benefits are smallest for stationary relift fields, but MI tends to pay for itself in this circumstance. Monetary benefits to MI increase with deeper pump lifts, primarily because savings in irrigation energy costs resulting from less applied water are magnified for the deeper pump lifts. The size of the monetary benefit also increases for a given level of water savings as the fuel price increases. The presence of a slight yield boost greatly increases the monetary benefit to MI, and the magnitude of the benefit increases in this instance for a given level of water savings as both the fuel price and the rice price increases. These results imply that potential yield increases resulting from MI irrigation do not have to be significantly large to increase the monetary payoff of MI in rice production.

Stochastic Analyses of Commodity Program for U.S. Rice:
Adjustments on Deficiency Payments, Target Price, and Loan Rate, 2012-2016

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

As budget constraints dominate Congressional legislative discussions, farm commodity program funding is being subjected to more scrutiny for dramatic cuts than ever before. This study analyzes the stochastic impact on farm income of potential elimination of direct payments and potential changes in target price and loan rate in rice. A number of ideas on possible program changes to generate government savings have been proposed. However, there is scarcity of quantitative estimates of the potential impacts of such changes. This study focuses on analyzing the impact on farm income of potential elimination of direct payments and potential changes in target price and loan rate in rice using the Arkansas Global Rice Model (AGRM). The AGRM is a multi-country econometric framework that has over 250 equations representing rice supply and demand relationships in 40 countries and five regions around the world developed and maintained by the Department of Agricultural Economics and Agribusiness, University of Arkansas in Fayetteville. The theoretical structure and the general equations of the AGRM are documented online.

Being able to look at several potential alternatives, as well as a possible range of options, is important in good policy decision-making. This study addresses this need by making use of stochastic analysis that provides information on the possible range of outcomes for any given change or scenario. The analysis covers the 5-year period 2012 through 2016. The three specific scenarios analyzed include the following:

Scenario 1: Stochastic analysis of eliminating total direct payments starting in 2012 and maintaining the current target price and loan rate.

Scenario 2: Stochastic analysis of eliminating total direct payments starting in 2012 and increasing both the current target price and loan rate by 25%.

Scenario 3: Stochastic analysis of eliminating total direct payments starting in 2012 and removing the current target price and maintaining the current loan rate.

The starting point for this analysis is the August 2011 AGRM baseline. The baseline projections are based on assumptions of current policies, macroeconomic variables, and average weather conditions. The stochastic framework used in this study is generated using empirical distributions of the variable yield for each country and region in the model, as well as for each of the six rice-producing states in the U.S. Yield is used because it is the variable that not only differs by year and region but is also very sensitive to changes in weather conditions and water availability. A total of 500 random draws were implemented using a 28-year empirical distribution of historical yields generated using the software SIMETAR.

Results of scenario 1 show that the probable production market values (PMVs) range from \$2.11-\$4.19 billion, with an average of \$2.81 billion. It is probable that 93% of the time there will be zero counter-cyclical payments (CCP) and 7% of the time there is probable government CCP expenditure of \$300 thousand or more, with maximum of \$201.3 million. Scenario 2 shows that the probable PMVs range from \$2.11-4.19 billion, with an average of \$2.82 billion. It is probable that 21% of the time there will be zero CCP and 79% of the time there will be government CCP expenditure of \$40 thousand or more, with maximum of \$704 million. On a per kg basis, there will be an average probable CCP payment of \$0.0176 per kg (\$0.80 per hundredweight) under scenario 2, with maximum payment of \$0.0811 per kg (\$3.68 per hundredweight). Scenario 3 results in no government payment at all, i.e., only PMVs are generated, which range from \$2.11-4.19 billion, with an average of \$2.82 billion.

Arkansas Representative Panel Farm Analysis of Loan Rates and Target Prices for the 2012 Farm Bill

Karov, V., Wailes, E.J., and Watkins, K.B.

The 2008 Farm Bill will expire in 2012 and the need to draft a new legislation has emerged. The intellectual debate on how to modify the 2008 Act, given the prospects of reduced funding for the 2012 legislation due to large Federal budget deficits, relatively high crop prices and agricultural incomes, and WTO constraints while maintaining a safety net for producers, is currently underway. Hence, the need to examine the impacts of alternative (or modified) safety net programs has recently emerged. In light of the currently high crop market prices, most interest groups have endorsed a complete removal of the direct payments program in favor of a revenue-based risk management program. However, direct payments have historically played a prominent role in providing a safety net for Arkansas producers. In addition, under the current market price environment, Arkansas producers do not receive any loan deficiency payments (LDPs) and counter-cyclical payments (CCPs) (with rare exceptions for cotton) while participation rates in the Average Crop Revenue Election (ACRE) program have remained low.

The main objective of the study is to estimate the effects of a full removal of the direct payments program during the 2012 Farm Bill on Arkansas farmers. The goal is to determine what size of adjustment in loan rates and target prices would be meaningful in maintaining a safety net for Arkansas producers during this period. Five eastern Arkansas representative panel farms provide the framework for the analysis. Ten-year historical data are employed to develop national/world crop price, farm-specific yield, and farm expense empirical distributions by using multivariate empirical (MVE) probability distributions. SIMETAR is used to simulate stochastic baseline 5-year projections for the period 2012-2016, with 500 random draws annually.

To achieve the main objective, four scenarios are considered. Results from the first (baseline) scenario suggest that a full continuation of 2008 Farm Bill commodity programs during the period 2012-2016 results in one of the five panel farms having a negative net income on a per hectare basis as an annual average during this 5-year period. Under this scenario, across all sample crops on a per hectare basis, most direct payments as an annual average for the years 2012-2016 are paid for rice with cotton being a distant second. Results from the second scenario imply that a complete removal of the direct payments program during the years 2012-2016 results in two of the five panel farms having a negative net income on a per hectare basis as an annual average for this period. In this scenario, changes in net farm income relative to the baseline for the sample farms range from -181% to -14%.

The third scenario examines how high loan rates would have to be increased by policy makers to begin to result in LDPs being made to farmers in the face of a relatively strong market price environment for the period 2012-2016 as FAPRI projects. The analysis suggests that in 2012, the rice loan rate would have to be raised to $0.2663 per kg ($12.08 per hundredweight), an 86% increase relative to the 2008 Farm Bill rice loan rate level, before any LDPs are received by rice producers. On the other hand, the soybean loan rate would have to be increased to $0.2815 per kg ($12.77 per hundredweight), a 155% increase compared with the 2008 Farm Bill soybean loan rate level, before any LDPs are received by the Stuttgart farm. The final scenario estimates how high target prices would have to be raised before any CCPs are received by producers. The results suggest that in 2012, the rice target price would have to be increased to $0.3181 per kg ($14.43 per hundredweight) before any CCPs are received by long-grain rice producers, a 37% increase relative to the 2008 Farm Bill rice target price level.

Chinese Rice Production and Future Development

Jin, J. and Wailes, E.J.

Rice is one of the most important crops for Chinese agriculture. It has been listed as one of the eight protected crops by the State Administration of China. The Chinese government has applied a special policy in those eight crops. China is the No.7th rice exporter in the record of USDA, and it has occupied the 10th place in the rice imports. The export right of rice is only been issued to China Oil and Foodstuff Cooperation which is a leading grain, oils, and foodstuffs import and export group, the largest state owned agriculture enterprise in China. The import right of rice has been limited by the Government to fulfill the food security standard. Rice production in China is at the top in a worldwide rank. However, based on the huge population in China, the amount of rice production is slightly over autarky. Based on research, the main propose of Chinese rice importation is to fulfill customer taste. The majority of imported rice comes from Thailand and Vietnam as jasmine rice. This article is a brief introduction of Chinese rice production and trade policy and further analysis of the future development of Chinese rice production based on the hybrid rice, the newest biotechnology developed by Longping Yuan. The method of this research to analyze the influence for rice production of the hybrid rice technology is Basic Simulation Modeling.

Is ACRE Program Participation During the 2012 Farm Bill Likely to Pay Off for Arkansas Producers? Preliminary Evidence from the Representative Panel Farms Framework

Karov, V., Wailes, E.J., and Watkins, K.B.

The bipartisan “Super Committee” failed in November 2011 to reach a Federal deficit reduction agreement in which the 2012 Farm Bill would have been included based on a proposal drafted by the House and Senate agricultural committees. As a result, the need to draft a new legislation during the upcoming months has strongly emerged. Such an Act is destined to be a result of a much more open process with proposed agricultural programs facing added public scrutiny, as well as congressional amendments through floor debates. The 2008 Farm Bill introduced the Average Crop Revenue Election (ACRE) program as a voluntary alternative program to receiving counter-cyclical payments (CCPs). The program was made available starting in the 2009 crop year and provides revenue support. Once farmers elected to participate in the ACRE program, such a decision was irrevocable throughout the duration of the 2008 Farm Bill. ACRE participants were ineligible for CCPs, and their direct payments (DPs) were reduced by 20 percent and their loan-deficiency payments (LDPs) by 30 percent. In order for a farmer to receive an ACRE payment, two revenue-related triggers (one at the farm and one at the state level) have to be met. Since DPs are of critical importance to the subsistence of Arkansas farms, the current structure and rules of the ACRE program have not been attractive to State producers during the 2008 Farm Bill. This has been followed by low producer participation rates.

The objective of this study is to examine what is the likely impact on Arkansas farmers of participation in the ACRE program during the 2012 Farm Bill (pending full program continuation). Five eastern Arkansas representative panel farms provide the framework for the analysis. Ten years of historical data are used to develop national/world crop price and farm and state-specific yield, as well as farm expense empirical distributions by using multivariate empirical (MVE) probability distributions. SIMETAR is used to simulate stochastic baseline 5-year projections for the period 2012-2016 with 500 iterations annually. The preliminary results suggest that the probabilities of receiving an ACRE payment during the period 2012-2016 are low across all farm-crop combination pairs. For example, such probabilities are in the 11 - 39% range for long-grain rice and the 18 - 43% range for irrigated soybeans. Average projected per hectare (acre) ACRE payments range from $59 per hectare ($24 per acre) for the Stuttgart farm to $91 per hectare ($37 per acre) for the Leachville farm. Across all sample crops, the highest ACRE payments per hectare on average are received for corn and medium-grain rice and the lowest for wheat and irrigated/dry soybeans. Finally, in terms of profitability for ACRE enterprise participants, only one of the five sample farms (Wynne farm) has a negative net farm income on a per hectare (acre) basis as an annual average during the 2012-2016 period (-$277 per hectare (-$112 per acre)).

Southeast Asia's Rice Market to 2021

Hansen, J., Baldwin, K., Childs, N., and Dyck, J.

USDA's annual Baseline projections exercise looks at the global rice market through 2020, using a multi-commodity global model. Results show continuing slowing of consumption growth in Southeast Asia, based on income elasticities that are near zero or negative, and slowing rates of population growth. Production growth is projected to remain slow, as in the last decade. Rice area is projected to rise in Burma and Cambodia but be almost flat elsewhere in the region. Yields are expected to show slow growth, following recent trends. It is assumed that incentives remain strong to grow high quality rice varieties that have relatively long growing seasons and relatively low yields. Prices are projected to begin the period at high levels, influenced by Thai government offering to buy all rice at prices that are high by historical standards. However, this is likely to lead to large Thai stocks that require sales at lower prices in the middle and later years of the projection period. This will cause world prices to ease somewhat. The total size of Southeast Asia's rice surplus is expected to be relatively constant throughout the projections.

The Underpinnings of Southeast Asia's Rice Surplus

Baldwin, K., Childs, N., Dyck, J., and Hansen, J.

Southeast Asia's rice surplus is the leading source of world rice imports. The paper reviews the factors that underpin the surplus and examines recent trends in those factors in light of current concerns about global food supply. Production growth in Southeast Asia as a whole has slowed in the last two decades, although substantial expansion has taken place in Cambodia. Slowing production growth can be traced to constraints on expansion of paddy land, to reluctance to intensify multiple cropping of rice, and to slow growth in yields. Yield growth may be slow in part because of price signals that encourage farmers to plant high quality but lower yielding varieties of rice. Slow production growth needs to be considered in the context of slowing consumption growth. The region's consumers already eat very large quantities of rice, and rapidly growing incomes have not been spent on greater quantities of rice. Slowing population growth throughout the region also means that growth in consumption has slowed down. The result has been an increasing surplus of production over consumption. Major uncertainties include the degree to which rice is used for feed and industrial purposes, stock levels, and estimates of loss and waste.

Long-term International Rice Baseline Projections, 2011-2020

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

This paper provides a 10-year projection of the global rice economy, with focuses on key exporting and importing countries. Baseline estimates on production, consumption, trade, and prices that are useful in analyzing the impacts of alternative policy and market scenarios are generated using the Arkansas Global Rice Model (AGRM). AGRM is a multi-country econometric framework that has over 250 equations representing rice supply and demand relationships in 40 countries and five regions around the world developed and maintained by the Department of Agricultural Economics and Agribusiness, University of Arkansas in Fayetteville.

The global model is disaggregated into 43 of the major rice producing, consuming, and trading rice countries and the rest of the world into five regional aggregations: Africa, the Americas, Asia, Europe, and Oceania. Each country and regional model includes a supply sector, a demand sector, trade, stocks, and price linkage equations. The analysis in this paper is based on the October 2011 baseline.

Detailed results of the analysis by country and by region show that over the 10-year baseline period (2011/12 - 2020/21), world rice output grows at 1.09% per year with 0.74% coming from yield improvement and 0.35% coming from growth in area. Global rice consumption gains 1.09% annually, as population grows at 1.06% and per capita use gains slightly at 0.03% per year. Net trade continues to grow at 1.97% per year. International rice prices are projected to increase steadily, as population-led growth in consumption and gains in trade continue.

Over the same period, India and China remain as the largest rice economies which combined account for 45.6% of global rice area harvested, 50.5% of total milled production, and 49.5% of total consumption. Indonesia, Bangladesh, Thailand, and Vietnam combined account for 26.4% of world area harvested and 26.0% of global production. Indonesia, Bangladesh, Vietnam, and the Philippines combined account for 23.7% of total consumption. The top rice net exporters are Thailand, Vietnam, India, Pakistan, and the U.S., which combined account for 86.1% of total global net trade. However, export growth is projected to be faster in India and Pakistan than Thailand, with Vietnam and the U.S. experiencing flat to declining trade due to area limitations. Cambodia and Myanmar are projected to increase rice exports steadily over the projection period, as production continues to exceed consumption. The bulk of the cumulative rice import demand (44.3% of total) over the same period is projected to come from the Philippines, Nigeria, Indonesia, Bangladesh, Malaysia, and the Middle East.

The global rice area harvested is projected to grow by 5.6 million hectares over the next decade, with 84.7% coming from India, Pakistan, Thailand, and Cambodia. The largest projected expansion in area is in India by 3.1 million hectares, as the country recovers from the 3-million hectare decline over the last two years. However, China is expected to contract harvested rice area by 1.4 million hectares over the same period. Global milled rice production is projected to expand by 51.8 million metric tons (mmt) over the same period, with 62.5% of the growth coming from six countries combined (India, Indonesia, Bangladesh, Thailand, Vietnam, and Pakistan).

World total rice consumption is projected to expand by 51.1 mmt (net) over the same period, with 65.7% coming from India, Bangladesh, Indonesia, Vietnam, the Philippines, Nigeria, and Myanmar combined. The bulk (75.8%) of the 6.2 mmt-growth in net exports is accounted for by the three countries of India, Thailand, and Pakistan combined. On the other hand, 70.0% of the growth in net import demand comes from the Philippines, Nigeria, Malaysia, and the Middle East combined.

Analysis of annual changes by world regions improves understanding of the dynamics of the global rice economy. Annual growth in rice area harvested is relatively high in Africa (+0.81%), followed by Oceania (+2.28%; as it recovers from drought-reduced base year), Asia (+0.27%), the Americas (+0.16%), and the European Union (-0.15%).

Total rice consumption growth rates are +3.26% for Africa, 2.45% for Oceania, 1.49% for the Americas, +1.42% for the European Union, and +0.96% for Asia. Growth rates in net rice trade are +4.62% for Asia, +4.55% for Africa, +2.66% for the Americas, and +2.23% for the European Union. Thus, while the African rice economies are still relatively small, the continent is emerging as a relatively dynamic future growth region for rice, thus offering food security opportunities for the continent.

Rice Trade Negotiations: A Case Study in the Western Hemisphere

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

After being left out of most multilateral negotiation rounds auspice by the General Agreement on Tariffs and Trade (GATT), agriculture was brought into multilateral negotiations in the framework of the Uruguay Round of GATT. The World Trade Organization's Agreement on Agriculture was drafted so as to allow for further, beyond the most-favored-nation (MFN) market access concessions in the event of regional trade integration. Since the mid 1990s, regional trade agreements (RTAs) have flourished, counting currently over 200 RTAs in force. The U.S. has been very active in the regional integration arena, with 14 RTAs currently in force, six of which have being signed with Western Hemisphere countries. The economics of rice in the Western Hemisphere partners varies significantly. For instance, rice is a staple in Colombia, Peru, and Costa Rica but has little relevance as a caloric source in Chile, Honduras, and El Salvador. Furthermore, rice is a relevant production sector in Colombia, Peru, and Nicaragua but is a marginal sector in Chile, Guatemala, and Honduras. Variability is also found in the level of sectoral organization, with strong representativeness in some countries, such as Colombia, and poorly organized farm organizations in Peru and Honduras. The variability cited above likely has strong implications on the political economy of the rice sector and, consequently, its power to influence sectoral policy, including trade policy. The goal of this study is to analyze the political economy of rice in the selected Western Hemisphere countries, namely Chile, Peru, Colombia, Panama, and DR-CAFTA, and assess the relationship between political economy and the negotiated market access outcome.

Rice Consumption and Trade in the Caribbean: Implications for Food Security

Brown, D. and Wailes, E.J.

The Caribbean region, traditionally a major exporter of primary food products to developed countries, has today become a net importer of food. This development is due in part to the changing food production situation in the islands. This paper will examine trends in rice consumption for selected countries in the English-speaking Caribbean and relevant agricultural policies pertaining to food security. The Anglophone Caribbean Islands, which forms the Caribbean Common Market (CARICOM), has a population of just over 16 million. In this region, the earnings from cash crop export agriculture have been used to finance food imports because the combined effect of population, urbanization and income growth have had a significant impact on the quantity and composition of food consumption. To satisfy a growing demand, the Caribbean region continues to import key food products, primarily cereals and coarse grains. The changing fortunes of the Caribbean are seen in the fact that two decades ago, the Caribbean accounted for more than 2% of the world's agricultural trade but today this has declined to less than 0.3%. The UN FAO reports that Latin America and the Caribbean recorded one of the most rapid growths in per capita consumption of basic foods in recent years.

After World War II, the Caribbean region experienced a period of rapid urbanization. This large-scale movement of rural populations to urban centers, coupled with the region's historical emphasis of cash crop production for export markets is responsible, in part, for the region's inability to produce enough food for local consumption. The Caribbean region's food import bill reached approximately USD 3 billion in 2009. Jamaica and Barbados import all the rice consumed in their countries while Trinidad produces a small amount for local consumption and regional trade. Rice is a staple in Jamaica now and the level of consumption is increasing; from approximately 70 million kg in 2000 to 93 million kg in 2010.

The recent global food crisis pointed to the vulnerability of the Caribbean and highlighted the urgent need for regional agricultural production to meet food security and nutrition needs. It emphasized the need for policy makers to respond effectively to the problems relating to food insecurity. Policy makers have recognized that the Caribbean region's heavy dependence on the global economy for basic food requirements has to be seriously addressed. Caribbean scholars have pointed out that consumption and production patterns were skewed in favor of imports which can drain the local economy because such practices are not sustainable based on earnings. In Jamaica, since 2008, the Government has been trying to re-establish the cultivation of rice. To this end, the government has made

3,000 acres of land available for rice production. Polices are designed to attract investments for public-private sector partnership and plans are afoot to have more land available through the acquisition of some land formerly used for growing cane. Over the next three years, Jamaica hopes to plant eight thousand acres of rice, in an effort to satisfy at least 20 percent of domestic consumption with locally produced rice. In the wider Caribbean, a draft of a Regional Policy for Food and Nutrition Security seeks to address key policy actions and investment programs and projects that can propel CARICOM Member states in the direction of self reliance within the next 15 years. The proposed concrete actions will complement national actions to achieve food security.

Considerations on the Growing Competitiveness of MERCOSUR Rice Economy

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

Trade statistics show a significant gain in market share by the MERCOSUR region in international rice trade. While the volume and constant value of global rice trade over the last decade grew at an average of 5 and 18% a year, respectively, MERCOSUR volume of rice exports to the world grew 26%, that is, five times faster than global rice trade, and 50% in value, almost three times faster than global rice trade. While South America and the Middle East (primarily Iran) have accounted for most of its rice exports, MERCOSUR have become very competitive in other markets such as Western Africa, the fastest growing import market worldwide. Over the last few years, Western Africa has accounted for over a quarter of MERCOSUR rice exports, putting pressure on traditional rice suppliers such as the U.S. and other large Asian exporters. Rice experts tend to agree in that the MERCOSUR region has a great potential for expanding rice production given the right economic incentives, given that the resource limitations observed in other major rice producing and exporting regions, such as Pakistan and Egypt, are less constraining in MERCOSUR. Furthermore, the temperate environment where most rice is grown opens new market opportunities to expand the traditional long-grain production system into the medium/short and even fragrant rice production, expanding the potential effect to other rice market segments. The goal of this study is to describe the economics of rice production in the MERCOSUR region, and to assess the potential market impact of further increases in the competitiveness of the MERCOSUR rice sector and the implications for major rice exporters competing in world markets.

Challenges and Prospects for U.S. Rice into Cuba

Bloechl, F. and Wailes, E.J.

Rice plays a major role in the Cuban diet. In Cuba, the two main major crops are wheat and rice. Today, rice covers around 20% of the total consumed calories. In the 1960s and 1970s, wheat was the major staple food. But with the collapse of the Soviet Union, the supply of wheat was reduced and rice became more important as food in Cuba. Also, the food supply became more difficult for the Cuban population. Average grain consumption declined from 500 calories per capita per day down to 400 calories per capita per day. Since the 1970s, rice consumption in Cuba has been stable at approximately 500,000 metric tons per year. Since the 1980s Cuban rice production has declined. Recently, annual rice imports have approached 500,000 metric tons of milled rice. Approximately 80% of the Cuban rice supply is imported. The production of rice in Cuba is limited due to the shortage of water and a lack of fertilizers and modern agricultural technology. The yield per hectare remains lower than the average of Central American and Caribbean countries. Since Cuban agriculture is in crisis and cannot produce a self-sufficient food supply, most of Cuba's rice must be imported. Since the geopolitical change in 1990, Cuban trade partners have changed. In the past, the U.S. and then Thailand were the largest suppliers of rice to Cuba. Currently, China and Vietnam are the most important trade partners in terms of rice. From the point of shipping charges, trade partners, such as Vietnam, China, and Thailand, are much less competitive than the United States. Unless there is political reform in Cuba or a change in U.S. trade policy with Cuba, U.S. trade in rice with Cuba will be limited despite the competitive advantage of the U.S. in shipping logistics. Given the size of this market, there exists an incentive to supply U.S. rice to Cuba to support producers in Arkansas and other mid-south States. This paper assesses the economic benefits and losses of current U.S.-Cuban trade relations and finds overwhelmingly that costs of the status quo are very large for Cuban consumers and U.S. rice producers.

Abstracts of Posters on Economics and Marketing
Panel Chair: Bradley Watkins

Assessing Policies for Provision of Public Goods through Rice Production

Bektemirov, K.K. and Wailes, E.J.

This study examines the main public goods features associated with the rice sector and assesses policies for developing incentives for their enhanced provision. In certain respects, the rice sector looks like other economic sectors, with a large number of producers participating in markets for rice and its by-products. In other respects, it produces a number of non-commodity outputs as joint products of rice. Decision makers, consumers, and farmers should be aware that rice production may play important roles in the provision of particular public goods. Not only does rice production provide food, it also maintains natural amenities and preserves the environment by contributing to water resources management, soil conservation, and biodiversity. Furthermore, rice farming itself contributes to rural viability and helps to preserve traditional culture. Because these extra functions are closely linked with agricultural production, a certain reduction in agricultural activities may result in an environmental degradation, a food crisis, and damage to the rural economy and the cultural heritage.

The study identifies several positive and negative externalities associated with rice production and assesses those externalities, explicitly factoring them into the policy framework so that the full costs of their environmental impacts are recognized. Incentives are the result of the rules used to reward and constrain the benefits and costs of diverse activities. There is a wide range of valuable ecosystem services that are produced by adequately functioning rice farms, but historically, only a few have dominated the management goals and use of resources, including fishing and hunting. Property rights, social rules and norms, and markets have evolved to provide incentives to manage farms to produce these services. But for many others, incentives do not exist and landowners have tended to allow degradation of the capacity to produce such services in the process of responding to the incentives for the few dominant uses. Recognition of the wider range of ecosystem services that are of value can motivate an examination of incentives for their production to equalize their standing with the traditional uses incentivized by markets.

The multiple uses and functions of rice production systems are often ignored in policy reform and institutional setups and need to be better valued. Non-food ecosystem services provided by the rice landscape, such as cultural aspects, groundwater recharge, and control of soil erosion, flood mitigation and sustenance of biodiversity, including unique and endangered species, are equally often overlooked. Therefore, the environmental and socio-cultural functions of paddy farms are an important issue to be considered in policy discussions on rice production. Full social benefits of rice production can be determined by conducting a series of contingent valuations experiments. Many things can be done to optimize the environmental appearances of rice production by technology improvement, institution reform, and internalizing negative externalities.

The study explores cases of undersupply of public goods as positive externalities because of not being remunerated. A shortfall in the provision of public goods underpins the case for public intervention. The reason for this under-provision is because public goods are not supplied satisfactorily through the market and without a functioning allocation mechanism, the provision of public goods will remain below the level desired by society. This rationale for public intervention underpins a number of sectors or realms of public policy, including the provision of ecological services through rice production. In the U.S., there are several government programs from a variety of agencies that provide subsidies for provision or enhancement of ecosystem services. The extent to which these programs specifically target ecosystem services on paddies can be debated. The point is that the mechanisms are well-established; they could be tailored to target any given set of ecosystem services on any type of land. However, it is necessary to note that these are government programs, and because of government deficits and tight agency budgets, broad use of these types of programs might be constrained. Therefore, of greater interest could be incentive mechanisms that are more private sector-oriented.

Multifunctional roles of rice farming are formed by the external economies of agriculture. They have the characteristics of public goods. However, the general public goods that benefit from these multifunctional roles do not place a proper value on them. If these functions are not traded in the market, policy intervention may be required in order to maintain them. Public goods' provision through paddy fields should be politically supported by financial incentives because, depending on production systems that are incentivized, it contributes to the path towards sustainable development of agriculture and the environment.

Economic Risk and Return Analysis of Hybrid Rice Production in Louisiana

Deliberto, M.A. and Salassi, M.E.

Diversification of farm hectares with hybrid rice varieties has gained significant interest amongst rice producers in southwestern Louisiana in recent years. Economic cost of production comparisons are distinguished among conventional, CLEARFIELD®, and hybrid rice varieties. Gross income from hybrid yields are largely influenced by higher yield levels when compared with the non-hybrid varieties, making hybrid varieties appealing to produce. The necessary breakeven yield increases that are required to cover the additional production expenses are calculated for each variety and estimated over a range of rough rice market price levels. These estimates consider both owned and rented land tenure situations. Rough rice market price adjustments resulting from grading differences from milling yields are also calculated. Considering the milling characteristics of each variety can provide an accurate estimation of the economic return generated compared with assuming a uniform milling quality. Accounting for milling difference per variety does introduce more variability in returns per hectare per variety.

Abstracts of Papers on Postharvest Quality, Utilization, and Nutrition
Panel Chair: Rolfe Bryant

Consumer Taste Preference Test of U.S. Southern-grown Medium-grain Cooked Rice (*Oryza sativa* L.)

Jung, W.K. and Kwak, K.S.

Rice (*Oryza Sativa* L.) is a major staple food for much of the world population. In 2010, the United States produced 12 million tons of rice from 1.5 million ha and ranked fourth in the world export market supplying 12% of the rice to the world trade market. The long-grain rice acreage accounts for 79% and medium and short grains are remains. Long-grain rice has been produced mostly in the state of Arkansas, Louisiana, Mississippi, Missouri, and Texas, while medium- and short-grain rice has been produced mainly in the state of California. U.S. rice was consumed 58% in domestic and remains were exported to other countries. While U.S. medium-grain rice has been used for processing and table rice, Asian American has been a major consuming group of medium-grain rice as table rice in the United States. Recently, demand for high quality medium-grain rice has been increased due to greater interests in healthy diets, food safety, and taste preferences.

We evaluated the public opinion on U.S. southern-grown medium-grain rice varieties through a sensory test of cooked rice. Conventional U.S. southern medium-grain rice varieties (i.e., Bengal, CL261, Jupiter, and Neptune) were cultivated for the examination under conventional flooded and reduced nitrogen (N) fertilization condition (i.e., 80 kg N ha^{-1}) in the research farm at the University of Missouri-Columbia Delta Research Center, Portageville, MO. A taste preference test was conducted in the sensory testing facility of Department of Food Science at the University of Missouri-Columbia. The test involved 212 voluntary panels who regularly eat rice. Based on scores of sensory test categories (i.e., shape, smell, taste, stickiness, texture, and overall), there were significant different panel responses of rice taste among the rice varieties. The most preferred rice varieties by the panel were shown in order of Jupiter > Neptune > Bengal > CL261. In the question of priority to purchase rice at the market, "taste" accounted for 73% of the preference and "price" accounted for 16%. Asians and other participants who eat rice more than five times a week could detect variety differences. The non-Asian group did not have a taste preference for a specific variety. The medium-grain rice varieties used in this research were usually ranked higher by participants in the in-home taste test than by the standardized panel test in the controlled environment. The results indicate that the U.S. southern medium-grain rice variety grown under reduced N fertilization management improved grain quality and it may appeal to Asians and to other frequent rice consumers using as a table rice. Further study on high quality rice varieties and their management technologies are necessary to improve grain quality.

Rice Bran Phytochemicals and Dietary Colon Chemoprevention Teamwork

Borreson, E., Forster, G., Kumar, A., Keller, A., Chen, M., McClung, A.,
Weir, T.L., Wdowik, M., Brown, R.J., and Ryan, E.P.

A growing body of evidence supports that dietary rice bran exhibits gastrointestinal cancer control and prevention activity using carcinogen-induced animal models and human colon cancer cell lines. Our laboratory has recently reported metabolomic differences in rice from globally and genetically distinct varieties, and we hypothesize that bran compounds from these different rice cultivars exhibit variability for inhibition of colon cancer viability. Bioactive rice bran components, including tocotrienols and tocopherols (alpha, gamma, delta), gamma oryzanol, ferulic acid, total phenolics, and fatty acid profiles were quantified from 20 diverse varieties using biochemical assays, HPLC, and GC-MS. Seven varieties were selected that showed a range of total bran oil content (6-16% total lipids) and were analyzed for differences in colon cancer viability *in vitro* by alamar blue staining and MTS assays. Correlation analysis was performed to identify significant associations between bioactive compounds and colon cancer growth inhibition. Differences in the ratios and stoichiometry of rice bran components support potential for additive/synergistic effects of rice bran. Rice bran contains a number of colon chemopreventive agents that target multiple key hallmarks and metabolic mechanisms in cancer, and dietary intervention strategies with whole rice bran consumption are warranted for enhanced efficacy. Pilot data from a prospective, placebo controlled, dietary rice bran intervention study titled 'BENEFIT' (Bran-rice Enriching Nutritional Eating for Intestinal Health Trial) demonstrates translational feasibility of increasing rice bran intake in healthy adults and colon cancer survivors. The accessibility, affordability, and availability of dietary rice bran further support the strong public health impact potential for novel "phytochemical teamwork" based colon cancer control and chemoprevention strategies. This work was supported by NCI-Cancer Prevention Grant program, 5R03CA150070-2.

Got Rice? Enhancing Nutritional Qualities in Rice

Hirschi, K.D., Morris, J., Pinson, S.R.M., and Tarpley, L.

Humans and animals acquire minerals exclusively through dietary intake. These bioavailable minerals affect various developmental processes, including bone formation, immune function, and calcification. Although mineral bioavailability from fruits, vegetables. and grains has been studied for decades, we know little regarding what entities define the structural, organizational, cell biological, or molecular determinants of their bioavailability from plant matrices.

Biofortified foods offer a potentially powerful intervention tool that targets the most vulnerable people (resource-poor women, infants, and children). Recent reviews have highlighted the benefits of these foods and the various risk factors of such an approach. However, few studies have measured the most important parameter to determine the eventual successes of conventionally bred foods or genetically modified lines; namely, are these foods actually functional foods with the enhanced minerals being available for human or animal digestion and absorption?

Seed of two pure line varieties, 'Lemont' and 'TeQing,' were analyzed using ICP-MS for grain concentrations of 16 elements of nutritional or antinutritional interest, including Zn, Ca, Mg, Fe, K, and As. These genotypes were selected for study because they are the parents of two important rice gene-mapping populations. Among the elements differing most significantly in grain concentration between these two parental lines was Zn, with Lemont grains having up to 55% higher concentration of Zn than TeQing. This relationship held true for both milled and unmilled grain samples. What was not yet known was whether the increased Zn found in Lemont grains was in a bioavailable or a non-digestible form.

The mouse has become the pre-eminent mammalian model for mineral bioavailability studies because of the underlying biological similarity to humans, the emerging genomic sequence data, and the ability to manipulate the mouse genome in a targeted or random fashion. We have modified protocols previously used in rat feeding studies for analyzing calcium bioavailability in mice using radioisotopes of calcium. However, this approach cannot be used to measure Zn bioavailability. Here, we harvest tissue from mice after they have eaten various diets and measure the ionome content in the tissue. Ionomics is the quantitative and simultaneous measurement of the elemental composition of tissues, and of changes in this composition in response to physiological stimuli, developmental state and genetic modifications. Here, we report the ionome as an inference of bioavailability in various mice tissues after feeding rice diets that vary in Zn content.

To determine the bioavailability of minerals and nutrients from rice grain, we used a modified rodent chow and subsequent ionome analysis of liver and spleen tissues. C57/BL6 mice were stratified at 42 days of age and fed either normal chow or two different minimal rice chows. These diets used grains of either Lemont (high Zn) or TeQing (low Zn) rice harvested from 2005 research plots that were milled then ground. Sucrose, corn oil, and casein were added to the ground rice powder at 10, 7, and 15% (w/w), respectively, to provide simple sugars, fat, and protein to the test diets. The diets were isocaloric. Mice were weighed at the beginning of feeding and after 21 days consuming the rice diets. After 21 days, the mice were euthanized and tissues removed. The liver and spleen were placed in microcentrifuge tubes and dried at 70 C for 24 hours. After drying, the samples were ashed in a muffle furnace at 500 C for 16 h. The remaining inorganic materials were dissolved in 0.1N HCl. The samples were then analyzed by ICP-MS to determine the concentrations of various minerals.

The mice fed the Lemont minimal diets gained slightly less weight than control animals while the TeQing diet produced animals with similar weights as the controls. The concentrations of minerals in the mice livers were similar between the control and TeQing diets while the Lemont diet produced higher concentrations of zinc, magnesium, calcium, potassium, phosphorus, and sodium. Liver concentrations of iron from both treatment diets was lower compared with those from animals fed normal chow. Concentrations of zinc, calcium, and iron in the spleens of mouse fed the two rice diets was much lower compared with normal chow diets. There was little difference in sodium or magnesium concentrations among the three diets.

The present study suggests that the differences in Zn concentration between Lemont and TeQing equate to differences in bioavailability. From this observation, we posit that is a worthwhile scientific endeavor to identify QTLs associated with grain element concentrations among the Lemont x TeQing and other mapping populations because these differences appear to reflect traits important not just for nutrient composition but also for nutrient bioavailability.

Functional Starch in Parboiled Rice and Its Benefits on Postprandial Blood Glucose Level in Humans

Newton, J., Poquette, N., Lee, S.-O., and Wang, Y.-J.

It has been reported that the parboiling conditions can be altered to promote the formation of ordered starch structures, thus decreasing starch digestibility. This work investigated the effects of cultivar and feedstock under different parboiling, storage, and milling conditions on the starch fractions (rapidly digestible starch, RDS; slowly digestible starch, SDS; and resistant starch, RS) in the resultant parboiled rice. We also studied the postprandial blood sugar level in 14 healthy men after consuming one parboiled rice product high in SDS and RS. Rice was soaked, steamed under pressure, dried immediately or stored at room temperature for 24 hr prior to drying, and then treated with or without repeated steam cycle prior to milling. Starch fractions in parboiled rice were significantly affected by cultivar and storage and the interactions of cultivar and parboiling conditions. The storage treatment significantly increased SDS and generally decreased RDS in parboiled rice. After consuming the rice product, subjects showed significantly lower blood glucose response at 15, 30, 45, 60, 75, and 90 min in comparison with the control glucose solution. In addition, the incremental area under curves of plasma insulin response reduced significantly to 37-40% when subjects ingested the rice product compared with the glucose solution. Results suggest the parboiled rice product high in SDS and RS would assist in managing blood glucose levels for individuals suffering from diabetes.

Rice Degree of Milling Effects on Extractable Starch and Real Degree of Fermentation

Teague, J.T., Siebenmorgen, T.J., and Lanning, S.B.

Rice is often used as a starch adjunct in the brewing process. The brewing industry aims to maximize the amount of extractable starch and fermentable sugars (known as Real Degree of Fermentation, or RDF) from rice. The amount of lipids left on rice kernels after milling is also of concern to brewers, as lipid oxidation can affect beer quality.

Degree of milling (DOM) has a strong effect on several quality parameters in rice, including milled rice yield (MRY), head rice yield (HRY), sensory aspects of cooked rice, and rice pasting properties. Surface lipid and protein contents decrease with increased DOM, but the effect of DOM on extractable starch and RDF has not been reported. Moreover, pureline and hybrid cultivars have unique physiological properties that produce different milling characteristics. The effect of differences in milling characteristics between hybrid and pureline cultivars with respect to extractable starch and RDF has not been reported.

This study was conducted to determine the effect of DOM on MRY, HRY, extractable starch, and RDF of several pureline and hybrid rice cultivars. Nine cultivars were used in the study: four pureline cultivars (Wells, CL 181, Cheneire, and Taggart) and five hybrid cultivars (CL XL729, CL XL745, CL XL751, CL XP752, and CL XP756). Rough rice samples (150 g) were milled in a McGill No. 2 laboratory-scale mill for 10, 20, 30, or 40 s. Surface lipid content was measured for each sample to determine DOM, and MRY, HRY, extractable starch, and RDF were measured and analyzed with respect to SLC.

Degree of milling significantly affected MRY and HRY in that both decreased as SLC decreased, but at different rates for each cultivar. This confirms that SLC should be considered when comparing milling yields. Conversely, extractable starch percentages increased slightly, yet significantly, with decreasing SLC. However, DOM had no significant effect on RDF. There was no DOM and cultivar interaction for extractable starch or RDF, indicating the effect of each is independent and can be considered the same across cultivars.

Maximizing both MRY and extractable starch percentage is desirable for the brewing industry. The results suggest that since MRY decreases, but extractable starch percentage slightly increases, as rice is progressively milled to lesser SLCs, the brewing industry should consider both measurements in assessing the optimal economic DOM level to maximize the amount of starch available for brewing. Because the extractable starch percentage change with SLC was slight, it is speculated that MRY levels would drive this assessment and that rice used for brewing could be milled less, i.e., to a higher SLC, to gain more available starch, provided that increased lipid and protein content does not affect beer quality.

Degree of Milling Effects on Rice Cooking Characteristics and Texture

Billiris, M.A. and Siebenmorgen, T.J.

Milling rice to lesser degrees, that is leaving more bran on milled kernels, can lead to greater milling yields and potential human nutrition benefits. Additionally, rice milled to lesser degrees requires less energy for milling. However, milling to lesser degrees could decrease water absorption rates, thereby increasing cooking durations, leading to greater energy use for cooking. The purpose of this study was to assess the effect of degree of milling (DOM) on cooking characteristics and texture of non-parboiled and parboiled rice. Commercial milling equipment was adjusted to produce parboiled and non-parboiled rice samples that were milled to varying DOMs, including brown rice lots having no milling. The rice lots were milled to four DOMs; 0.15, 0.20, 0.40, and 0.55% surface lipid content (SLC) for non-parboiled rice and to 0.40, 0.45, 0.70, and 0.95% SLC for parboiled rice. Moisture content of cooked rice, which was used as an indicator of water absorption rate, was determined as a function of cooking duration using an oven method. Peak force of cooked rice, which indicates cooked rice hardness, was determined as a function of cooking duration using instrumental texture analysis. To assess the gelatinization kinetics of non-parboiled rice with various milling degrees, the number of gelatinized kernels was determined as a function of cooking duration using the Ranghino test.

For a given SLC, the number of gelatinized kernels increased as cooking duration increased until all kernels were gelatinized, which occurred at after approximately 20 minutes for non-parboiled milled rice and after 33 minutes for brown non-parboiled rice. Hardness of cooked rice decreased as cooking duration increased leveling off for cooking durations of 40 minutes or greater for non-parboiled milled rice and for cooking durations of 50 minutes or greater for non-parboiled brown and parboiled rice, for all SLCs. Moisture content of cooked rice increased as cooking duration increased for all SLCs, leveling off for cooking durations of 50 minutes or greater for non-parboiled milled rice. Moisture content of parboiled and non-parboiled brown rice did not reach a steady state before 60 minutes of cooking. Cooking kinetics and texture trends were found to be similar among rice samples with SLCs ranging from 0.15 to 0.55% for non-parboiled rice and among rice samples with SLCs ranging from 0.40 to 0.95% for parboiled rice. Therefore, non-parboiled rice could be milled at least up to 0.55% SLC and parboiled rice at least up to 0.95% SLC without affecting cooking kinetics and texture. Non-parboiled and parboiled brown rice cooking kinetics and texture were found to be significantly different from those of the milled rice samples. Within the SLC range tested, this study suggests that cooking durations would not need to increase for rice milled to lesser degrees, and thus the energy used for cooking rice should not increase when rice is milled to lower degrees.

Single-pass Drying of Rough Rice Using Glass-transition Principles: Effect on Milling Quality

Ondier, G.O. and Siebenmorgen, T.J.

Drying rice in a single pass could increase dryer throughput thus easing the congestion observed in most commercial drying facilities during the harvest season. Rice samples harvested at moisture contents ranging from 17.8 to 18.1% from different locations in Arkansas were used for this study. Drying experiments were conducted at 60, 70, and 80°C and relative humidities ranging from 13 to 83%. Long-grain pureline cultivars Wells and Francis, medium-grain pureline cultivar, Jupiter, and long-grain hybrid cultivar, CL XL729, were dried from harvest moisture content to the desired 12.5% moisture content in a single-pass. At the end of drying, samples were tempered in the drying container or in plastic bags at the drying air temperature for 0, 30, and 60 min. The effects of drying air temperatures and relative humidities, tempering methods, and tempering durations on milling quality of rice dried in a single pass were determined.

For all drying air temperatures and tempering methods, milling quality was not significantly different from the control when the relative humidity of the drying air was maintained above 63% and rice was tempered for at least 60 min at the drying air temperature after drying. Single-pass drying with minimal reduction to milling quality was achieved at the low relative humidities by tempering in a sealed environment with limited headspace for at least 60 min. The reduced headspace minimized moisture loss from kernels into inter-particle air, thus preventing continued drying.

High-temperature Exposure Impacts on Rice Functional Properties

Siebenmorgen, T.J. and Ambardekar, A.A.

Rapid drying using high-temperature air has gained interest in the rice industry, but the effects of elevated-temperature exposure on physicochemical properties are of concern. This study investigated the effects of exposing rough rice to elevated temperatures for various durations without removing moisture. Physicochemical property response was evaluated in terms of head rice yield (HRY), germination percentage, milled-rice yellowing, pasting properties, and gelatinization temperatures. Two long-grain cultivars, pureline Wells and hybrid CL XL729, at initial moisture contents (IMCs) of 17.9 and 18.6%, respectively, and dried moisture content (DMC) of 12.5%, were hermetically sealed and exposed to 40°, 60°, and 80°C for various durations.

Exposure to 40° and 60°C did not affect HRY for either cultivar or MC level, regardless of exposure duration. Exposing samples of Wells and CL XL729 at IMC to 80°C for 4 h resulted in significantly reduced HRYs of 2.3 and 2.5 percentage points, respectively. A slight trend for reduced HRY of both cultivars at DMC was observed at the 80°C/4-h exposure, but was statistically insignificant. Exposure of rice to 40°C, regardless of cultivar, MC, or duration, did not affect germination percentage. While a 2-h, or longer, exposure of both cultivars at IMC to 60°C completely inhibited germination, shorter exposure of either cultivar at IMC or DMC had little impact on germination percentage. In contrast, exposure of the cultivars to 80°C, at both IMC and DMC, completely inhibited germination.

Exposure to 80°C for even very short durations and to 60°C for durations greater than 4 h produced significant yellowing in both cultivars at IMC. Significant yellowing in both cultivars at DMC was also observed during a 28-day storage following 80°C exposure. In general, peak viscosities of both cultivars, at both moisture contents, increased only after extended exposure to 40°C, but peak viscosities increased sharply and immediately upon exposure to 60° and 80°C. No significant differences were observed in gelatinization temperatures of either cultivar, at either moisture content, from elevated-temperature exposure.

Results from this study suggest that extreme-temperature exposure of rough rice affects HRY, germination percentages, yellowing, and pasting properties. The extent of impact is dependent on duration of exposure and rough rice moisture content.

Extreme Nighttime Air Temperatures in 2010 Impact Rice Chalkiness and Milling Quality

Lanning, S.B., Siebenmorgen, T.J., Counce, P.A., Ambardekar, A.A., and Mauromoustakos, A.

Previous research has shown that elevated nighttime air temperatures (NTATs) are correlated with increased chalk formation and reduced milling quality in rice. To evaluate these effects at the field level, three long-grain, pureline cultivars, Cypress, LaGrue, and Wells; one long-grain, hybrid cultivar, XL723; and two medium-grain, pureline cultivars, Bengal and Jupiter, were grown and harvested across northern to southern locations in Arkansas during a 4-year field study from 2007 to 2010. Growing locations were strategically selected to increase the probability of NTAT differences during rice reproductive stages. Arkansas rice-growing regions experienced exceptionally warm weather conditions during the summer of 2010, providing a wide temperature range under which to more robustly quantify NTAT impacts.

In a randomized block design, 18 experimental plots were assigned at each location, such that each of the six cultivars was planted in three randomly-assigned plots. Air temperatures were recorded at 30-minute increments throughout the growing season at each of the locations. Temperatures recorded during the time of day extending from 8:00 p.m. to 6:00 a.m. were considered NTATs. Cultivars grown in Stuttgart, AR, were visually observed throughout their reproductive developmental (R) stages and the day-of-year (DOY) upon which the distinguishing morphological characteristics of each R-stage (R2-R9) appeared was recorded for each cultivar. At the other locations, only the R3 stage was visually identified for each cultivar. The subsequent stages and the DOYs of their initiation for each cultivar at each location were estimated using the Stuttgart staging progression data and the amounts of thermal energy accrued through air temperature exposure at each location.

After harvest, triplicate samples from each year/location/cultivar combination were dehulled, and the resultant brown rice was measured for the presence of chalk using an image analysis technique. Additional sub-samples were milled and separated into head rice and broken fractions. Head rice yield (HRY) analysis included only those lots that were harvested within the optimal moisture content (MC) ranges of 19-21% for long-grain and 22-24% for medium-grain cultivars. Head rice yields associated with these lots were considered to be peak HRYs (pHRYs) and were used in order to minimize the effects of immature kernels and/or fissuring associated with varying harvest MC, thereby focusing on the effects of NTAT on milling quality. The 95th percentiles of NTAT frequencies (NT_{95}) occurring during the R-stages of each cultivar were then calculated and correlated with chalk and pHRYs.

Long-grain cultivars produced chalk values that were positively correlated, and pHRYs that were inversely correlated to NT_{95} during the R5 through R8 stages. Medium-grain cultivars, which in previous studies showed little or no response to elevated NTATs during all R-stages, also showed significant correlations during the R7 and R8 stages; this is believed to be due to the inclusion of the extreme NTATs observed in 2010. As with the long-grains, medium-grain correlations between chalk and NT_{95} were positive, while correlations between pHRY and NT_{95} were negative. The 4-year data set revealed the relationships of chalk vs NT_{95} and pHRY vs NT_{95} to be quadratic in nature for all cultivars, suggesting that an optimal temperature range may exist, above which chalk formation is triggered and subsequent pHRYs are affected. The extreme temperatures observed in 2010 verified that while cultivars vary in their level of resistance to NTAT effects, all of the rice cultivars analyzed throughout the study exhibited some degree of susceptibility to extreme NTAT temperatures occurring during critical grain-filling stages.

Effects of Nighttime Air Temperature during Kernel Development on Rice Physicochemical and Functional Properties

Lanning, S.B., Siebenmorgen, T.J., Ambardekar, A.A., Counce, P.A., and Bryant, R.J.

Elevated nighttime air temperatures (NTATs) occurring during critical grain-filling stages affected rice physicochemical properties, which impacted functional quality. Three long-grain, pureline cultivars, Cypress, LaGrue, and Wells; one long-grain, hybrid cultivar, XL723; and two medium-grain, pureline cultivars, Bengal and Jupiter, were grown and harvested across northern to southern locations in Arkansas during a 4-year field study from 2007 to 2010. Growing locations were strategically selected to increase the probability of NTAT differences during rice reproductive stages.

In a randomized block design, 18 experimental plots were assigned at each location, such that each of the six cultivars was planted in three randomly-assigned plots. Air temperatures were recorded at 30-minute increments throughout the growing season at each of the locations. Temperatures recorded during the time of day extending from 8:00 p.m. to 6:00 a.m. were considered NTATs. Cultivars grown in Stuttgart, AR, were visually observed throughout their reproductive developmental (R) stages and the day-of-year (DOY) upon which the distinguishing morphological characteristics of each R-stage (R2-R9) appeared was recorded for each cultivar. At the other locations, only the R3 stage was visually identified for each cultivar. The subsequent stages and the DOYs of their initiation for each cultivar at each location were estimated using the Stuttgart staging progression data and the amounts of thermal energy accrued through air temperature exposure at each location. The 95th percentiles of NTAT frequencies (NT_{95}) were then calculated for each cultivar's R-stages and correlated with physical, chemical, and functional properties.

Amylose content and crude protein content decreased linearly, while total lipid content increased linearly with increasing NTATs occurring during the grain-filling stages (R6-R8). Effects of NTAT on proximate composition influenced functional properties. Peak viscosities increased linearly as NTAT increased, while setback viscosities decreased. Setback viscosities were linearly correlated to NTATs for medium-grain cultivars, but correlations for the long-grain cultivars were quadratic. Gelatinization temperatures (GTs) increased linearly with increasing NTAT; slopes were not significantly different among cultivars, and the average rate of increase in GT across all cultivars was 0.5°C for every unit increase in NT_{95}.

The R-stages in which correlations were strongest varied by cultivar and by property. It is hypothesized that this variation is due to differences in kernel development patterns among cultivars. Since the staging system used in the study is based on the first kernel progression on the main-stem tiller, it is possible that a plant classified in the R8 stage may have the majority of its kernels in the R6 and/or R7 stages.

These findings have significant implications for rice production scientists and processors. Understanding the effects of NTAT on physicochemical and functional properties may help explain and reduce quality variation.

Reproductive Timing and Rice Quality Determination

Counce, P.A., Siebenmorgen, T.J., Bryant, R.J., and Ambardekar, A.A.

Conditions during reproductive growth stages largely determine rice yield and quality. Consequently, determining the timing and the duration of various reproductive growth stages is critical to understanding rice plant responses to environmental conditions. The following study was conducted.

Three long-grain (Cypress, LaGrue, and Wells) and two medium-grain (Bengal and Jupiter) pureline cultivars and a long-grain hybrid (XL723) cultivar were grown at Stuttgart AR, as part of the Arkansas Rice Performance Trials (ARPT) each year from 2007 to 2010. Eighteen experimental field plots in each year were arranged in randomized complete blocks with each of the six cultivars planted in three replications. Each of the five pure-line rice cultivars (Bengal, Jupiter, LaGrue, Cypress, and Wells) and a hybrid (XL 723) were drill-seeded at the nine-row (0.18-m.

spacing) plots, which were 4.57-m long. Plots received 120 to 135 kg N ha^{-1} as a single application of urea at the V3 to V6 growth stage within one day of flooding. Management practices, including planting dates, flooding, fertilization and pesticide applications, were carried out to achieve near optimum yields. The permanent flood was applied and maintained until at least two weeks after rice reached the 50% heading stage.

In this study, the data collection process for staging process started with tagging a set of culms at stage R2. Subsequently, the date of each individual panicle was recorded daily beginning at R3 and ending with R9. Stage R3 refers to beginning panicle exertion from the collar of the flag leaf of the main stem. R3 is also known by practitioners as "heading" referred to in standard plot notation as the 50% heading date, the date at which 50% of the panicles in a field emerge from the sheath of flag leaf or have reached R3 stage. The "flowering" stage, or R4, indicates that one or more florets on the main stem panicle have reached anthesis (anther and the filament emerge from the floret). The R5 stage occurs when at least one caryopsis on the main stem begins to elongate. The start of the grain-filling stage is termed R6 and is determined when at least one caryopsis on the main stem panicle completely lengthens to the end of the hull. The stages at which one yellow hull and one brown hull appear on the main stem panicle are termed R7 and R8, respectively. The stage R9 occurs when all grains on the panicle that had reached the R6 stage have completed R8 Stage. At R6, R7, and R8 plant growth stages, there are some individual grains at R6. The duration of grain filling for the crop, therefore, occurs in plant growth stages R6, R7, and R8 and the interval from beginning R6 and ending at R9 is the grain filling period for the crop. The R6 grains during plant stage R6 fill rapidly, the R6 grains at plant growth stage R7 fill more slowly and the R6 grains at plant growth stage R8 fill even more slowly.

For the duration of R3-R9, R6-R9, and Growth Stage R8, there were significant cultivar and year effects with no cultivar by year interactions. Cypress had the shortest intervals in days for R8, between R3 and R9 and between R6 and R9. For the intervals R3-R9 and R6-R9, LaGrue, Wells, and XL723 were intermediate between Cypress and the two medium grains (Bengal and Jupiter). Cultivar rankings for the intervals in DD50 units for R3-R9 and R6-R9 were the same as those for days. LaGrue and Wells did not differ for R8 in days from XL723 and were shorter than R8 for Bengal and, Jupiter. R8 in days were shorter for Bengal and XL723 than for Jupiter. Rankings for R8 in DD50 units were the same as those for R8 length in days except that Bengal and Jupiter did not differ for R8 length in DD50.

The ramifications of these results are important for a number of reasons. At least part of the stability of head rice yield in Cypress is related to the shorter R8 period for Cypress. This, in turn, is likely at least partially related to the shorter panicle with fewer grains per panicle for Cypress compared to the other cultivars. Subsequent analysis of data from the ARPT from all locations in 2007 through 2010 has shown a consistent negative relationship between nighttime temperatures at R8 and head rice yield and a positive relationship with nighttime temperature and chalk. The slowest growing grains are at R6 when the plant is at Growth Stage R8. Consequently, the grain filling conditions during R8 are likely associated with overall quality parameters due to the slower growing grains which are exposed to ambient air and radiation conditions longer than the earlier filling grains. Research is being continued and extended on this subject. Collection of accurate growth staging information can improve the value of a wide range of experiments with rice including not only pre-harvest, quality considerations but also experiments with production practices, plant protection, and breeding.

Putative Fissure-Resistance QTLs Mapped to Chromosomes 1 and 8 Based on Allelic Frequency Differences Observed Between Fissure-Resistant and Fissure-Susceptible Progeny from Two Segregating Populations

Pinson, S.R.M., Gibbons, J., Jia, Y., and Yeater, K.

Whole rice kernels have two to three times more market value than brokens, which means that any reduction in milling yield results in financial losses for both rice producers and millers. One of the primary causes of rice breakage during milling is fissuring of the rice before it even enters the mill. A common cause of rice fissuring is the exposure of drying, mature kernels to humid field or postharvest conditions that cause the outer layers of the kernels to reabsorb moisture and swell, creating an inward pressure on the endosperm that can cause it to crack. Rain and dew are common causes of rice field-fissuring. 'Cypress,' a southern U.S. variety released in 1993, is known for its resistance to kernel fissuring but is not grown widely today, having been replaced with cultivars having higher yield potential and disease resistance. While breeders would like to incorporate Cypress' fissure resistance into improved cultivars, their efforts have been limited due to a lack of methods for identifying and selecting for fissure-resistance in early breeding generations.

Marker-assisted selection is based on the principle that when markers linked to the genes affecting a desired trait are selected for the physically linked gene(s) and conferred trait are also in the selected individuals. But the reverse also holds true. The present study was accomplished by selecting for fissure resistance (FR) versus fissure susceptibility (FS) phenotype in two populations, then identifying molecular marker alleles that were present in different proportions within and between the FR and FS subgroups. A laboratory method wherein small samples of seed are evaluated for fissure rates after exposure to controlled rewetting conditions was used to divergently select for the 10% most FR and the 10% most FS progeny among 300 Cypress x 'LaGrue' F_2 progeny, then F_3 progeny testing conducted in both TX and AR, two replications per State was used to verify the F_2 phenotypic selections. The laboratory evaluation method was also used to select 30 FR and 30 FS lines from among 280 Cybonnet x Saber recombinant inbred lines (RILs) that were grown and then progeny tested in four replications over two states. With fewer chances for recombination, linkage blocks are larger in F_2 progeny than in RILs. The larger the linkage blocks in a mapping population, the fewer markers are needed to tag the genome and identify statistically significant marker-trait linkages. Therefore, we first characterized the FR and FS Cypress x LaGrue F_2 progeny for 85 SSR markers scattered throughout the rice genome with a maximum marker gap of 30 cM, then characterized the Cybonnet x Saber RILs for markers on chromosomes 1 and 8 in order to cost-effectively verify and map in greater detail the fissure-resistance loci detected on these two chromosomes.

Strong linkage between semidwarf plant height and FR was identified while conducting F_3 progeny testing to verify the divergent FR and FS Cypress x LaGrue F_2 selections. Cypress (FR) is semidwarf while LaGrue (FS) is tall, making segregation for height among the F_2 and F_3 progeny anticipated. What was not anticipated was that all of the FR F_3 progeny were of semidwarf height, while mostly tall but also some short F_3 progeny were noted among the FS selections. This suggested that at least one of Cypress' FR genes is linked to the *sd1* allele on chromosome 1. Since the *sd1* gene was detected among some of the FS progeny, however, it also suggested that to achieve the strong FR exhibited by Cypress, this FR gene required assistance from at least one other FR gene located elsewhere in the genome. The present marker analysis of FR and FS Cypress x LaGrue F_2 selections confirmed linkage disequilibrium for a section on the end of the long arm of chromosome 1 that contained the known location of the *sd1* gene. Marker disequilibrium was also detected on a region of chromosome 8. The FR and FS Cybonnet x Saber RILs were then characterized for markers in these two chromosomal regions, and linkage disequilibrium in this second population confirmed the presence of FR loci on these two chromosomes. It is important to note that both Cybonnet and Saber are semidwarf in height do to the *sd1* allele. If the association between *sd1* and FR had been noted only among the Cypress x LaGrue progeny, it would have suggested that FR was associated in some way with the short stature and/or other plant architectural changes associated with the *sd1* gene. However, the fact that analysis of the Cybonnet x Saber RILs also indicated linkage between markers near *sd1* and FR without segregating for *sd1* or plant height suggested instead that a FR gene is linked to but not allelic with the *sd1* locus.

The entire set of 280 Cybonnet x Saber RILs were then characterized for SSR markers along both chromosomes 1 and 8 so that the location of the FR loci could be determined more precisely by using multiple interval mapping analysis, conducted using QGene software. This analysis placed LOD peaks for FR between RM404 and RM22952 on chromosome 8, and suggested the existence of two FR loci on chromosome 1, one between RM6292 and RM104 near but distal to the position of *sd1*, and another on the short arm of chromosome 1, near RM580.

Comparison of Moisture Predictions among Different Rice Drying Models

Pan, Z., Prakash, B., and Bingol, G.

Mathematical modeling of moisture movement within rice kernels is a very important method for optimizing drying processes. In last three decades, different standard geometries such as sphere, cylinder, prolate spheroid, and ellipsoid were considered to represent the rice kernel in models. In this study, our goal was to compare the predicted rice moisture during drying using the models based on different shapes. We developed models for the four types of shapes to describe moisture in different rice forms namely white rice, brown rice, and rough rice. We solved these models by finite element method in COMSOL Multiphysics simulation program. Analytical solutions were used to validate the model predictions when they were available. Each model was run in identical drying conditions and root mean square error between their moisture predictions and experimentally measured moisture were determined. Drying experiments were conducted for medium-grain rice variety M206 in the three rice forms by heated air at 25º, 35º, and 45ºC. Models of all four shapes predicted average moisture reasonably well. Among these models, sphere-shaped rice models predicted slowest drying profiles for same diffusivity of rice components. Information obtained from this study could help choose suitable shapes for modeling rice drying.

Determining Amylose Content of Milled Rice Using a Rapid Colorimetric Analysis

Grigg, B.C., Ambardekar, A.A., Siebenmorgen, T.J., and Pereira, T.

Amylose content (AC) of rice is considered an important predictor of cooking and processing performance. Several methods have been utilized to determine AC of rice. However, these methods are either time-consuming (AACC 61-03.01 and ISO 6647-2:2007) or require expensive equipment. The goal of this study was to use a colorimetric method to develop a predictive model for head rice AC using minimal time and equipment.

Using the standard method for routine AC analysis (ISO 6647-2:2007), a standard curve for AC versus absorbance ($ABS_{720\ nm}$) was generated with five rice-flour standards of known AC (0 to 25%). These standards, originating from the International Rice Research Institute (IRRI), were provided courtesy of the International Network for Quality Rice (INQR). Using this method, starch granules from rice flour standards were broken down into amylose and completely dispersed into solution by soaking the flour in a 9 mL of a 0.09 *N* sodium hydroxide for 12 h, then adding 0.1 mL of 1 *N* acetic acid and 0.2 mL of an iodine solution (0.2 g iodine and 2.0 g potassium iodide in 100 mL deionized water), then adjusted to a final 10 mL volume with deionized water. This final solution was mixed for 1 min, allowed to stand for 20 min, and $ABS_{720\ nm}$ of the iodine-starch complex was measured using a spectrophotometer (Beckman DU520, Fullerton, CA). Amylose content was then plotted against $ABS_{720\ nm}$ to create a standard curve. A strong linear relationship (R^2 = 0.99) between $ABS_{720\ nm}$ and known ACs of the standard rice-flours was observed.

For development and validation of the proposed predictive model, 24 samples of rough rice, comprising 1 waxy, 3 short-, 10 medium-, and 10 long-grain cultivars with a broad range of ACs, were harvested between 2009 and 2011. These samples were cleaned and conditioned to approximately 12.5% moisture content, and four milling replicates were prepared from each sample. Each milling replicate was de-hulled, milled, and separated into head rice and broken fractions. The resulting head rice was defatted by swirling in a 70% ethanol solution for 3 min, and was then reconditioned to 12.5% moisture content.

For each milling replicate, 5 g of head rice was ground into flour, and AC determined using the standard method and standard curve. For the predictive model, 10 sub-samples of head rice (9 g) from each milling replicate were stained by soaking in 27 mL of an iodine solution (0.5 g iodine and 2.5 g potassium iodide in 1 L deionized water) for 10 min, thoroughly drained, and subjected to colorimetric analysis. International Commission on Illumination (CIE) $L*$ and $b*$ scalar values were measured for each sub-sample using a spectrophotometer (HunterLab ColorFlex 45/0, Reston, VA). Analysis of covariance (ANCOVA, α = 0.05) was used to evaluate precision between sub-samples, and between slopes of regression lines for each milling replicate. $L*$ and $b*$ averages were calculated for each sample/milling-replicate/sub-sample, and were linearly regressed with AC to create predictive models. Linear regression and ANCOVA were performed using JMP v.8 (SAS Institute, Cary, NC).

Amylose content ranged from 0.1 to 26.1% for the 24 test samples. Visual differences were apparent in the color of iodine-stained head rice as a function of AC, with waxy rice exhibiting a more yellow color, and short- to long-grain cultivars exhibiting increasing purple intensity, corresponding to increasing AC (waxy < short-grain < medium-grain < long-grain cultivars). Visual observation was confirmed, as linear regression lines of *L** and *b** values versus AC were strongly correlated (R^2 = 0.96 and 0.97, respectively). As determined using ANCOVA, no significant differences were observed between sub-samples of a milling replicate, nor were there significant differences between slopes of regression lines for milling replicates. Precision of the staining method was validated, as ANCOVA showed no significant differences in *L** and *b** values among sub-samples, and among slopes of lines of the predictive model among milling replicates. Accuracy of the predictive models was validated by the strong correlation coefficients of the predictive models. The quality of the predictive model for AC would likely be improved with additional samples, particularly short-grain rice cultivars of low AC. Results of this study indicate that AC of an individual sample can be predicted from *L** and *b** values of head rice kernels stained by the developed technique. Although further testing is warranted, the findings suggest that this colorimetric method could potentially be used in situations where instrumentation and/or time constraints do not allow the standard method to be applied.

Genetic Variation and Association Mapping of Protein Concentration in Rice Using a Germplasm Collection

Bryant, R.J., Jackson, A., Yeater, K., Yan, W., Fjellstrom, R., and McClung, A.M.

Rice protein is an important source of nutrition and energy for a majority of the world's population. However, the protein concentration in rice can have an impact on its flavor, texture, cooking, and processing quality, thus, affecting its acceptability. It is, therefore, important to know if markers for protein concentration can be identified.

An association analysis for protein concentration in brown rice was performed using a "Mini-Core" set of 200 accessions representative of the germplasm diversity found in the USDA world collection (>18,000 accessions) of rice. The accessions were from 14 global regions and contained representatives from *O. glaberrima*, *O. rufipogon,* and five sub-populations of *O. sativa*. Protein concentration was determined in replicated trials conducted in two southern states, AR and TX, and analyzed for its association with 165 genome-wide DNA markers. The markers were distributed across the genome approximately every 10 cM.

Among the accessions, the average protein concentration ranged from 4.9 to 11.9%. The accessions grown in AR had a higher protein concentration then those grown in TX, 5.8 – 11.9% and 4.9 – 11.1%, respectively. Ample variation was seen within each of the rice subpopulations of rice, as well as the 14 geographic regions that the accessions originated from. Accessions from Eastern Europe had the highest level of protein. There was also an effect due to location and accession x location (GxE) interaction demonstrating the importance of assessing protein concentration across multiple environments.

Nine markers on eight chromosomes were significantly associated with protein concentration. Three of these markers had been previously reported in other mapping studies. Marker RM125 overlaps a QTL associated with for albumin storage proteins (RA5, RA14, and RA17) and is within 0.3 Mb of a predicted prolamin precursor. Marker RM302 is within 1 Mb of GluA-1, a glutelin gene, and marker RM541 is within 1.5 Mb of a predicted prolamin gene. Our results provide germplasm and genetic markers that will assist breeding efforts to develop cultivars that have either high or low protein concentration.

Structural and Genetic Factors Influencing Rice Milling Quality

Abayawickrama, A.S.M.T., Harper, J., Reinke, R., Fitzgerald, M., and Burrows, G.

Head rice yield (HRY) is the primary parameter used to quantify rice milling quality. HRY is defined as the weight percentage of rough rice that remains as head rice (kernels that are at least 75% of the original kernel length) after complete milling. The rice industry predominantly targets whole grain export markets. HRY reduction decreases the value of rice since broken kernels are typically worth half the value of head rice. On average 10% and 20% of rice grains are discarded due to breakage during milling. In addition, cooking and eating quality is reduced with the presence of broken grains. Grain fissuring is considered one of the key factors that affect breakage during the milling process thus reducing HRY. The occurrence of fissuring is influenced by environmental and genetic factors. The problem of grain fissure has been longstanding, despite considerable research, attempts to breed fissure out of rice have been unsuccessful. The objectives of this study are to determine the effects of environmental factors; moisture adsorption and removal during storage on grain fissuring. Determination of efficient fissure evaluation method and grain structural properties related to fissure resistance will be investigated in the proposed project. Further, recombinant inbred lines (RILs) derived from hybridization between Cypress, a variety with fissure resistance and YC-53-00-7, a fissure susceptible variety will be used to explore the QTLs responsible for grain fissure resistance. This project aims to generate a platform for a molecular breeding program to increase HRY through incorporation of fissure resistance in rice. Two rice varieties resistance to grain fissuring; Reiziq (medium grain) and Cypress (long grain) and two varieties that are susceptible to fissuring; Baru (medium grain) and YC-53-00-7 (long grain) will be raised in pots inside the glasshouse.

Randomized complete block design will be used with five replicates. Temperature inside the glasshouse is controlled at 25/27ºC and light/dark 11/13 hrs. Plants will be harvested at 20-22% moisture content. Harvested seed will be gently dried down to 12% moisture content. Thereafter, sampling will be separated into two lots, namely A and B. Then, the moisture content of both A and B samples will be gently increased up to 18 and 25%, respectively. Again, the moisture content of both lots will be dried down to 12%. At the end of each cycle, samples will be taken for analysis. First cycle samples will be used as the control. Evaluation of grain appearance after milling will be done using the Cervitec (Grain Inspector). The optimum moisture content at harvesting and storage is 22 and 12%, respectively. After drying, moisture adsorption and removal have a close relationship with grain fissuring. The fissure formation takes place by tension forces when the outside of the kernel absorbs water and expands while the inside is still dry and brittle. Perfect grains (fully matured) from the control and stressed treatments will be examined by the scanning electron microscope to compare the pattern of fissure formation, compactness of the packing of amyloplasts, and the cellular arrangement. The mapping populations or the F_4 generation of Cypress x YC-53-00-7 will be adopted by the single seed descent method. Seeds of individual plants will be harvested as they approach 20% grain moisture. Rough rice samples will be dried to 12% moisture using an ambient-forced-air drier and will be then stored in sealed plastic bags until phenotypic analysis. Illumina SNP BeadXpress with IRRI's *indica/japonica* SNP chips will be used to identify mutations in candidate genes, which are responsible for grain fissure formation. Primers will be designed to screen QTLs association allelic state with grain fissuring, thereby allowing them to be used as putative molecular markers in breeding programs.

Properties of Gluten-free Pasta Prepared from Rice and Different Starches

Mertz, A.W. and Wang, Y.-J.

Rice is one of the few cereal products that do not contain gluten. However, the absence of gluten poses problems in the structure of and cooking quality of rice pasta. The objective of this project was to investigate the addition of starch on the physicochemical properties and cooking quality of rice-based pasta. Rice-based pasta was prepared from parboiled long-grain rice flour with the addition of 25% cooked starch from different sources. The color and pasting properties of the ground pasta flour were measured, and the pasta was cooked to the optimum cooking time to evaluate its textural attributes. The water absorption and cooking loss of pasta were determined by weight difference. Overall, the addition of starch improved the processibility of rice pasta and enabled the yellow color of the uncooked rice pasta to be close to that of the semolina control. Upon cooking, the rice flour control had higher water absorption and greater cooking loss than the semolina control. The effect of starch addition on the textural properties of rice-based pasta varied with the type of starch. This project demonstrates that the addition of starch significantly changes the color, pasting, cooking, and texture properties of rice pasta, and these changes are governed by the type of starch incorporated into the rice pasta. Gluten-free rice pasta can be prepared with properties similar to the semolina pasta by incorporating starches.

Description and Initial Testing of a Pilot-Scale Parboiling Unit

Siebenmorgen, T.J., Hunt, M.B., and Duffour, A.

Parboiling is a process that includes soaking, steaming, and drying rough rice. The parboiling process strengthens rice kernels by fusing fissures in the endosperm, and thus improving head rice yields. Parboiling performance can differ among cultivars and from year to year, creating variability in rice end-products.

Conducting trials using industrial-scale equipment to determine optimal parboiling conditions can be expensive and time-consuming. Currently, there are no commercially-available, pilot-scale parboiling units for conducting such trials. The University of Arkansas Rice Processing Program has recently developed a pilot-scale, experimental parboiling unit (EPU). The EPU is automated so as to minimize pressure and temperature variability within and across parboiling trials. The unit also has a user-friendly interface to set specified conditions, including soaking temperature and duration, and steaming temperature and duration. The cylindrical parboiling chamber is capable of holding four screened sample containers, each with a rough rice capacity of 500 g. The sample containers are stationary and positioned in each 90° quadrant of the chamber cylinder. This study measured the EPU parboiling performance by evaluating the effects of sample size and sample container location within the EPU on parboiling uniformity.

Long-grain, pureline cultivar Wells was used for the study. Rough rice sample sizes of 200, 350, and 500 g were evaluated in separate trials. All samples were parboiled under similar conditions: soaking for 2 h at 70°C and 124 kPa (18 psi), steaming for 10 min at 110°C and 69 kPa (10 psi), and gently drying to 12.5 ± 0.5% moisture content, wet basis, in a humidity- and temperature-controlled environment. Temperature and pressure measurements were recorded as part of the unit's automated operation during each parboiling run. A degree of milling curve was established by milling parboiled rice for 30, 45, 60, 75, and 90 s, and then plotting the surface lipid content of the milled rice against milling duration. From this curve, the milling duration required to achieve a surface lipid content of 0.4% was determined and subsequently used for all milled, parboiled rice samples. Milled rice color was also measured for each sample using a Hunter colorimeter. The parboiling trials were replicated three times.

The parboiling chamber pressure and temperature varied very little during soaking and steaming, indicating satisfactory system control. Milled rice quality was assessed by milled rice yield, head rice yield, and L* (whiteness) values. Sample size did not affect milled rice yield, head rice yield, or color value uniformity of the parboiled rice. Sample location within the EPU parboiling chamber did not affect milled rice or head rice yields; however, color values were slightly darker (α=0.05) in samples positioned at the top of the EPU than at the bottom locations. The steam injection port being positioned at the top of the EPU parboiling chamber cylinder could be responsible for this slight color difference.

Equilibrium Moisture Content of Pureline, Hybrid, and Parboiled Rice Cultivars

Ondier, G.O., Siebenmorgen, T.J., and Mauromoustakos, A.

Equilibrium moisture content, defined as the moisture content at which a hygroscopic material, such as rice kernels, is neither gaining nor losing moisture, depends on the temperature and relative humidity of the air surrounding the materials. A thorough knowledge of the relationship between equilibrium moisture content and equilibrium relative humidity, at a given temperature, is required to facilitate proper modeling and control of rough rice drying and storage processes. In this study, equilibrium moisture contents of long- and medium-grain rough rice of both pureline and hybrid cultivars, and a parboiled rough rice of unknown cultivar, were measured at temperatures of 10, 20, 30, 45, and 60°C and relative humidities in the range of 10 to 70%. For each air condition, rough rice samples were allowed to equilibrate, after which the equilibrium moisture content of each sample was measured by drying duplicate, 15-gram samples in a convection oven set at 130°C for 24 h. Five sorption isotherm prediction models, namely Modified Chung-Pfost, Modified Henderson, Modified Oswin, Modified Halsey, and Modified Guggenheim Anderson DeBoer, were tested to determine the model that best described equilibrium data at the experimental conditions. Nonlinear regression analysis was used to estimate empirical constants of the five models. The appropriateness of each model in describing the equilibrium data was evaluated using root mean square errors, and residual patterns.

Results showed that there were no consistent significant differences between the equilibrium moisture contents of pureline and hybrid or medium- and long-grain rice cultivars. However, the equilibrium moisture content of parboiled rice was significantly less than that of non-parboiled rice, for almost all air conditions. The Modified Chung-Pfost equation best described equilibrium data of non-parboiled samples, followed by the Modified GAB, Modified Oswin, Modified Halsey, and Modified Henderson equations. The Modified Chung-Pfost and Modified GAB equations were equally effective when describing equilibrium data of individual cultivars.

Equilibrium Moisture Contents of Rice Fractions

Ondier, G.O., Siebenmorgen, T.J., and Mauromoustakos, A.

In this study, the effects of temperature and relative humidity on the equilibrium moisture contents of rough rice, brown rice, broken kernels, head rice, rice bran, and rice hulls from non-parboiled pureline cultivars Wells (long-grain) and Jupiter (medium-grain), hybrid cultivar CL XL730 (long-grain), and a parboiled rice (long-grain) of unknown cultivar, were investigated. Air conditions were maintained at temperatures of 10 – 60°C, and relative humidities of 10 – 70%. For each air condition, rough rice and constituent fractions were allowed to equilibrate, after which the equilibrium moisture content of each fraction was measured by drying duplicate, 15-gram samples in a convection oven set at 130°C for 24 h. Five sorption isotherm equations, namely the Modified Henderson, Modified Chung-Pfost, Modified Halsey, Modified Oswin, and Modified Guggenheim-Anderson-DeBoer, were evaluated for their ability to describe the sorption data of each kernel fraction.

Results showed that for a given temperature and relative humidity air condition, rice hulls attained the lowest equilibrium moisture content followed by rice bran, brown rice, broken kernels, and head rice; this held for both parboiled and non-parboiled samples. The measured equilibrium moisture content of rough rice was closely predicted by the weighted average equilibrium moisture content of the kernel fractions. The Modified Chung-Pfost and Modified Guggenheim-Anderson-DeBoer equations were the most suitable for describing equilibrium data of rough rice, brown rice, broken kernels, and head rice of both parboiled and non-parboiled samples, followed by the Modified Oswin and Modified Henderson equations. The Modified Oswin equation was the most suitable for rice bran and hulls.

Estimating the Theoretical Energy Required to Dry Rice

Billiris, M.A. and Siebenmorgen, T.J.

To determine the energy efficiency of a dryer, accurate theoretical energy requirements, which can be used as a basis for comparison, are needed. The theoretical amount of energy that is required to dry rice can exceed the latent heat of vaporization of water, depending on the moisture content. The strength of water-rice binding increases as moisture content decreases. Therefore, the energy required to dry rice increases as drying progresses. The energy required to dry rice, termed the heat of desorption, was determined at different moisture content levels and kernel temperatures using a semi-theoretical approach that involves the use of rice desorption isotherms, in conjunction with the Clausius-Clapeyron equation. Desorption isotherm data were obtained from two studies. One study was conducted at temperatures ranging from 60 to 90°C for long-grain Cybonnett rough rice using a fluidized bed drying system. Drying data from this system were described using the Page equation; equilibrium moisture content values were obtained as asymptotic values of this equation. The other study was performed at temperatures ranging from 10 to 60°C for long-grain Wells and CL XL730, medium-grain Jupiter and a long-grain parboiled rice of unknown cultivar using a chamber with controlled temperature and relative humidity. Equilibrium moisture contents for this study were determined by measuring the final sample moisture content via an oven drying method. To predict heat of desorption, equilibrium moisture content and relative humidity data were used as inputs for the Clausius-Clapeyron equation.

The energy required to remove water from rice was found to essentially be equal to the latent heat of vaporization at moisture contents of 20% wet basis (w.b.) or greater but increased exponentially as moisture content decreased. Heat of desorption varied for long-grain Wells from 2,371 to 3,488, for long-grain CL XL730 from 2,371 to 3,413, for medium-grain Jupiter from 2,372 to 3,624, and for parboiled rice from 2,368 to 3194 kJ/kg water, for moisture contents from 8 to 22% at 60°C. Heat of desorption of parboiled rice at 12.5% moisture content was significantly less than that of non-parboiled lots. Heat of desorption of medium-grain Jupiter was significantly greater than that of long grains at 12.5% moisture content. Equations that predict the energy required to dry a unit mass of rice from an initial moisture content to a final moisture content were derived.

Drain Time, Soil Moisture Content, and Harvest Grain Moisture Effects on Milling and Yield Stability

Mutters, R.G., Thompson, J.F., and Espino, L.A.

The optimal harvest moisture content (MC) for high head rice yields (HRY) varies between varieties and may be influenced by soil MC during grain maturation. In a controlled, replicated study at the RES, the yields and HRY of varieties M202, M205, and M206 were evaluated when drained at 16, 20, 24, and 28 days after heading (DAH).

In 2010, the rate of kernel drying below 25% MC was similar for all varieties across drain date treatments. The rate of moisture loss averaged across all varieties was about 0.4 percentage points per day. The 16, 20, and 24 DAH treatments reached harvestable MC 3 to 5 days sooner than the 28 DAH treatments. There was no apparent advantage to postponing field drainage beyond 24 DAH in M205 and M206. However, the yield of M202 was higher at a 28 DAH when compared with 24 DAH. The HRY was unaffected by harvest MCs above 17% for M205 and M206. Total rice yield (TRY) of all varieties were unaffected by drain date. However, TRYs for M205 and M206 were adversely affected at harvest MCs above 24% grain MC.

The observed differences in yield and quality were not attributable to drain time treatments (i.e. soil moisture) during the latter stage of grain maturation. Soil moisture at the 0-10 cm depth significantly declined over time in all treatments but was unaffected by drain date. Soil MC over the course of the harvest sequence remained basically unchanged at the 10-20 cm soil depth in all drain time treatments. The productivity of the three test varieties may be adversely affected by the loss of flooded conditions, in that yield and grain quality are unfavorably compromised when the soil transitions from an anaerobic to an aerobic state.

End-of-season water-use averaged across varieties was about 0.4 and about 0.8 inches per day in 2010 and 2009 (data not shown), respectively. The difference in water-use between years was attributed to cooler weather in 2010. Shifting the drain date by a few days would result in nominal water savings at the individual field level. It is not advisable to harvest M205 and M206 below 17% or above 24% MC due to loss in head rice and TRY, respectively. Draining M205 and M206 later than 24 DAH did not improve yield or quality. The draining of a field sooner than 20 DAH is not recommended.

Gene Expression and Enzymatic Shifts in Response to Increased Nighttime Air Temperatures in Developing Rice Grain

Nelson, L.D., Lawson, N.L., Counce, P.A., Moldenhauer, K.A., Siebenmorgen, T.J., Korth, K.L.

It is clear that increasing environmental temperatures can have an important impact on both the yield and quality of rice harvests. Previous research using both field and controlled-climate experiments showed a reduction in head rice yields and an increase in chalky kernels following exposure to high nighttime temperatures, especially during grain filling stages. Importantly, the data also show that there must be strong genetic components that lead to this interaction because some varieties are much more susceptible to endosperm chalk formation under these conditions. Our goal is to determine some of the fundamental changes that occur in developing rice grains as they respond to high air temperatures, especially at night. We have examined relative levels of rice gene transcripts in response to high nighttime temperatures in varieties resistant (cvs. Cypress and Jupiter) and susceptible (cvs. LaGrue and Wells) to chalk formation. Endosperm, hulls, and flag leaves were collected during grain development from plants maintained in growth chambers with nighttime temperatures of either 18^{o} or 30^{o}C. Plant treatment was initiated at the developmental stage R5, and tissue was collected at the late filling stage of the panicles (R8). We have measured gene expression for a small number of candidate genes in the collected endosperm tissue. Our preliminary data do not indicate a major shift in daytime transcripts for sucrose/starch synthesis genes; however, the data demonstrate a slight increase in transcript levels of genes for starch degradation, such as amylase, under higher temperatures. In addition, panicles were collected from field-grown Cypress and LaGrue plants at growth stages R6, R7, and R8. Kernels at R6 for each cultivar at the three reproductive growth stages (R6, R7, and R8) will be assayed for starch synthase and sucrose synthase activities, along with corresponding gene expression measurements and activities of other enzymes related to grain filling. The longer term goals of this work are to determine whether key molecular and enzymatic differences exist between these varieties and how any such differences might lead to the differential levels of starch packing that occur in grains responding to high air temperatures. Ultimately, the goal will be to apply this information for the development and selection of improved varieties with improved grain quality.

Effect of Hydrothermal Processes on Antioxidants and Their Capacities in Whole Grain Rice (*Oryza sativa* L.)

Chen, M.-H., Min, B., and McClung, A.

The impacts of parboiling and wet-cooking alone or in combination on concentrations of lipophilic antioxidants (vitamin E homologs and γ-oryzanol), soluble phenolics (including proanthocyanidins and anthocyanins), and antioxidant capacities (DPPH radical scavenging capacity (DPPH), oxygen radical absorbance capacity (ORAC), and iron-chelating capacity (ICC)) in whole grain rice from six rice cultivars of different colors were investigated. The six rice cultivars were selected on the basis of their bran colors: one white, light brown, brown, and red, and two purple. The color of whole grain rice is classified on the basis of the descriptions for rice bran color in the on-line database of the Germplasm Resources Information Network. The hydrothermal processes included parboiling of rough (PR) and brown rice (PB) for comparison with non-parboiled brown rice (raw control). Brown rice that was produced following these treatments and the control were then wet-cooked using 1 rice:2 water ratio in a rice cooker.

Analysis of samples following PR and PB, with or without wet-cooking, demonstrated increased concentrations of lipophilic antioxidants in all rice cultivars compared with the raw control and the wet-cooked brown rice. Parboiling of rough and brown rice decreased concentrations of phenolics, DPPH, ORAC, and ICC in the soluble fraction of most rice cultivars, and their decreases were more prominent in red rice cultivars. Furthermore, parboiling of brown rice led to more extreme decreases than parboiling of rough rice suggesting protection by the hulls against thermal degradation or leaching of water-soluble antioxidants. Wet-cooking of parboiled rice (PR and PB) caused greater decreases compared with wet-cooking of raw brown rice. In conclusion, the parboiling process increased concentration of extractable lipophilic antioxidants, and parboiling rough rice was preferable to parboiling brown rice to preserve soluble antioxidants. At every step of the thermal processes, with the losses due to thermal degradation and leaching, dark bran whole grain remained several-fold higher in water-soluble antioxidant concentrations and capacities than light bran whole grain rice.

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INSTRUCTIONS FOR PREPARATION OF ABSTRACTS FOR THE 2014 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.

Instructions for preparation and submission of abstracts for the 2014 RTWG meeting will be posted on the Rice Technical Working Group web page: www.rtwg.net.

Presented Paper, Poster, and Symposia Abstracts

To be published in the printed proceedings, presented paper, poster, and symposia abstracts for the 35th RTWG meeting 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 35th RTWG meeting in 2014, or earlier as stated in the Call for Papers issued by the 35th RTWG meeting chair and/or panel chairs.

   The respective panel chairs for the 2014 RTWG meeting and their email and mailing addresses are presented following this section. In case of other questions or in the absence of being able to access the Call for Papers, contact:

   Dr. Michael Salassi
   Agricultural Economics and Agribusiness
   LSU AgCenter
   101 Martin D. Wooden Hall
   Baton Rouge, LA 70803
   Phone: 225/578-2713
   Fax: 225/578-2716
   Email: msalassi@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 35th RTWG meeting. The appropriate due date will be identified in the Call for Papers for the 35th RTWG meeting. **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 35th RTWG meeting and submitted to Michael E. Salassi, RTWG Publication Coordinator, 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 Coordinator, 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 meeting. A copy of the previous recommendations and panel participants will be provided to each panel chair prior to the meetings.

ADDRESSES FOR 2014 PANEL CHAIRS

Breeding, Genetics, and Cytogenetics:

Jim Oard
Rice Research Station
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
Phone: (225) 281-9447
Fax: (337) 788-7553
Email: joard@agcenter.lsu.edu

Economics and Marketing:

Mike Salassi
Dept. of Agricultural Economis & Agribuiness
LSU AgCenter
101 Martin Woodin Hall
Baton Rouge, LA 70803
Phone: (225) 578-2713
Fax: (225) 578-2716
Email: msalassi@agcenter.lsu.edu

Plant Protection:

Michael Stout
Dept. of Entomology
LSU AgCenter
404 Life Sciences Building
Baton Rouge, LA 70808
Phone: (225) 578-1837
Fax: (225) 578-1643
Email: mstout@agcenter.lsu.edu

Postharvest Quality, Utilization, and Nutrition:

Joan King
Department of Food Science
LSU AgCenter
111 Food Science Building
Baton Rouge, LA 70803
Phone: (225) 578-5157
Fax: (225) 578-5300
Email: jking@agcenter.lsu.edu

Rice Culture:

Dustin Harrell
Rice Research Station
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
Phone: (337) 788-7531
Fax: (337) 788-7553
Email: dharrell@agcenter.lsu.edu

Weed Control and Growth Regulation:

Eric Webster
School of Plant, Environmental & Soil Sciences
LSU AgCenter
104 Sturgis Hall
Baton Rouge, LA 70803
Phone: (225) 578-5976
Fax: (225) 578-1403
Email: ewebster@agcenter.lsu.edu

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.

IN MEMORY OF

Candido Ricardo Bastos

Dr. Bastos received his Bachelor degree in Agronomy from the University of Sao Paulo, Brazil, and Masters and Ph.D. degrees from Mississippi State University. He conducted post-doctoral research with Texas A&M University at the Beaumont research station. Although he worked in other crops including sugar cane and sorghum, he served as a rice breeder at the Institute of Campinas (IAC) in Brazil for over 30 years. He utilized such techniques as mutation breeding and somaclonal variation along with conventional crossing to develop varieties for irrigated and upland production environments in the State of Sao Paulo. He collaborated with rice researchers in the southern United States and in other countries throughout his career. Dr. Bastos developed numerous varieties for conventional markets, as well as niche markets for sushi and aromatic rice. He collaborated with USDA ARS researchers in Texas and Arkansas to evaluate diverse high yielding germplasm and develop genetic markers for grain quality traits. He is a co-developer of the USDA ARS rice variety Sabine that is currently grown in the southern USA for the parboiling market. He developed the variety IAC 600 that has purple bran and has been demonstrated to have unique health beneficial properties in addition to its excellent aromatic flavor. It is currently being grown in both Brazil and the USA. Dr. Bastos maintained close ties with his rice research colleagues in the USA, participated in several Rice Technical Working Group meetings, and attended a number of rice field days in the southern states. He facilitated collaborations and technology transfer opportunities between researchers, producers, and processors between the two countries. His colleagues will greatly miss his friendship and generosity.

Howard L. Carnahan

Dr. Howard L. Carnahan served as Director of Rice Breeding at the Rice Experiment Station from 1969 to 1988. He led a team of breeders and staff that built an accelerated rice breeding program that introduced semidwarf height, early maturity, new grain types and dozens of rice varieties they developed propelled the California rice industry into the modern era. Those varieties and the scope and scale of the breeding program approach remain the foundation and inspiration for the RES rice breeding program today. Howard, as recognized by all who knew him, was thoroughly committed and stimulated by the intellectual challenge of rice breeding. He continued to be engaged in it after retiring from the Rice Experiment Station. He was a regular visitor to the station and the Annual Rice Field Day offering his analysis, insights, and suggestions on rice breeding challenges. He enjoyed writing and provided a number of witty compositions and letters to the editor. Before retiring, he was recognized for his contributions by the California industry, receiving the California Rice Industry Award in 1987, 1st RTWG Outstanding Research & Education Group Award in 1984 and Distinguish Service Award in 1988, and Achievement Award from the American Society of Agronomy in 1987.

Thomas Hargrove

Tom Hargrove received a double degree in agricultural science and journalism from Texas A&M University in 1966. During the Vietnam War, he served in the U.S. Army as an agricultural advisor for the Military Assistance Command and helped extend information regarding cultivation of the then newly released variety IR8. This was done to help stabilize food production in South Vietnam and helped to dramatically increase rice yields there. After the war, he became a writer and editor for the International Rice Research Institute located in Los Banos, the Philippines, and helped to extend the green revolution in rice to many poverty stricken areas of the world. From these experiences, he wrote a book "A Dragon Lives Forever: War and Rice in Vietnam's Mekong Delta 1969-1991 and Beyond." In 1991, he joined the staff at the International Center for Tropical Agriculture located in Cali, Colombia, where he continued to serve as a writer on their journalism staff. Among many other things, he developed an educational video that used genetic markers as well as historical and cultural information to trace the origins of a strain of rice found in the Amazon to Carolina Gold, the variety which is the basis for the U.S. rice industry. It was believed that Confederate soldiers from South Carolina who fled to Brazil after the Civil War brought the variety with them. While working at CIAT, he was captured one day on his way to work by FARC revolutionaries. He was held hostage for 11 months before he was released after his family paid two ransoms. He kept notes of his captivity on scraps of paper tucked in his belt that he later used to write a book, "Long March to Freedom" that was the basis for the movie "Proof of Life." Tom lived an exciting and varied life. He worked with rice researchers from around the globe to help capture their story of how agricultural science and technology has been used to help feed the world.

Ranjit Kadan

Dr. Ranjit Kadan served as a Research Food Technologist at the United States Department of Agriculture, Agricultural Research Service, Southern Regional Research Center, in New Orleans, Louisiana, for 32 years. He received his Bachelor of Veterinary Science and Animal Husbandry degree from Punjab University in 1958, Masters of Science in Food Science at Kansas State University in 1962, and his Ph.D. in Food Science from Rutgers University in 1967. He joined USDA ARS in New Orleans after working for nine years in industry, much of this time with Quaker Oats, Co. He worked on a number of projects over the years at the Southern Regional Research Center to develop novel food processes and products. These projects included development of a method to separate protein from cottonseed and development of novel carbonated and non-carbonated beverages using milk. He is best known in the rice research community for development of rice fries and rice bread. Rice fries were developed as a potential replacement of potato-based fries. These were produced using low value broken rice, were found to absorb about one third less oil than their potato counterpart and could be fortified with protein, fiber, minerals and vitamins. He also worked to develop rice-based bread that would be suitable for people suffering from Celiac Disease who require gluten-free foods. Dr. Kadan was a long-term member of the American Association of Cereal Chemists and the Institute of Food Technologists. He presented his research at these meetings as well as at the Rice Technical Working Group meetings. He is the holder of four U.S. patents and has published over 45 scientific articles.

Marco Antonio (Toni) Marchetti

Dr. Marchetti's career as a Research Pathologist began in 1963 with the U.S. Department of the Army where he conducted research on the epidemiology and etiology of rice blast disease at Ft. Detrick, MD. Several of Dr. Marchetti's earliest scientific publications related to the development of a set of international rice varieties that, through differential host-response, could be used to distinguish between the various known races of what was then known as *Pyricularia oryzae*. The international set of differential host varieties that Dr. Marchetti helped establish in the 1960s continues to be a useful method for identifying pathogenic races today in the USA.

In 1972, the Plant Pathology Division of the Army was transferred to the U.S. Department of Agriculture where Dr. Marchetti became a Research Pathologist with the Agricultural Research Service. His research focus shifted to preventing disease development and minimizing rice yield losses. Toni joined the USDA-ARS Rice Research Unit in Beaumont, TX, in 1974 where he was responsible for conducting research on the genetics, evaluation and control of diseases of rice, including blast, sheath blight, bacterial leaf blight, narrow brown leaf spot, straighthead and brown spot. He was responsible for identifying and characterizing several major *Pi*-genes for resistance to rice blast disease and went on to contribute to the identification of molecular markers linked to these major genes, as well as others that are associated with dilatory resistance. His research on the presence of *Pi* blast resistance genes in U.S. germplasm has been the basis for on-going breeding efforts to pyramid genes for multi-race resistance in domestic cultivars.

He is a co-author on the registration of 29 rice cultivars and germplasms that have been used throughout the southern United States, as well as parental sources in breeding programs worldwide. Although Toni is recognized internationally as an expert in rice blast disease, he also has conducted extensive research on the sheath blight pathogen, *Rhizoctonia solani*. For over 30 years, he has evaluated elite breeding materials from the southern U.S. programs for resistance to these diseases. He has authored or co-authored over 150 publications and presentations and has served as a consultant for public and private researchers, farmers, extension agents and government officials throughout the U.S., as well as in the Philippines, Egypt, Indonesia and Japan. He has participated in the training of graduate students and has collaborated with visiting senior scientists from China, Yugoslavia, Korea and Egypt.

Throughout his career in Texas, he monitored the presence of the blast pathogen in the southern United States and amassed one of the most extensive pathotype collections in the country. With colleagues at Purdue University, this historical collection was characterized using molecular techniques and demonstrated how the blast pathogen has evolved in response to the deployment of resistance genes in rice cultivars.

Even after Dr. Marchetti's retirement from his position as Research Pathologist at the USDA-ARS Rice Research Unit in Beaumont, TX, in January 2001, he continued to positively impact U.S. rice research by returning on a consulting basis to rate field plots for various rice research projects and helping to train those who continued to conduct disease evaluations to support his well-founded efforts to improve the disease resistance of U.S. rice varieties.

In 2010, Dr. Marchetti was honored at the 5th International Rice Blast Conference with an award recognizing his exceptional achievement in rice blast research. During his 39-year career as a plant pathologist, Toni had remarkable impact that continues to shape the way rice blast research is conducted today. Toni had many friends throughout the research community that miss him greatly.

Toni actively contributed to the RTWG for over 26 years, including service on 14 committees and multiple panel chair positions. Dr. Toni Marchetti was honored for his career contributions to the rice industry through the Distinguished Service Award from the RTWG in 2002.

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	C.C. Bowling	L. Drew	R.J. Smith, Jr.	B.A. Huey
Hot Springs, AR	J.P. Craigmiles		F.L. Baldwin	
1984	M.D. Morse	E.A. Sonnier	California Rice Varietal Improvement Team	
Lafayette, LA	L.C. Hill	D.L. Calderwood	H.L. Carnahan	J.N. Rutger
			C.W. Johnson	S.T. Tseng
			J.E. Hill	J.F. Williams
			C.M. Wick	S.C. Scardaci
			D. M. Brandon	
1986	D.S. Mikkelsen	J.B. Baker	Texas Rice Breeding and Production Team	
Houston, TX			C.N. Bollich	B.D. Webb
			M.A. Marchetti	G.N. McCauley
			J.E. Scott	J.W. Stansel
			F.T. Turner	A.D. Klosterboer
			E.F. Eastin	M.O. Way
			N.G. Whitney	M.E. Rister

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1988	M.D. Androus	H.L. Carnahan	Arkansas DD-50 Team	
Davis, CA	S.H. Holder	B.A. Huey	N.R. Boston	G.L. Davis
	M.D. Faulkner	W.R. Grant	F.N. Lee	N.P. Tugwell
	C.H. Hu	F.J. Williams	D.A. Downey	G.L. Greaser
			T.H. Johnson	G. Rench
			B.R. Wells	M.S. Flynn
			B.A. Huey	T.C. Keisling
			R.J. Smith	F.J. Williams
			D. Johnson	
1990 Biloxi, MS	H.R. Caffey O.R. Kunze	B.R. Jackson	None	
1992 Little Rock, AR	C.N. Bollich B.D. Webb	A.A. Grigarick C.M. Wick	J.W. Stansel	
1994 New Orleans, LA	S.H. Crawford J.V. Halick R.J. Smith	K. Grubenman R.N. Sharp	M.C. Rush	

Continued.

Past RTWG Award Recipients (continued)

Year Location	Distinguished Service Award Recipients		Distinguished Rice Research and/or Education Award Recipients	
1996 San Antonio, TX	P. Seilhan	K. Tipton	D.M. Brandon	
1998 Reno, NV	G. Templeton S.-T. Tseng	B. Wells	S.D. Linscombe	
			Advances in Rice Nutrition Team	
2000 Biloxi, MS	D.M. Brandon J.W. Stansel	R.K. Webster	P.K. Bollich R.J. Norman	C.E. Wilson
			Bacterial Panicle Blight Discovery Team	
2002 Little Rock, AR	F.L. Baldwin R.H. Dilday	M.A. Marchetti J.F. Robinson	M.C. Rush	D.E. Groth A.K.M. Shahjahan
			Individual	
			K.A.K. Moldenhauer	
			Discovery Characterization and utilization of Novel Blast Resistance Genes Team	
2004 New Orleans, LA	P.K. Bollich A.D. Klosterboer F.N. Lee W.H. Brown	J.A. Musick J.E. Street J.F. Williams S.L. Wright	F.N. Lee A.K. Moldenhauer	M.A. Marchetti
			Individual	
			R.D. Cartwright	

Continued.

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	
			Bakanae Team	
			J. Oster	R. Webster
2008	M.C. Rush	R. Dunand	C. Greer	
San Diego, CA	C. Johnson			
			Individual	
			D. Groth	
2010	T. Miller	J. Thompson	Individual	
Biloxi, MS	J. Kendall		E. Webster	
			Advances in Nitrogen Use Efficiency Team	
			D. Harrell	N. Slaton
			G. McCauley	B. Tubaña
2012	E. Champagne	G. McCauley	R. Norman	T. Walker
Hot Springs, AR	J. Hill		T. Roberts	C. Wilson
			J. Ross	
			Individual	
			A. McClung	

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
32nd	2008	San Diego, California	G. McCauley	C. Mutters	D.E. Groth M.E. Salassi
33rd	2010	Biloxi, Mississippi	C. Mutters	T.W. Walker	M.E. Salassi
34th	2012	Hot Springs, Arkansas	T.W. Walker	C.E. Wilson, Jr.	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

2012

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 (ERS), the Cooperative State Research, Education, and Extension Service (CSREES), 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) Postharvest Quality, Utilization & Nutrition; 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 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) Rice Crop Germplasm, iii) Rice Variety Acreage, iv) Awards, and v) Location and Time.

II. Revised Memorandum of Agreement

The previous Memorandum of Agreement is published in the 33rd RTWG Proceedings in 2010. The following is a revised Memorandum of Agreement accepted by the 34th RTWG membership in 2012.

REVISED MEMORANDUM OF AGREEMENT

FEBRUARY 2012

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 several rice producing states and the United States Department of Agriculture shall be developed by a Rice Technical Working Group (henceforth designated RTWG), composed of all personnel actively engaged in rice investigations and extension in each of the agencies, as well as participating rice industry groups.

It is further agreed that there shall be a minimum of three Administrative Advisors to the RTWG to represent the major agencies involved, including:

1) A director of an Agricultural Experiment Station from a major rice-growing state elected by the Station Directors of the rice-growing states,

2) A director of a State Cooperative Extension Service from a major rice-growing state elected by the Extension Directors of the rice-growing states, and

3) A USDA Administrative Advisor from ARS named by the Administrator of Agricultural Research Service.

The RTWG shall convene <u>at least biennially</u> 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:

<u>Officers</u> (2):

<u>Chair</u> -- presides at meetings of the RTWG and of the Executive Committee and otherwise provides leadership.

<u>Secretary/Program Chair</u> -- (normally moves up to Chair).

<u>Geographic Representatives</u> (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.

<u>Immediate Past Chair</u> -- provides guidance to incoming chair to facilitate a 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 the publication of the RTWG Proceedings.

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, 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 being 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, and Nominations) 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 setting up the RTWG website. The Secretary/Program Chair is responsible for the resolutions pertaining to the biennial meeting and for the Necrology Report when appropriate. The Secretary/Program Chair authors 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 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 Immediate Past Chair assists the Publication Coordinator in editing the nontechnical sections of the proceedings and revises the MOP as required. The Chair is nominated by the Nominations Committee to be the Immediate Past Chair at the next biennial meeting. The Immediate Past Chair will incorporate the changes approved by the Executive Committee in the MOP.

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. The Coordinator is assisted in the editing the nontechnical session portions of the proceedings by the Immediate Past Chair. The Coordinator serves on the Executive Committee to handle all matters related to the publication of the RTWG Proceedings. Currently, one publication coordinator serves this position. 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, and 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. 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 nominates a slate of members. This committee maintains the diversity of the membership. Nominations also are requested from the floor and elections take 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.

3. **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. English units of measure should be used for the acreage tables for continuity.

4. **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.

5. **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

A third-party website host and developer will be used to maintain a permanent RTWG website. A permanent (100 years from 2010) address (www.rtwg.net) has been purchased through www.networksolutions.com. The Chair and Secretary Program Chair are to meet and transfer responsibilities no later than one year after the preceeding meetings to ensure a smooth transition from one host state to the next.

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. The Immediate Past Chair will incorporate the approved changes in the MOP.

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)

Old Business

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.

New Business

The Necrology Report read by Chair.
The Chair announces RTWG award recipients and asks the Executive Committee to keep this information secret until after the Awards Banquet.
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)

Old Business

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 RWTG meeting)
   i) The Chair opens the meeting and thanks the host state delegation for preparing the program.
   ii) The Secretary welcomes the RTWG membership to their state.
   iii) 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.
   iv) The Chair opens the Business Meeting and informs the RTWG membership of business discussed at the Opening Executive Committee Meeting.
   v) The Chair reads the Necrology Report and asks for a few moments of silence.
   vi) 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.
   vii) 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.
   viii) The Secretary informs the membership of last minute alterations in the program and any additional information on the meeting, hotel, etc.
   ix) The Chair asks for a motion to adjourn the Opening Business Meeting.
   x) 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 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 everyone 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 is 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) Postharvest Quality, Utilization, and Nutrition; 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 Publication 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 Coordinator(s), 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 meeting. A copy of the previous recommendations and panel participants will be provided to each Panel Chair prior to the meeting.

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 meeting. 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 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.

   i. If the previous host state is unable to provide any or all of the $6,000 in start-up money for the next host state to initiate meeting preparations, the current Chair should be informed of this situation as soon as possible (as the Chair will normally have served as Secretary of the previous meeting, he/she will probably be aware of this situation). The Chair should then communicate to the Executive Committee how much money will be needed from the Contingency Fund to provide the next host state the full $6,000 in start-up funds. The Chair will then ask for approval from the Executive Committee to make arrangements to have the appropriate funds transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the next host state. Providing the next host state adequate ($6,000) start-up funds will be the highest priority for the use of contingency funds.

   ii. If a host state has gone into debt as a result of hosting the annual meeting and will request the use of contingency funds to cover all or part of that debt (over and above the inability to provide the $6,000 in start-up funds to the next host state), it must submit a detailed request for approval of the use of these funds to the Chair, who will than make this request available to the Executive Committee. The request should include a detailed accounting of all financial aspects of the hosted meeting, including all funds received and sources thereof, as well as a detailed accounting of all expenses incurred as a result of hosting the meeting. The Chair will have discretion on how to proceed with polling the Executive Committee (e.g., email or conference call) on approval of the use of contingency funds to cover all or part of the incurred debt. The Executive will then decide through parliamentary procedure whether to use contingency funds to cover all or part of the incurred debt. The Chair will then make arrangements to have the amount of any funds approved by the Executive Committee for this purpose transferred from the Agriculture Development Council Foundation at the University of Arkansas to the appropriate account in the host state. No repayment of these funds will be required.

7. Complementary Rooms, Travel Reimbursements, and 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, 10	Secure Hotel
May 1, 11	Pre-RTWG planning meeting
June 15, 11	Announcement of when and where the RTWG meeting will be held. (E-mail only)
July 1, 11	Invite guest speakers and begin soliciting for donations. Upon receipt of donations, send out acknowledgment letters.
Aug.1, 11	First call for papers and a call for award nominations
Sept. 15, 11	Second call for papers (Reminder; e-mail only)
Oct. 15, 11	Titles and interpretive summaries due
Dec. 1, 11	Abstracts due
Dec. 1, 11	Award nominations due to Chair
Dec. 1, 11	Registration and housing packet sent
Jan. 3, 12	Reminder for registration and hotel (e-mail only)
Jan. 29, 12	Last day for hotel reservations
Jan. 30, 12	Abstracts due to Publication Coordinator(s) from Panel Chairs
Jan. 30, 12	Registration due without late fee
Feb. 28, 12	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, a second poster session is held on Tuesday.

<u>Wednesday:</u> 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 or 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 or 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 meeting, 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, 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 RTWG 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 each RTWG meeting and their e-mail and mailing addresses are presented in the 'Instructions for Preparation of Abstracts" in each Proceedings. In case of other questions or if unable to access the Call for Papers, contact:

Dr. Michael E. Salassi
LSU AgCenter
Dept. Agricultural Economics and Agribusiness
101 Martin D. Wooden Hall
Baton Rouge, LA 70803
Phone: 225/578-2713
Fax: 225/578-2716
Email: msalassi@agcenter.lsu.edu

b. 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.

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 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 designate 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. In the event that a real or perceived conflict of interest regarding award nomination packets exist, the Chairman reserves the right to pass the responsibilities of award elections to the immediate past chair, the secretary, or an executive committee member who does not have a conflict of interest.

c. 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.

d. 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.

e. 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 if the award is 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. The executive committee reserves the right to entertain Distinguished Service Award packets at the opening executive committee 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 a 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.

Drafted by Richard J. Norman and approved by the 31st RTWG Executive Committee on March 1, 2006; revised by Garry McCauley and approved by the 32nd RTWG Executive Committee on February 21, 2008; revised by Cass Mutters and approved by the 33rd RTWG Executive Committee on February 25, 2010; revised by Tim Walker and approved by the 34th RTWG Executive Committee on March 1, 2012.

34th RTWG ATTENDANCE LIST

Adcock, Tim
Diligence Technologies, Inc.
219 Redfield Drive
Jackson, TN 38305
731-499-3381
timadcock@charter.net

Adviento-Borbe, Arlene
UC Davis
1210 PES Bldg One Shields Avenue
Davis, CA 95616
530-754-5338
aaadvientoborbe@ucdavis.edu

Ahrent, Debra
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
dahrent@uark.edu

Alexander, Cory
BASF
2402 Pom Roy Road
Lake Arthur, LA 70549
337-337-6721
cory.a.alexander@basf.com

Allen, Tom
Mississippi State University
P.O. Box 197
Stoneville, MS 38776
662-686-3272
tallen@drec.msstate.edu

Andaya, Virgilio
CA Coop. Rice Res. Foundation, Inc.
P.O. Box 306
Biggs, CA 95917
530-868-5481
vcandaya@crrf.org

Anders, Merle
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
manders@uark.edu

Arthur, Karen
Valent U.S.A. Corporation
2301 Ohio Drive, Suite 137
Plano, TX 75093
972-523-0913
karen.arthur@valent.com

Aviles, Lucas
University of Puerto Rico
P.O. Box 836
Lajas, PR 00667
787-550-1964
lucas.aviles@upr.edu

Bacon, Robert
U of A
1028 Sunset Drive
Fayetteville, AR 72701
479-521-1375
rbacon@uark.edu

Bagavathiannan, Muthu
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-466-8588
muthu@uark.edu

Baker, Stan
U of A
1009 Liberty Drive
DeWitt, AR 72042
870-946-3231
sbaker@uaex.edu

Baldwin, Gregory
BASF
47 Oak Fern Lane
Willow Spring, NC 27592
gregory.baldwin@basf.com

Baldwin, Ford
Practical Weed Consultants
412 Webber Lane
Austin, AR 72007
501-681-3413
ford@weedconsultants.com

Baldwin, Tomilea
Practical Weed Consultants
412 Webber Lane
Austin, AR 72007
501-681-3413
tomi@weedconsultants.com

Banks, Van
U of A
609 Madison Street
Clarendon, AR 72029
870-747-3396
vbanks@uaex.edu

Barrentine, Jim
Cheminova, Inc.
1519 North Starr Drive
Fayetteville, AR 72701
479-236-5103
james.barrentine@cheminova.com

Beckwith, Grant
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
gbeckwith@uaex.edu

Beer, Kathryn
Southeast Missouri State University
14632 CR 616
Dexter, MO 63841
573-624-7998
katjbeer@yahoo.com

Beighley, Donn
Southeast Missouri State University
14632 CR 616
Dexter, MO 63841
573-624-7998
dbeighley@semo.edu

Belmar, Scott
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
sbelmar@uark.edu

Benson, Lance
Lundberg Family Farms
P.O. Box 369
Richvale, CA 95974
530-538-3403
lbenson@lundberg.com

Berneri, Francesco
Societa' Agricola Berneri
Via Togliatti, 7
Rivolta di'Adda, Italy 26027
339 335292509
nos.82@libero.it

Bett Garber, Karen
USDA-ARS-SRRC
1100 Robert E. Lee Blvd.
New Orleans, LA 70124
504-286-4459
karen.bett@ars.usda.gov

Beuzelin, Julien
LSU AgCenter 404 Life Sciences Bldg.
Baton Rouge, LA 70803
225-578-5404
jbeuzelin@agcenter.lsu.edu

Billiris, Alejandra
U of A
Business Affairs, ADMN 317
Fayetteville, AR 72701
479-575-4564
mbilliri@uark.edu

Black, Bryan
Syngenta
272 Jaybird
Searcy, AR 72143
501-305-4365
david.black@syngenta.com

Black, Howard
USDA-ARS
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
howard.black@ars.usda.gov

Blackman, Bryce
LSU Dept. of Entomology
103 J. Norman Efferson
Baton Rouge, LA 70803
225-578-1811
bblackman@agcenter.lsu.edu

Blochl, Fabian
U of A
Business Affairs, ADMN 317
Fayetteville, AR 72701
479-575-2276
ewailes@uark.edu

Bockelman, Harold
USDA - ARS
1691 S. 2700 W.
Aberdeen, ID 83210
208-397-4162
harold.bockelman@ars.usda.gov

Bollich, Pat
LSU AgCenter
2310 Ben Hur Road
Baton Rouge, LA 70820
225-765-2876
pbollich@agcenter.lsu.edu

Bond, Jason
Mississippi State University
P.O. Box 197
Stoneville, MS 38776
662-830-7794
jbond@drec.msstate.edu

Booth, Veronica
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
vfrazie@uark.edu

Bottoms, Sunny
Horizon Ag
P.O. Box 266
Dumas, AR 71639
225-241-5526
sbottoms@horizonseed.com

Boyett, Virginia
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
vjohnso@uark.edu

Bradshaw, Dan
Crop Aid
456 Western Acres
El Campo, TX 77437
979-543-3416
ricepro@warpspeed1.net

Branson, Jamie
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
jdbrans@uark.edu

Braun, John
BASF
2712 Pinehurst Cove
Benton, AR 72019
501-766-6299

Brooks, Steve
RiceTec, Inc.
1925 FM 2917
Alvin, TX 77511
281-393-3502
sbrooks@ricetec.com

Brown, Deborah
U of A
Business Affairs, ADMN 317
Fayetteville, AR 72701
479-575-2276
ewailes@uark.edu

Bryant, Rolfe
USDA-ARS
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
rolfe.bryant@ars.usda.gov

Brye, Kristofer
U of A
ADMN 317
Fayetteville, AR 72701
479-575-5718
kbrye@uark.edu

Buehring, Nathan
Mississippi State University
127 Annsley Cove
Cleveland, MS 38732
662-822-7359
nathanb@ext.msstate.edu

Bullington, Jeremy
U of A - SEREC
P.O. Box 3508
Monticello, AR 71656
870-460-1091
bullington@uamont.edu

Bulloch, Jill
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
jbulloch@uark.edu

Burchfield, Michael
Jimmy Sanders, Inc.
1606 Bellavista Rd
Cleveland, MS 38732
mikeb@jsanders.com

Camargo, Edinalvo
Texas A&M University
370 Olsen Blvd, Heep Ctr., Rm. 339
College Station, TX 77843
979-422-3687
ecamargo@ag.tamu.edu

Capps, Chuck
U of A
210 S. Main #H
Monticello, AR 71655
870-460-6270
ccapps@uaex.edu

Carey, Frank
Valent USA
8603 Lakeview Drive
Olive Branch, MS 38654
901-827-3866
frank.carey@valent.com

Carruth, Sam
SQM North America
2727 Paces Ferry Rd., B-2, Ste. 1425
Atlanta, GA 30339
770-916-9423
samuel.carruth@sqm.com

Cartwright, Robert
RiceTec, Inc.
15329 Highway 1 North
Harrisburg, AR 72432
870-578-1817
rtcartwright@ricetec.com

Cartwright, Rick
U of A
2301 S. University Ave.
Little Rock, AR 72204
501-671-2042
rcartwright@uaex.edu

Castaneda-Gonzalez, Eduardo
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
ecastane@uark.edu

Cenghialta, Cesare
Ente Nazionale Risi
40 Via San Vittore
Milano, Italy 20123
39038425601
c.cenghialta@enterisi.it

Champagne, Elaine
USDA ARS SRRC
201 Tchefuncte Drive
Covington, LA 70433
504-236-6283
etwine@aol.com

Chavez, Eddie
U of A
Business Affairs, ADMN 321
Fayetteville, AR 72701
479-575-2276
echavez@uark.edu

Chen, Zhiqiang
South China Agricultural University
Room 712, Keji Bldg, No 483 Wushan Road,
Tianhe District Guangzhou,
Guangdong Province, China 510642
chenlin@sacu.edu.cn

Childs, Nathan
USDA-ERS
355 E. Street SW
Washington, DC 20024
202-694-5412
nchilds@ers.usda.gov

Chlapecka, Randy
U of A
649 Jackson 917
Newport, AR 72112
870-523-7450
rchlapecka@uaex.edu

Chou, Nanyen
Bayer CropScience
1623 Kelliwood Oaks Drive
Katy, TX 77450
979-253-0090
nanyen.chou@bayer.com

Coats, Bobby
U of A
2301 S. University Ave
Little Rock, AR 72204
501-671-2347
rcoats@uaex.edu

Conner, Corey
BASF
207 Grand Avenue
Lake Arthur, LA 70549
corey.conner@basf.com

Corbin, Billy
Valent USA
3800 Old Leland Road
Leland, MS 38756
662-390-4406
billy.corbin@valent.com

Corbin, Jennifer
Mississippi State University
501 South First Avenue
Cleveland, MS 38732
479-414-9981
jcorbin@drec.msstate.edu

Correa, Fernando
Rice Technology Solutions
P.O. Box 1305
Alvin, TX 77512
979-319-6412
fcorrea@ricetec.com

Correll, Jim
U of A
64 N. Skyview Lane
Fayetteville, AR 72701
479-283-1628
jcorrell@uark.edu

Counce, Paul
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
pcounce@uark.edu

Courville, Barrett
LSU AgCenter
3042 Englewood Drive
Jennings, LA 70546
337-384-4128
bcourville@agctr.lsu.edu

Cranek, Kyle
Bayer CropScience
676 CR 324
El Campo, TX 77437
979-541-3902
kyle.cranek@bayer.com

Cross, Becky
USDA-NASS
10800 Financial Center Pkwy, Ste. 110
Little Rock, AR 72211
501-228-9926
becky.cross@nass.usda.gov

Crow, Mitch
U of A
313 S. Izard St, Suite 14
Forrest City, AR 72335
870-261-1730
mcrow@uaex.edu

Crum, Krissi
BASF
11637 Fairway Circle
Dexter, MO 63841
919-667-3273
kristina.crum@basf.com

Cuevas, Federico
U of A
P.O. Box 1305
Alvin, TX 77512
979-319-6412
fcuevas@ricetec.com

Davis, Brad
U of A
P.O. Box 357
Lonoke, AR 72086
501-676-3124
bmdavis@uaex.edu

DeLong, Russ
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-575-3909
rdelong@uark.edu

Deren, Chris
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
cderen@uark.edu

Devkota, Pratap
Valent USA Corporation
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-463-0098
pdevkota@uark.edu

DeWitt, Thomas
CA Rice Research Board
7498 N. Remington Ave, Suite 102
Fresno, CA 93711
559-269-1754
tdewi@valent.com

Dickey, Dana
1505 Starr Dr
Yuba City, CA 95993
530-673-6247
ricebrd@syix.com

Dickson, Jim
U of A
2001 Hwy 70 E
Lonoke, AR 72086
501-626-8009
jdickson@uaex.edu

Dillon, Troy
U of A
P.O. Box 357
Lonoke, AR 72086
501-626-7002
twdillon@uaex.edu

Dischler, Carl
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-230-5179
cdischler@agcenter.lsu.edu

Dou, Fugen
Texas AgriLife Research
Aggie Dr. 1509
Beaumont, TX 77713
409-752-2741
f-dou@aesrg.tamu.edu

Dowdy, Amy Beth
ABD Crop Consultants, LLC
9201 St Hwy Zz
Dexter, MO 63841
573-614-1679
ricelady@live.com

Downing, Kelly
Valley Irrigation
1550 County Road D
Wahoo, NE 68066
402-359-6051
kdowning@valmont.com

Driggs, Keith
Syngenta
4 Dove Creek Circle
North Little Rock, AR 72116
501-231-9474
keith.driggs@syngenta.com

Du, Hanlin
RiceTec, Inc.
7226 Beja Court
Elk Grove, CA 95757
916-847-0027
dhanlin@ricetec.com

Dunn, David
University of MO - Delta Center
P.O. Box 160
Portageville, MO 63873
573-379-5431
dunnd@missouri.edu

Edwards, Michael
DuPont Crop Protection
1014 Belle River Rd
Pierre Park, LA 70339
225-264-0413
michael.t.edwards@dupont.com

Eizenga, Georgia
USDA-ARS-DBNRRC
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
georgia.eizenga@ars.usda.gov

Ellis, Mike
Jimmy Sanders, Inc.
512 Robinson Dr.
Cleveland, MS 38732
667-721-7892
mikee@jsanders.com

Fish, John
LSU AgCenter
4115 Gourrier Ave
Baton Rouge, LA 70808
225-324-6919
jfish@agcenter.lsu.edu

Fitts, Paxton
Mississippi State University
2 Juniper Lane
Ruleville, MS 38771
662-721-0033
pfitts@drec.msstate.edu

Fjellstrom, Bobby
USDA-ARS-DBNRRC
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
bob.fjellstrom@ars.usda.gov

Fluitt, Jacob
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-230-7707
jfluitt@agcenter.lsu.edu

Fontenot, Joseph
Crop Production Services
31032 Bornsdall Road
Elton, LA 70532
337-584-3556
joseph.fontenot@cpsagu.com

Foster, Ken
Kennan Corporation
7235 Pacific Ave
Pleasant Grove, CA 95668
916-655-3455
kfoster@kennancorporation.com

Freeze, Dave
U of A
217 Chickasawba, Box 717
Blytheville, AR 72316
870-762-2075
dfreeze@uaex.edu

Frey, Marty
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-788-7531
mjfrey@agctr.lsu.edu

Frizzell, Donna
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
dfrizze@uark.edu

Frost, Ford
1331 Lamar, Suite 1350
Houston, TX 77010
713-658-8000
frost-ht@swbell.net

Fulford, Anthony
U of A
115 Plant Science Bldg.
Fayetteville, AR 72701
479-575-7653
afulford@uark.edu

Gauthier, Stuart
LSU AgCenter
1105 West Port
Abbeville, LA 70510
337-898-4335
sgauthier@agctr.lsu.edu

Gealy, David
USDA-ARS-DBNRRC
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
david.gealy@ars.usda.gov

Geddes, Rick
Dow AgroSciences
1800 Pacifica Dr
Yuba City, CA 95991
530-632-8828
rdgeddes@dow.com

Gilbert, Erik
ASU
P.O. Box 1570
Jonesboro, AR 72467
870-972-2137
egilbert@astate.edu

Glover, Keith
Producers Rice Mill
P.O. Box 1248
Stuttgart, AR 72160
870-673-4444
kglover@producersrice.com

Godfrey, Larry
UC-Davis
One Shields Avenue
Davis, CA 95616
530-752-0473
ldgodfrey@ucdavis.edu

Golden, Bobby
Mississippi State University
511 Gerald
Leland, MS 38756
479-409-6191
bgolden@drec.msstate.edu

Goldman, Evan
UC Davis
5063 Veranda Terrace
Davis, CA 95618
631-379-3466
ebgoldman@ucdavis.edu

Gordon, Katrina
RiceTec, Inc.
1925 FM 2917
Alvin, TX 77511
281-393-3502
kgordon@ricetec.com

Gray, Blake
Koch Agronomic Services
7303 Pine Drive
Paragould, AR 72450
870-215-3171
blake.gray@kochind.com

Greer, Chris
University of California
142A Garden Highway
Yuba City, CA 95991
530-822-7515
cagreer@ucdavis.edu

Greub, Chester
U of A
1366 W. Altheimer Dr
Fayetteville, AR 72704
479-575-3912
cgreub@uark.edu

Griffin, Brent
U of A
DeValls Bluff Courthouse, Box 388
DeValls Bluff, AR 72041
870-998-2614
bgriffin@uaex.edu

Grigg, Brandon
U of A
2650 North Young Ave
Fayetteville, AR 72704
479-575-6827
bcgrigg@uark.edu

Groth, Donald
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-6853
dgroth@agcenter.lsu.edu

Guice, Brad
BASF
6583 Main Street
Winnsboro, LA 71295
318-435-3621
john.guice@basf.com

Guo, Tao
South China Agricultural University
Room 712, Keji Bldg, No 483 Wushan Rd.,
Tianhe District Guangzhou,
Guangdong Province, China 510642
guo.tao@vip.163.com

Gutierrez, Nestor
CRA 100 25H-55
Bogota, Cundinamarca, Columbia
5.73E+11
gutifamilia2@hotmail.com

Hadden, James
Syngenta
97 William Gibbs Road
Tifton, GA 31793
229-391-9032
james.hadden@syngenta.com

Hamilton, Mike
U of A
302 North Main Street
Harrisburg, AR 72432
870-568-4490
mhamilton@uaex.edu

Hamm, Jason
LSU Dept. of Entomology
103 J Norman Efferson
Baton Rouge, LA 70803
225-578-1811
jhamm@agcenter.lsu.edu

Hancock, Teresa
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
thancoc@uark.edu

Harper, Chersty
TX AgriLife Research
1509 Aggie Drive
Beaumont, TX 77613
409-752-2741
c-harper@aesrg.tamu.edu

Harrell, Dustin
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-250-3553
dharrell@agcenter.lsu.edu

Healey, Timothy
Koch Agronomic Services, L.L.C.
911 Washington Ave, Ste. 625
St. Louis, MO 63101
314-236-4128
tim.healey@kochind.com

Helms, Ronnie
G&H Associates
1010 S. Lowe
Stuttgart, AR 72160
870-673-7051
ronniehelms@centurytel.net

Henry, Chris
U of A
2900 Hwy 130E
Stuttgart, AR 72160
870-673-2661
cghenry@uark.edu

Hensgens, Michael
G & H Seed Company
P.O. Box 321
Crowley, LA 70527
337-785-7706
mkhensgens@ghseed.com

Hill, Jim
UC Davis
39926 Barry Road
Davis, CA 95616
530-756-5378
jehill@ucdavis.edu

Hoffpauir, Herman
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-224-3534
hhoffpauir@agcenter.lsu.edu

Hollier, Clayton
LSU AgCenter
302 Life Sciences
Baton Rouge, LA 70803
225-578-4487
chollier@agcenter.lsu.edu

Holmes, Keith
Gowan
10313 Del Rey
Yuma, AZ 85367
928-580-2198
kholmes@gowanco.com

Holwerda, Harmen
SQM Europe NV
St. Pietersvliet 7 bus 8
Antwerp, Belgium 2000
3232039726
harmen.tjalling.holwerda@sqm.com

Honda, Hisashi
11 Martine Avenue
White Plains, NY 10606
914-682-8934
hhonda@kichem-usa.com

Hristovska, Tania
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
thristov@uark.edu

Huang, Bihu
U of A - Pine Bluff
1200 N. University Drive
Pine Bluff, AR 71601
870-575-8821
huangh@uapb.edu

Hummel, Natalie
LSU AgCenter
404 Life Sciences Bldg.
Baton Rouge, LA 70803
225-578-5404
nhummel@agcenter.lsu.edu

Hung, Shawn
Rice Researchers Inc.
7875 County Road 32 1/2
Glenn, CA 95943
530-891-1355
vvierra@riceresearchers.com

Hyun Ham, Jong
LSU AgCenter
302 Life Sciences Building, LSU
Baton Rouge, LA 70803
225-578-6798
jham@agcenter.lsu.edu

Jia, Yulin
USDA-ARS
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
yulin.jia@ars.usda.gov

Jiang, Yiming
Bayer CropScience
676 County Road 324
El Campo, TX 77437
979-253-0451
yiming.jiang@bayer.com

Jin, Jing
U of A
217 AGRI
Fayetteville, AR 72701
479-575-2276
ewailes@uark.edu

Jodari, Farman
CA Cooperative Rice Research
Foundation, Inc.
P.O. Box 306
Biggs, CA 95917
530-868-5481
fjodari@crrf.org

Johnson, J. D.
FMC Corporation
109 Shoreline Drive
Madison, MS 39110
816-507-4318
don.johnson@fmc.com

Johnson, Jimmy
Koch Agronomic Services
P.O. Box 1888
Collierville, TN 38027
901-853-3506
jimmy.johnson@kochind.com

Johnson, Kirk
Bayer CropScience
3926 Yana Place
Davis, CA 95618
530-756-7367
kirk.johnson@bayer.com

Johnson, Brent
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-575-6611
dbj03@uark.edu

Jones, Dave
Farmers' Rice Cooperative
1760 Creekside Oaks, Suite 200
Sacramento, CA 95833
916-689-0004
jonesd@farmersrice

Jung, Won
University of Missouri
147 W. State Highway 7
Portageville, MO 63873
573-379-5431
jungw@missouri.edu

Kanter, Dwight
MSU
P.O. Box 292
Stoneville, MS 38776
662-686-3284
dgkanter@drec.msstate.edu

Karov, Vuko
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
vkarov@uark.edu

Kaur, Kirandeep
LSU AgCenter
302 Life Sciences
Baton Rouge, LA 70803
225-578-4487
kkaur2@tigers.lsu.edu

Kelsey, Christy
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
cbagwell@uark.edu

Kennedy, Paul
Helena Chemical Company
266 E. Nolley Drive
Collierville, TN 38017
901-752-4409
kennedyp@helenachemical.com

Kerr, Shelly
U of A
2900 Highway 130E
Stuttgart, AR 72160
870/673-2661
slk001@uark.edu

Kinard, Gary
USDA-ARS
10300 Baltimore Avenue
Beltsville, MD 21217
301-504-5115
gary.kinard@ars.usda.gov

Kirkpatrick, Wes
U of A
310 Oak St, Box 230
McGehee, AR 71654
870-222-3972
wkirkpatrick@uaex.edu

Knoblauch, Ronaldir
Arno G. Knoblauch
ItajaA-, 222
Gaspar, Santa Catarina, Brazil 89110
5.55E+11
ronaldirkn@gmail.com

Koger, Trey
Syngenta
112 Meadowlake Lane
Indianola, MS 38751
662-207-1604
trey.koger@syngenta.com

Korth, Kenneth
U of A
2398 E. Victoria Lane
Fayetteville, AR 72701
479-251-1674
kkorth@uark.edu

Kurtz, Mark
K-I Chemical USA, Inc.
11 Martine Ave
White Plains, NY 10606
662-686-9373
mark@kichem-usa.com

Kwak, Kang Su
Rural Development Administration,
Korea Gwonseon-gu, Suin_ro 150
Suwon City, Gyeonggi Province
82312992278
kskwak@korea.kr

Lan, Yubin
USDA-ARS
2771 F & B Road
College Station, TX 77845
979-260-3759
yubin.lan@ars.usda.gov

Lanclos, David
Syngenta
1381 Lake Drive
Woodworth, LA 71485
318-448-4275
david.lanclos@syngenta.com

Lanka, Srinivas
LSU Dept. of Entomology
103 J Norman Efferson
Baton Rouge, LA 70803
225-578-1811
slanka@agcenter.lsu.edu

Lassiter, Ralph
Dow AgroSciences
10 Cherry Creek Cove
Little Rock, AR 72212
501-590-5225
rblassiter@dow.com

Lee, Donna
LSU AgCenter
502 1st Street
Lake Providence, LA 71254
318-559-1459
drlee@agctr.lsu.edu

Lee, Steve
Bayer CropScience
2303 Morningside Drive
Jonesboro, AR 72404
870-704-9879
steve.lee@bayer.com

Leon, Chris
Isagro
122 Beaufort Circle
Madison, MS 39110
601-927-9410
cleon@isagro-usa.com

Leonards, James
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-581-8471
jleonards@agcenter.lsu.edu

Leonards, Jr., Bill
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-6857
wleonards@agcenter.lsu.edu

Lequerica, Frank
ISAGRO-USA
567 Harwood Cove
Memphis, TN 38120
901-489-7447
flequerica@isagro-usa.com

Lewis, Austin
U of A
1222 W. Mount Comfort Road
Fayetteville, AR 72703
870-761-9169
all007@uark.edu

Liakat, Md. Ali
U of A
2900 Hwy 130E
Stuttgart, AR 72160
870-674-4146
mlali01@uark.edu

Linquist, Bruce
UC Davis
601 Woodland Ave
Woodland, CA 95695
530-902-2943
balinquist@udavis.edu

Linscombe, Steve
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-6858
slinscombe@agcenter.lsu.edu

Lisko, Katherine
ASU
504 University Loop East, Room 101
Jonesboro, AR 72401
870-680-4323
katherine.lisko@smail.astate.edu

Liu, Aiguo
Valley Irrigation
2015 Elmhurst Avenue, #402
Montreal, Quebec Canada H4B 1Y2
514-295-2239
ai-guo.liu@valmont.com

Liu, Yongzhu
South China Agricultural University
Room 712, Keji Bldg, No 483 Wushan Rd
Tianhe District Guangzhou,
Guangdong Province, China 510642
86-20-3860-4903
lively@scau.edu.cn

Long, Josh
KAS
1515 Chestnut St.
Forrest City, AR 72335
870-270-7947
josh.long@kochind.com

Lorenz, Gus
U of A
2301 S. University Avenue
Little Rock, AR 72204
501-671-2047
glorenz@uaex.edu

Lu, Shien
Mississippi State University
32 Creelman St., MS 9655
Mississippi State, MS
662-325-2640
sl332@msstate.edu

Lundberg, Eric
Lundberg Family Farms
P.O. Box 369
Richvale, CA 95974
530-538-3403
eric@lundberg.com

Lundberg, Jessica
Lundberg Family Farms
P.O. Box 369
Richvale, CA 95974
530-538-3403
jessica@lundberg.com

Mackill, David
Mars, Inc.
2501 Dali Place
Davis, CA 95618
530-752-4940

Majure, Keith
241 Windlake Lane
W Monroe, LA 71291
kmajure@gowenco.com

Manuello, Dario
Ente Nazionale Risi
4 Strada per Ceretto
Castello d'Agogna, Italy 27030
39038425601
dmanuello@enterisi.it

Martin, Scott
Syngenta
778 Mitcham Orchard Road
Ruston, LA 71270
318-245-0662
scott.martin@syngenta.com

Massey, Colin
U of A
1366 West Altheimer Drive
Fayetteville, AR 72704
479-575-3912
cgmasse@uark.edu

Massey, Joseph
MSU
117 Dorman Hall
Mississippi State, MS 39762
662-325-4725
jmassey@pss.msstate.edu

Mazzanti, Ralph
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
rmazzanti@uaex.edu

McCarty, Danny
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
dmccarty@uark.edu

McCaskill, Don
Riceland Foods, Inc.
2120 S. Park Avenue
Stuttgart, AR 72160
870-673-5333
dmccaskill@riceland.com

McCauley, Garry
TX AgriLife Research
P.O. Box 717
Eagle Lake, TX 77434
979-234-3578
gmccaule@elc.net

McClung, Anna
USDA-ARS
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
anna.mcclung@ars.usda.gov

McKenzie, Kent
CA Cooperative Rice Research Foundation, Inc.
P.O. Box 306
Biggs, CA 95917
530-868-5481
ksmckenzie@crrf.org

McKnight, Benjamin
TX AgriLife Research
370 Olsen Blvd.
College Station, TX 77843
979-845-5375
bmcknight@ag.tamu.edu

McNeely, Van
RiceTec, Inc.
P.O. Box 1305
Alvin, TX 77512
870-578-1800
vmcneely@ricetec.com

Meador, Chris
Valent U.S.A. Corporation
3800 Old Leland Road
Leland, MS 38756
662-822-9981
chris.meador@valent.com

Meier, Jason
U of A
P.O. Box 3508
Monticello, AR 71656
870-460-1091
meier@uamont.edu

Meszaros, Anna
LSU AgCenter
404 Life Sciences Bldg
Baton Rouge, LA 70803
225-578-5404
ameszaros@agcenter.lsu.edu

Miller, Robert
RiceTec, Inc.
Box 1305
Alvin, TX 77512
281-393-3502
rbmiller@ricetec.com

Miller, Nicky
RiceCo.
148 Jeanne Street
Eunice, LA 70535
337-207-6572
nicky.miller@ricecollo.com

Mitchell, Henry
FMC Corporation
P.O. Box 678
Louisville, MS 39339
662-773-6697
rusty.mitchell@fmc.com

Mohammed, Abdul
TX AgriLife Research
1509 Aggie Drive
Beaumont, TX 77713
409-752-2741
abdulrazack@neo.tamu.edu

Moldenhauer, Karen
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
kmolden@uark.edu

Moore, Scott
Syngenta Crop Protection
2701 Youngwood Lane
Opelika, AL 36801
318-282-6552
scott.moore@syngenta.com

Morris, Charles
BASF
26 Davis Drive
Research Triangle Park, NC 27709
919-659-3422
charles.b.morris@basf.com

Morsello, Shannon
Syngenta
6540 Pine Ln.
Vero Beach, FL 32967
281-254-4513
shannon.morsello@syngenta.com

Motschenbacher, Jill
U of A
115 Plant Science Bldg, U of A
Fayetteville, AR 72701
615-944-0359
jmotsche@uark.edu

Mujahid, Hana
MSU
100 Old Hwy 12
Mississippi State, MS 39762
662-325-2085
hm73@msstate.edu

Mutters, Cass
UCA
2279 Del Oro Avenue
Oroville, CA 95926
530-538-7200
rgmutters@ucdavis.edu

Mysore-Venkata Rau, Sheerekha
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
smysorev@uark.edu

Norman, Rick
U of A
115 Plant Science Bldg, U of A
Fayetteville, AR 72701
479-790-3301
rnorman@uark.edu

Norsworthy, Jason
U of A
1366 West Altheimer Drive
Fayetteville, AR 72704
479-575-8740
jnorswor@uark.edu

Oard, James
LSU AgCenter
SPESS, 104 Sturgis Hall
Baton Rouge, LA 70803
225-578-1301
joard@agcenter.lsu.edu

Odle, Bill
Valent USA Corporation
3405 Marsalis Lane
Plano, TX 75074
972-948-3700
bill.odle@valent.com

Okamoto, Polly
Rice Researchers Inc.
7875 County Road 32 1/2
Glenn, CA 95943
530-891-1355
vvierra@riceresearchers.com

Okamoto, Jr., George
Rice Researchers Inc.
7875 County Road 32 1/2
Glenn, CA 95943
530-891-1355
vvierra@riceresearchers.com

Okamuro, Jack
USDA-ARS
5601 Sunnyside Avenue
Beltsville, MD 20705
301-504-4608
jack.okamuro@ars.usda.gov

Olaya, Gilberto
Syngenta
7145 58th Avenue
Vero Beach, FL 32967
772-794-7149
gilberto.olaya@syngenta.com

Osborn, Jason
116 Center Street
Marion, AR 72364
870-739-3239
josborn@uaex.edu

Oster, Jeffrey
CA Cooperative Rice Research Foundation, Inc.
P.O. Box 306
Biggs, CA 95917
530-868-5481
jjoster@crrf.org

Ouzts, Randy
Horizon Ag
8275 Tournament Drive, Suite 255
Memphis, TN 38125
901-818-3070
rouzts@horizonseed.com

Pan, Xuhao
U of A
2890 Highway 130E
Stuttgart, AR 72160
870-672-9300
pan_411@yahoo.com

Pan, Zhongli
USDA-ARS
800 Buchanan Street
Albany, CA 94710
510-559-5639
zhongli.pan@ars.usda.gov

Pardue, James
Crop Production Services - CCA class
P.O. Box 391
Jonesville, LA 71343
318-481-7020
jimbopardue@bellsouth.net

Patterson, Suzanne
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
spatter@uark.edu

Peng, Zhaohua
MSU
100 Old Why 12
Mississippi State, MS 39762
662-325-2085
zp7@bch.msstate.edu

Perkins, Keith
U of A
2001 Hwy 70 E, Box 357
Lonoke, AR 72086
501-676-3124
kperkins@uaex.edu

Perry, Hunter
Dow AgroSciences
1462 South Colorado St., Apt. 12A
Greenville, MS 38703
dhperry@dow.com

Phillips, Steve
IPNI
3118 Rocky Meadow
Owens Cross Roads, AL 35763
256-529-9932
sphillips@ipni.org

Pinson, Shannon
USDA-ARS
2890 Hwy 130E
Stuttgart, AR 72160
870-672-9300
shannon.pinson@ars.usda.gov

Plummer, Andrew
U of A
2301 S. University Ave
Little Rock, AR 72204
501-671-2047
aplummer@uaex.edu

Polenghi, Giandomenico
Ente Nazionale Risi
40 Via San Vittore
Milano, Italy 20123
39038425601
g.polenghi@enterisi.it

Pope, C. Lorenzo
Rice Researchers Inc.
7875 County Road 32 1/2
Glenn, CA 95943
530-891-1355
vvierra@riceresearchers.com

Porro Rubiales, Manuel
Hidroponicas
De la Rotonda CA 300 mts Oeste
Edf.Agricorp Managua, Nicaragua
11111 1.15E+12
mporro@hidroponicas.com.ni

Prince, Robert
Syngenta
130 Myra Shirey Lane
Bernice, LA 71222
318-372-3457
robert.prince@syngenta.com

Ramesh Reddy, Babi
MSU
100 old Hwy 12
Mississippi State, MS 39762
662-325-2085
brn27@msstate.edu

Rana, Sandeep
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-871-4309
srana@uark.edu

Randriamady, Hervet
U of A
217 Agri
Fayetteville, AR 72701
479-575-2276
ewailes@uark.edu

Rasmussen, Russell
RiceTec, Inc.
1925 FM 2917
Alvin, TX 77511
281-393-3502
rrasmussen@ricetec.com

Ratnaprabha, Ratnaprabha
TX A&M
1509 Aggie Drive
Beaumont, TX 77713
409-752-2761
ratna125@tamu.edu

Re, Jose
RiceTec, Inc.
P.O. Box 1305
Alvin, TX 77512
281-393-3502
jre@ricetec.com

Reba, Michele
USDA-ARS
598 McElroy Drive
Oxford, MS 38655
870-819-2708
michele.reba@ars.usda.gov

Reddyvari-Channarayappa, Venu
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
vreddyva@uark.edu

Regan, Ronald
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-788-7531
rregan@agcenter.lsu.edu

Rene Gasore, Elie
U of A
763 W. Sandy Beach Lane
Fayetteville, AR 72701
479-445-5567
egasore@uark.edu

Rhodes, Alvin
BASF
137 Cypress Lake Blvd. South
Madison, MS 39110
601-853-1417
alvin.rhodes@basf.com

Riar, Dilpreet
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-575-6244
driar@uark.edu

Rich, Greg
K-I Chem USA
180 Brier Hills Drive
Piperton, TN 38017
901-488-6036
grich@kichem-usa.com

Rivera, Anthony
University of Puerto Rico
P.O. Box 2684
San German, PR 00683
787-368-5523
anthony.rivera5@upr.edu

Roberts, Dwight
US Rice Producers Association
2825 Wilcrest
Houston, TX 77042
713-299-8464
dwight@usriceproducers.com

Roberts, Trenton
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
479-575-6752
tlrobert@uark.edu

Robinson, John
Valley Irrigation
4467 Highway 142
Poplar Bluff, MO 63901
573-718-0698
john.robinson@valmont.com

Rogers, Chris
U of A
115 Plant Science
Fayetteville, AR 72701

Rothrock, Craig
U of A
Plant Science 217
Fayetteville, AR 72701
479-575-2445
rothrock@uark.edu

Runsick, Stewart
U of A
649 Jackson 917
Newport, AR 72112
870-718-1310
srunsick@uaex.edu

Saichuk, Johnny
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-788-7547
jsaichuk@agcenter.lsu.edu

Salassi, Michael
LSU AgCenter
1533 Stoneliegh Drive
Baton Rouge, LA 70808
225-767-1593
msalassi@agcenter.lsu.edu

Salazar, Milton
Fedearroz
Cra 100 25H-55
Boota, Cundinamarca, Colombia
5.73E+11
miltonsalazar@fedearroz.com.co

Samonte, Stanley
CA Cooperative Rice Research Foundation, Inc.
P.O. Box 306
Biggs, CA 95917
530-868-5481
ricestation@crrf.org

Sanchez, Paul
University of Arizona
1657 E. Helen Street
Tuscon, AZ 85721
520-626-9601
psanchez@ag.arizona.edu

Sandoski, Craig
Gowan
10413 Wynbrooke Lane
Collierville, TN 38017
901-268-7668
csandoski@gowanco.com

Sayler, Ronald
U of A
Plant Science 202
Fayetteville, AR 72701
479-575-2446
rjsayle@uark.edu

Scheffler, Brian
USDA-ARS
141 Experiment Station Road
Stoneville, MS 38776
662-686-5454
brian.scheffler@ars.usda.gov

Schobert Reeves, Brianne
BASF
136 Skipwyth Circle
Cary, NC 27513
919-564-6033
brianne.r.schobert@basf.com

Schultz, Bruce
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-5257
bschultz@agcenter.lsu.edu

Scott, Bob
U of A
2001 Hwy 70E, P.O. Box 357
Lonoke, AR 72086
501-837-0273
bscott@uaex.edu

Senseman, Scott
TX AgriLife Research
8320 Grassbur Rd.
Bryan, TX 77808
979-589-1275
s-senseman@tamu.edu

Sha, Xueyan
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-6302
xsha@agcenter.lsu.edu

Shafer, Joseph
U of A
201 East Wood St.
Palestine, AR 72372
870-494-5059
jshafer@uark.edu

Shao, Qiming
Bayer CropScience
676 County Road 324
El Campo, TX 77437
979-219-6903
qiming.shao@bayer.com

Shinkle, Aly
MSU
P.O. Box 5307
Mississippi State, MS 39762
662-686-9311
sas667@msstate.edu

Shinohara, Takuro
K-I Chemical U.S.A. Inc.
11 Martine Avenue, Suite 1460
White Plains, NY 10606
914-682-8934
tshinohara@kichem-usa.com

Sidhu, Jaspreet
LSU Department of Entomology
LSU Dept. of Entomology
Baton Rouge, LA 70803
225-578-1811
jsidhu1@tigers.lsu.edu

Siebenmorgen, Terry
U of A
Food Science N-217
Fayetteville, AR 72701
479-575-4564
tsiebenm@uark.edu

Sills, David
Crop Production Services
3301 Stonehurst Drive
El Dorado Hills, CA 95762
916-939-2324
davesills@att.net

Silva, James
LSU AgCenter
104 MB Sturgis Hall LSU Campus
Baton Rouge, LA 70803
225-614-3654
polluelo02@hotmail.com

Simpson, Greg
RiceTec, Inc.
15329 Hwy 1
Harrisburg, AR 72432
870-243-2604
gsimpson@ricetec.com

Slaton, Nathan
U of A
1366 W. Atheimer Drive
Fayetteville, AR 72704
479-575-3910
nslaton@uark.edu

Smartt, Alden
U of A
ADMN 317
Fayetteville, AR 72701
479-575-5718
adsmartt@uark.edu

Smith, Ken
U of A
P.O. Box 3508
Monticello, AR 71656
870-460-1091
smith@uamont.edu

Spatola, Kenneth
Mitsui Chemicals America
2 Kings Highway
Hampton, NH 03842
978-930-1168
k.spatola@mitsuichem.com

Starkey, Clay
U of A
1366 W. Altheimer Drive
Fayetteville, AR 72704
217-883-3869
claystarkey1@gmail.com

Stewart, Jim
Lundberg Family Farms
5311 Midway
Richvale, CA 95974
530-538-3400
jstewart@lundberg.com

Stivers, Alisha
RiceTec, Inc.
P.O. Box 1305
Alvin, TX 77512
281-393-3502
astivers@ricetec.com

Street, Joe
MSU
Box 9601
Mississippi State, MS 39762
662-325-3034
jstreet@ext.msstate.edu

Subudhi, Prasanta
LSU AgCenter
104 Sturgis Hall
Baton Rouge, LA 70803
225-578-1303
psubudhi@agcenter.lsu.edu

TaBeest, David
U of A
2448 Azalea Terrace
Fayetteville, AR 72703
479-575-2445
dtebeest@uark.edu

Tabien, Rodante
TX AgriLife Research
1509 Aggie Drive
Beaumont, TX 77613
409-752-2741
retabien@ag.tamu.edu

Taillon, Nichole
U of A
2301 S. University Ave.
Little Rock, AR 72204
501-671-2047
ntaillon@uaex.edu

Tally, Allison
Syngenta Crop Protection
410 Swing Road
Greensboro, NC 27419
336-632-7231
allison.tally@syngenta.com

Tarpley, Lee
TX AgriLife Research
610 Belvedere Drive
Beaumont, TX 77706
409-892-2669
ltarpley@tamu.edu

Taylor, Keith
BASF
6899 CR333
jonesboro, AR 72401
501-613-5050
keith.taylor@basf.com

Theunissen, Brent
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-581-3856
btheunissen@agcenter.lsu.edu

Theunissen, Shane
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-581-5687
stheunissen@agcenter.lsu.edu

Thompson, Vetress
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
vithomps@uark.edu

Thrash, Ben
U of A
P.O. Box 357
Lonoke, AR 72086
501-676-3124
bthrash@uaex.edu

Tomlinson, Jordan
RiceCo LLC
207 Michael St.
Bono, AR 72416
870-834-0499
jordan.tomlinson@ricecollc.com

Utomo, Herry
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-5939
hutomo@agcenter.lsu.edu

Vangilder, Andy
U of A
148 G. Main
Piggott, AR 72454
870-598-2246
avangilder@uaex.edu

Veazey, Brad
RiceCo LLC
67 Hudson Branch Dr
Austin, AR 72007
870-930-5866
brad.veazey@ricecollc.com

Venghiattis, Christophe
Arrocera Venllano
1401 Calumet St u602
Houston, TX 77004
713-527-9164
avsa.pcv@gmail.com

Venghiattis, Philippe
Arrocera Venllano
891 Massachusetts Ave, Apt. 14
Cambridge, MA 02139
617-710-1426
avsa.cev@gmail.com

Vierra, Vern
Rice Researchers Inc.
7875 County Road 32 1/2
Glenn, CA 95943
530-891-1355
vvierra@riceresearchers.com

Wailes, Eric
U of A
217 AGRI
Fayetteville, AR 72701
479-575-2276
ewailes@uark.edu

Walker, Chanse
BASF
2 Willow Creek Lane Apt 2107
Jonesboro, GA 72404
870-450-9786
chanse.l.walker@basf.com

Walker, Timothy
MSU
82 Stoneville Road
Stoneville, MS 38776
662-686-3278
twalker@drec.msstate.edu

Wallace, Mason
RiceTec, Inc.
15329 Hwy 1 North
Harrisburg, AR 72432
870-578-1800
mwallace@ricetec.com

Walton, Mark
MWalton Enterprises
9508 Westminster Glen Avenue
Austin, TX 78730
512-382-6269
mark.walton@mwaltonenterprisesllc.com

Wamishe, Yeshi
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
ywamishe@uaex.edu

Wang, Ya-Jane
U of A
2490 N. Worthington Way
Fayetteville, AR 72703
479-587-8138
yjwang@uark.edu

Wang, Jichun
U of A
2890 Highway 130E
Stuttgart, AR 72160
870-672-9300
wangjichun1972@yahoo.com

Wang, Hui
South China Agricultural University
Room 712, Keji Bldg, # 483 Wushan Rd.,
Tianhe District Guangzhou,
Guangdong Province, China 510642
86-20-3860-4903
huiwang@scau.edu.cn

Watkins, Brad
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
kbwatki@uark.edu

Way, Mo
TX AgriLife Research
1509 Aggie Dr.
Beaumont, TX 77713
409-658-2186
moway@aesrg.tamu.edu

Webster, Eric
LSU AgCenter
SPESS, 104 Stugis Hall
Baton Rouge, LA 70803
225-281-9449
ewebster@agcenter.lsu.edu

Wells, Jennifer
RiceCo
1621 Brackenshire Lane
Collierville, TN 38017
901-850-9401
jennifer.wells@ricecollc.com

Wenefrida, Ida
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-250-2085
iwenefrida@agcenter.lsu.edu

White, Larry
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-296-6870
lwhite@agcenter.lsu.edu

Wilbanks, Scott
RiceCo
4172 Swan Hill
Lakeland, TN 38002
901-652-4197
scott.wilbanks@ricecollc.com

Williams, Garrett
Horizon Ag
8275 Tournament Dr, Suite 255
Memphis, TN 38125
901-818-3070
gwilliams@horizonseed.com

Williamson, Stephanie
U of A
1366 W. Altheimer Dr
Fayetteville, AR 72704
479-575-7569
steph.m.williamson@gmail.com

Wilson, Chuck
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
cwilson@uaex.edu

Wilson, Chuck
USA Rice Federation
1902 S. Main Street
Stuttgart, AR 72160
870-673-7541
cwilson@usarice.com

Wilson, Dale
Valent BioSciences
6131 Oakwood Rd.
Long Grove, IL 60047
847-968-4903
dale.wilson@valent.com

Wilson, Lloyd
TX AgriLife Research
1509 Aggie Dr.
Beaumont, TX 77713
409-752-3045
lt-wilson@aesrg.tamu.edu

Wilson, Gus
U of A
523 Hwy 65 & 82 S
Lake Village, AR 71653
870-265-8055
gwilson@uaex.edu

Wood, Ross
RiceCo LLC
217 S.E. 4th St.
England, AR 72046
ross.wood@ricecollc.com

Xiao, Wuming
South China Agricultural University
Room 712, Keji Bldg, No 483 Wushan Road,
Tianhe District, Guangzhou,
Guangdong Province, China 510642
86-20-3860-4903
wumingxiao180@gmail.com

Xu, Peizhou
U of A
2890 Highway 130E
Stuttgart, AR 72160
870-672-9300
xpzhxj@gmail.com

Yan, Zongbu
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
zongbu@uark.edu

Yan, Wengui
USDA-ARS
2890 Highway 130E
Stuttgart, AR 72160
870-672-9300
wengui.yan@ars.usda.gov

Yang, Jie
MSU
100 Old Hwy 12
Mississippi State, MS 39762
662-325-2085
jy308@msstate.edu

Yang, Wonha
National Institute of Crop Science
151 Suinro, Kwonseongu
Suwon, Gyeonggido 441-857
82173199334
yangwh@korea.kr

Yeltatzie, George
CA Cooperative Rice Research Foundation, Inc.
P.O. Box 306
Biggs, CA 95917
530-868-5481
gyeltatzie@crrf.org

Youmans, Clete
BASF
1875 Viar Road
Dyersburg, TN 38024
731-445-8880
cletus.youmans@basf.com

Zaunbrecher, Gretchen
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-334-9672
gzaunbrecher@agcenter.lsu.edu

Zaunbrecher, Rick
LSU AgCenter
1373 Caffey Road
Rayne, LA 70578
337-207-9788
rzaunbrecher@agcenter.lsu.edu

Zaunbrecher, Joshua
Syngenta
1031 Soldier Rd
Scott, LA 70583
337-356-5338
josh.zaunbrecher@syngenta.com

Zhang, Zhen
U of A
2900 Highway 130E
Stuttgart, AR 72160
870-673-2661
zzhangcn@gmail.com

Zhou, Shane
TX AgriLife Research
1509 Aggie Drive
Beaumont, TX 77713
409-223-0178
xzhou@aesrg.tamu.edu

Louisiana State University Agricultural Center
Louisiana Agricultural Experiment Station